



ISSN NO. 2320-5407

Journal homepage: <http://www.journalijar.com>  
Journal DOI: [10.21474/IJAR01](https://doi.org/10.21474/IJAR01)

INTERNATIONAL JOURNAL  
OF ADVANCED RESEARCH

## RESEARCH ARTICLE

### COMBINING ABILITY AND GENE ACTION FOR FRUIT YIELD AND HEAT TOLERANCE IN TOMATO (*Lycopersicon lycopersicum* Mill.) UNDER HEAT STRESS CONDITIONS.

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#### Manuscript Info

##### Manuscript History:

Received: 19 May 2016  
Final Accepted: 19 June 2016  
Published Online: July 2016

##### Key words:

Combining ability, gene action, tomato, fruit yield, and heat tolerance.

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#### Abstract

Heat stress causes significant fruit yield loss in tomato (*Lycopersicon lycopersicum* Mill.). Breeding tomato varieties hybrids tolerant to high temperature will reduce fruit yield losses due to heat stress in Nigeria. Combining ability and gene action for fruit yield and heat tolerance was studied under heat stress conditions in tomato. The experiments were carried out at National Horticultural Research Institute, Bagauda Station farm (11°33'N; 8°23'E) and the Institute for Agricultural Research farm, Samaru (11°11'N; 07°38'E) between July to October, 2014 rainy season. Two heat tolerant and four susceptible tomato genotypes were crossed in a half diallel mating design. The results of combining ability analysis indicated that, both additive and non-additive actions were important for the inheritance of the traits. However, SCA variance components were higher than GCA variance components, indicating preponderance of dominance gene action for genetic control of the majority traits. The average degree of dominance values revealed over-dominance gene action for the most traits. The parent Icrixina was the best general combiner for the majority of the traits among the parents, while Petomech × Roma Savana and Icrixina × Rio Grande were the most desirable cross combinations for fruit yield per plant and percentage fruit set. Overall results indicated that hybrid vigor exploitation could be harnessed to produce high yielding and heat tolerant tomato hybrid under rainy season.

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#### Introduction:-

Tomato is widely produced and consumed. It ranks second high priority vegetable throughout the world after potato (FOASTAT, 2005). It is very rich in vitamins, minerals, essential amino acids, sugars and dietary fibers. It contains a high level of lycopene, an antioxidant that reduces the risk related to several cancers and neurodegenerative diseases (Srivinasan et al., 2010). The optimum temperatures for tomato cultivation are between 25 and 30°C during photoperiod and 20°C during the dark period (Camejo et al., 2005). An increase of 2-4°C over the optimal temperature had been adjudged to adversely affect gamete development, while inhibiting the ability of pollinated flowers to develop into fruits and thus reduced fruit yield (Peet et. al., 1997, Sato, et. al., 2001; Firon, et. al., 2006). Tomato is commonly grown during harmattan under irrigation and the rainy season in Nigeria and high temperature during the rainy season usually causes a substantial reduction of fruit size, increase in flower abortion and decrease in fruit set which reduced fruit yield. However, the presently cultivated tomato varieties in the country are sensitive to high temperature, which limits tomato production and causes a shortage of market supply and high cost during the rainy season. Consequently, there is need for producing high yield open pollinated or tomato hybrids that can thrive well and set fruit under high temperature environment. Combining ability analysis is a fundamental technique in understanding the genetic potential of parents and their hybrids. It also provides information on gene action and

effects controlling the inheritance of quantitative traits which help in formulating an effective breeding program. Cheema et al. (2003) reported significant GCA and SCA variance for most of the studied traits in the heat tolerant lines of tomato, revealing the importance of both additive as well as non-additive in the controlling the traits. Hazra and Ansary (2008) studied genetics of heat tolerance for floral and fruit set to high temperature and reported gene action to be predominantly non-additive. This study was conducted to identify the best parental combination with superior fruit yield and heat tolerance of tomato under heat stress conditions.

### Materials and Methods:-

Two heat tolerant (Icixina and Rio Grande) and four heat susceptible tomatoes (Tima, Tropimech, Petomech and Roma Savana) were crossed using half diallel mating design. The resultant 15 hybrids, 6 parents and 4 checks (Roma VF, UC82 B, Thorgal F<sub>1</sub> and Jaguar F<sub>1</sub>) were evaluated at National Horticultural Research Institute, Bagauda experimental farm (11°33'N; 8°23'E) in the Sudan savannah and Institute for Agricultural Research farm, Samaru (11°11'N; 07°38'E) Guinea savannah 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 4. The plot size was 2 × 2m and 1m alleys. Seedlings of tomatoes were raised in nursery on 17<sup>th</sup> July, 2014 and transplanted to the field on three rows at inter-row spacing of 60cm and intra-row of 50cm on 17<sup>th</sup> August, 2014. Fertilizer (N.P.K 15:15:15) was split and applied at the rate of 45kgN, 45kg P<sub>2</sub>O<sub>5</sub> and 45kgK<sub>2</sub>O/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 both locations. Growth and yield data were taken randomly 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) with corresponding physiological traits such as (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 estimated using equation 1. The data from each location was subjected to analysis of variance separately to detect the significance of genotypic variations (Gomez and Gomez, 1984) before a combined analysis of variance. Diallel analysis was used for fixed effects, according to Griffin (1956) method 2 model 1. DIALLEL-SAS05 which is a comprehensive software program for Griffin's and Gardner-Eberhart analysis (Manjit et al., 2005) was used to estimate combining ability variance and effects. The average degree of dominance value was calculated using equation 4 according to Peyman et al. (2012) and classified according to Lagervall, (1961) as follows: 0 = no dominance, less than unity = partial dominance, 1 = complete dominance and greater than unity = overdominance. When the inbreeding coefficient (F) of parents equal to zero (no inbreeding). The additive and non-additive variances were estimated using equations 2 and 3 as follows:

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

Where:  $T_a$  = Air temperature

$T_c$  = canopy temperature

$$\sigma_A^2 = 4\sigma_{GCA}^2 \dots\dots (2) \quad \sigma_D^2 = 4\sigma_{SCA}^2 \dots\dots\dots (3) \quad \text{Degree of dominance (DH)} = \sqrt{\frac{\sigma_D^2}{\sigma_A^2}} \dots\dots\dots (4)$$

### Results and Discussion:-

#### Analysis of Combining Ability:-

The combined analysis of variance for combining ability of the traits under heat stress is given in Table 1. The result showed that mean squares due to location were highly significant (P<0.01) for most of the traits except number of flowers per cluster, number of fruits per cluster, average fruit weight, fruit length, fruit shape index and significant (P<0.05) for fruit diameter, indicating that the conditions in both locations were not the same, which was possibly why the genotypes behave differently in both locations regarding these traits. Highly significant (P<0.01) mean squares due to parents were observed for days to 50% flowering, average fruit weight, fruit length, fruit diameter, fruit shape index and significant for number of fruits per plant, showing that the parents were influenced by change in locations. Dagade et al. (2015) reported highly significant mean squares due to parents for fruit weight, fruit length, fruit diameter and highly significant was also observed for number of fruits per plant (Enang et al., 2015) and

50% flowering (Zengin et al., 2015). The mean squares due to parents vs. cross were not significant for all traits, with exception of number of fruits per cluster which recorded significant difference at ( $P < 0.05$ ) revealing that the hybrids formed were better than at least one of the parents with regard to this trait. Parents vs. cross measure average heterosis for non-additive gene effect. The mean squares due to crosses revealed high significance ( $P < 0.01$ ) for the all studied traits except plant height, number of branches per plant, average fruit weight, percentage fruit set, leaf chlorophyll content and canopy temperature depression suggesting that parents can be used to develop suitable hybrids regarding these traits. The results corroborated with the findings of Dagade et al. (2015) for fruit weight, fruit length and fruit diameter, Enang et al. (2015) for number of fruits per plant and Zengin et al. (2015) for 50% flowering and total fruit yield per plant. The GCA mean squares were highly significant ( $P < 0.01$ ) 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 percentage fruit set and significant ( $P < 0.05$ ) for days to 50% flowering and fruit yield per plant. Highly significant ( $P < 0.01$ ) mean squares due to SCA were observed for number of flowers per cluster and number of fruits per cluster while significant differences ( $P < 0.05$ ) were recorded for number of fruits per plant, fruit diameter and fruit yield per plant. The significant GCA and SCA variances for most of the traits revealed the importance of additive and non-additive gene actions in the controlling the inheritance of the traits. Aisyah et al. (2016) recorded highly significant GCA and SCA variances for fruit yield per plant, number of fruits per plant, individual fruit weight, fruit length and fruit diameter. The variance components due to SCA were higher in magnitude than GCA variance components (Table 2) depicting predominance of non-additive gene action for all traits, except for number of clusters per plant, number of fruits per clusters, fruit length and canopy temperature depression, again indicating that non-additive gene effect was largely influencing the expression of the traits under heat stress, hence selection will bring no or slow genetic improvement. Zengin et al. (2015) reported high SCA variance components for fruit yield per plant and 50% flowering. The GCA  $\times$  location interaction was significant for number of branches per plant, number of flowers per plant and canopy temperature depression, indicating that different parental varieties behave differently across the two locations. The significant SCA  $\times$  location interaction for the number of flowers per plant, percentage fruit set and leaf chlorophyll content, suggested that hybrid performance varied with the locations, thereby necessitating development of specific hybrid for specific locations. The GCA to SCA variance ratios were less than unity for all traits (Table 2), except for number of clusters per plant, number of flowers per plant, number of fruits per clusters, fruit length, fruit shape index and canopy temperature depression, suggesting the importance of dominance gene action in controlling the inheritance of the characters. The results validated the findings of Cheema et al. (2003), Hazra and Ansary, (2008), Shalini (2009) and Saleem et al. (2013) and Louis et al. (2016). Enang et al. (2015) reported GCA:SCA ratio less than unity for number of fruits per plant while Welegama et al. (2015) observed GCA:SCA ratio less than unity for plant height, number of clusters per plant, days to 50% flowering, number of fruits per plant, total fruit yield per plant and average width of fruit. The average degree of dominance values (Table 2) were greater than unity for all traits, except for number of branches per plant, number of clusters per plant, number of fruits per clusters, average fruit weight, fruit length, fruit shape index, percentage fruit set and canopy temperature depression, revealing the existence of overdominance gene action. Hazra and Ansary, (2008) reported overdominance and partial dominance gene action for most of the characters influencing heat tolerance.

### **Combining Ability Effects:-**

The gca effects for the traits across locations (Table 3) showed that none of the parent was the best general combiner for all traits indicating genetic variability among the parents. However, the parent Icrixina recorded high significance ( $P < 0.01$ ) and positive gca effects for the majority of the traits. Among the parents, Rio Grande was considered to be a good combiner for average fruit weight, fruit length, fruit diameter and fruit shape index. These parents were good combiner for the traits and could be utilized for hybrid breeding in an individual location. The result for sca effects showed that, Rio Grande  $\times$  Petomech and Tima  $\times$  Roma Savana had significant positive sca effect for days to 50% flowering, while, the hybrids Icrixina  $\times$  Tropimech, Tima  $\times$  Petomech, Tropimech  $\times$  Petomech and Petomech  $\times$  Roma Savana expressed significant negative sca effect for days to 50% flowering, highly desirable for early flowering. Among the cross combinations, only Petomech  $\times$  Roma Savana showed significant positive sca effects for a number of clusters per plant, number of fruits per plant, percentage fruit set and fruit shape index. However, Rio Grande  $\times$  Roma Savana and Rio Grande  $\times$  Tima recorded significant sca effects for number of flowers per plant. Rio Grande  $\times$  Roma Savana and Rio Grande  $\times$  Tima expressed significant sca effect for average fruit weight and fruit length respectively. The high sca effects manifested by these crosses for the traits were possibly due to one of the best general combiner parents involved (Icrixina and Rio Grande). The hybrids, Petomech  $\times$  Roma Savana and Icrixina  $\times$  Rio Grande were good cross combinations in a desirable direction for fruit yield per

plant and percentage fruit set. These hybrids could be selected and utilized for improving tomato yield under high temperature. The results were similar to findings of Hannan et al. (2007), Yashavantakumar (2008) and Saleem et al. (2013). Number of branches per plant, number of flowers per plant, fruit diameter, leaf chlorophyll content and canopy temperature depression revealed non-significant sca effects among hybrids. Singh and Narayanan (2004) observed that sca effect does not contribute much to the improvement of self-pollinated crop like tomato.

**Table 1:-** Mean squares of combining ability for Agronomic and Physiological characters combined across locations

Source of variation	df	PHT	DFPF L	NBPP	NCPP	NFLP C	NFLPP	NFRP C	NFRPP	AFW
Location	1	4592.70**	89.17**	6260.40**	1947.08**	0.77	172269.85**	0.02	7219.96**	70.29
Replication(location)	4	4592.70	14.51	21.04	13.48	0.66	531.31	0.22	137.10	283.217
Parents	5	17.63	9.96*	96.49	50.56	2.28	1409.85	0.38	104.04*	153.44**
Parents vs Cross	1	56.64	0.18	54.15	54.93	13.57	324.33	8.55*	41.12	83.06
Crosses	4	84.50	46.61**	84.03	84.65**	5.14*	1867.16*	2.38*	232.69*	236.57
GCA	5	37.24	57.25*	166.48	191.24*	10.16**	3750.52	5.36*	408.97*	426.62
SCA	9	110.76	40.70	38.22	25.43	2.35*	820.84	0.73*	134.76*	131.00
Parent × Location	5	102.29	0.50	103.87*	12.99	0.00	470.73	0.00	20.56	8.49
Parents vs Cross × Location	1	491.5**	24.87	223.19*	7.46	0.31	292.55	0.01	5.71	1.46
Crosses × Location	4	42.98	11.82	63.58**	17.69*	0.17	655.53**	0.03	26.01	156.09
GCA × Location	5	24.51	8.05	127.95*	15.71	0.35	922.14**	0.03	17.25	180.17
SCA × Location	9	53.24	13.92	27.81	18.78	0.07	507.41*	0.03	30.87	142.71
Error	80	16.64	1.67	7.16	2.92	0.34	73.87	0.15	13.50	34.32

PHT: Plant height, DFPFL: Days to fifty percent flowering, NBPP: Number of branches per plant, NCPP: Number of clusters per plant, NFLPC: Number of flowers per cluster, NFLPP: Number of flowers per plant, NFRPC: Number of fruits per cluster, NFRPP: Number of fruits per plant and AFW: Average fruit weight. \*\* and \* are significantly different at 1% and 5% levels of probability, respectively.

**Table 1:-** continued.

Source of variation	df	FRL	FRD	FRSI	FRYPP	PFRS	LCC	CTD
Location	1	0.34	0.57*	0.002	5258608.46**	1312.22**	2381.63**	321.28**
Replication(location)	4	0.28	0.95	0.16	2613.84	99.77	252.92	4.52
Parents	5	2.67**	0.06	0.15**	49862.02	111.37	37.93	6.54
Parents Vs Cross	1	0.02	0.0005	0.00002	80087.35	876.57	28.14	0.14
Crosses	14	3.83**	0.17**	0.28**	78066.21**	660.45	46.88	1.20
GCA	5	9.81**	0.18	0.57**	136734.03*	1258.59**	10.99	3.71
SCA	9	0.52	0.17*	0.11	45472.97*	328.15	66.82	1.05
Parent × Location	5	0.21	0.02	0.01	22460.51	55.95	126.24*	2.40
Parents vs Cross × Location	1	0.13	0.001	0.02	1188.64	60.98	14.02	0.76
Crosses × Location	14	0.39	0.05	0.03	15625.16	337.89**	88.36*	4.50*
GCA × Location	5	0.24	0.06	0.01	18521.71	90.34	62.39	8.00**
SCA × Location	9	0.47	0.04	0.04	14015.97	475.42**	102.79*	2.55
Error	80	0.08	0.03	0.01	6276.52	22.32	15.37	0.70

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

**Table 2:-** Estimates of combining ability variance components for agronomic and physiological characters across locations during 2014 rainy season

Character	PHT	DFPFL	NBPP	NCPP	NFLPC	NFLPP	NFRPC	NFRPP
$\sigma_{GCA}^2$	-3.06	0.69	5.34	6.91	0.33	122.07	0.19	11.43
$\sigma_{SCA}^2$	11.30	4.81	-4.23	1.29	0.36	27.55	0.12	18.13
$\sigma_{GCA \times location}^2$	-2.39	-0.49	8.35	-0.26	0.02	34.56	0.00	-1.14
$\sigma_{SCA \times location}^2$	12.20	4.08	6.88	5.29	-0.09	144.51	-0.04	5.79
$\sigma_D^2$	45.19	19.25	-16.91	5.16	1.45	110.21	0.47	72.50
$\sigma_A^2$	-12.25	2.76	21.38	27.64	1.30	488.28	0.77	45.70
GCA/SCA Ratio	-0.27	0.14	-1.26	5.36	0.90	4.43	1.65	0.63
DH	-3.69	2.64	0.89	0.43	1.06	0.48	0.78	1.26

PHT: Plant height, DFPFL: Days to fifty percent flowering, NBPP: Number of branches per plant, NCPP: Number of clusters per plant, NFLPC: Number of flowers per cluster, NFLPP: Number of flowers per plant, NFRPC: Number of fruits per cluster, NFRPP: Number of fruits per plant and DH: average degree of dominance.

**Table 2:-** continued.

Character	AFW	FRL	FRD	FRSI	FRYPP	PFRS	LCC	CTD
$\sigma_{GCA}^2$	12.32	0.39	0.0004	0.02	3802.54	38.77	-2.33	0.11
$\sigma_{SCA}^2$	-4.18	0.02	0.02	0.01	4974.64	-1.62	-3.59	-0.58
$\sigma_{GCA \times location}^2$	3.12	-0.02	0.002	-0.003	375.48	-32.09	-3.37	0.45
$\sigma_{SCA \times location}^2$	36.13	0.13	0.003	0.01	2579.82	151.03	29.14	0.62
$\sigma_D^2$	-16.73	0.09	0.08	0.05	19898.54	-6.49	-14.36	-2.30
$\sigma_A^2$	49.27	1.55	0.002	0.08	15210.18	155.07	-9.305	0.44
GCA/SCA Ratio	-2.95	17.87	0.02	1.44	0.76	-23.88	0.65	-0.19
DH	0.58	0.24	6.93	0.83	1.14	0.20	1.24	2.28

AFW: Average fruit weight, FRL: Fruit length, FRD: Fruit Diameter, FRSI: Fruit shape index, FRYPP: Fruit yield per plant, PFRS: Percentage fruit set, LCC: Leaf chlorophyll content, CTD: Canopy temperature depression and DH: average degree of dominance.

**Table 3:-** General combining ability and specific combining ability effects combined across locations for agronomic and Physiological characters

Parents/Crosses	PHT	DFPFL	NBPP	NCPP	NFLPC	NFLPP	NFRPC	NFRPP
Icixina	0.40	-2.89**	3.88*	5.53**	1.11**	22.81**	0.85**	7.12**
Rio Grande	0.35	0.15	-3.10	-2.05*	-0.19	-14.54	-0.28*	-4.94*
Tima	0.71	0.69	-0.72	-1.42	0.07	-1.40	0.23*	0.36
Tropimech	-2.52	0.07	-2.43	-1.43	-0.63**	-6.37	-0.42**	-3.14
Petomech	0.33	0.24	0.57	-0.94	-0.49**	-2.16	-0.14	0.40
Roma Savana	0.73	1.74**	1.80	0.30	0.04	1.66	-0.25*	0.20
SE(g <sub>i</sub> )±	1.317	0.417	0.864	0.552	0.188	2.774	0.125	1.186
Icixina × Rio Grande	-0.13	-1.21	0.59	2.58	0.25	16.03	0.26	3.77
Icixina × Tima	0.002	0.42	-0.81	-0.52	-0.58*	-3.22	-0.34	-1.75

Icixina × Tropimech	0.48	-2.46*	2.32	-0.39	0.55	0.52	0.31	0.31
Icixina × Petomech	2.55	1.71	-1.52	-1.91	-0.34	-1.26	0.09	-1.35
Icixina × Roma Savana	-2.90	1.54	-0.58	0.24	0.12	-12.07	-0.32	-0.97
Rio Grande × Tima	-0.43	-0.13	0.94	0.35	-0.03	-6.64	-0.14	3.91
Rio Grande × Tropimech	4.65	0.17	-0.90	0.99	-0.69*	-3.50	-0.36	2.01
Rio Grande × Petomech	1.86	2.67*	1.00	-0.67	-0.23	4.13	-0.04	-2.73
Rio Grande × Roma Savana	-5.95	-1.50	-1.62	-3.24	0.69*	-10.02	0.28	-6.97*
Tima × Tropimech	0.66	-1.04	2.66	0.57	0.63*	13.00	0.53**	1.21

**Table 3:-** continued.

Parents/crosses	PHT	DFPFL	NBPP	NCPP	NFLPC	NFLPP	NFRPC	NFRPP
Tima × Petomech	-2.74	-2.20*	-1.88	0.29	-0.08	-7.37	-0.09	-2.64
Tima × Roma Savana	2.50	2.96**	-0.91	-0.69	0.06	4.22	0.03	-0.74
Tropimech × Petomech	6.90*	-2.08*	2.40	1.29	-0.52	11.69	0.24	2.74
Tropimech × Roma Savana	1.11	1.25	-1.68	0.12	-1.00**	1.67	-0.25	-0.79
Petomech × Roma Savana	5.23	-4.25**	4.80	3.57*	0.13	16.19	0.27	9.46**
SE(s <sub>ij</sub> )±	2.986	0.946	1.958	1.251	0.427	6.291	0.283	2.689

PHT: Plant height, DFPFL: Days to fifty percent flowering, NBPP: Number of branches per plant, NCPP: Number of clusters per plant, NFLPC: Number of flowers per cluster, NFLPP: Number of flowers per plant, NFRPC: Number of fruits per cluster and NFRPP: Number of fruits per plant.

**Table 3:-** continued.

Parents/crosses	AFW	FRL	FRD	FRSI	FRYPP	FRY/ha	PFRS	LCC	CTD
Icixina	-1.50	-1.14**	-0.05	-0.29**	137.88*	2297.95**	13.74**	1.31	-0.44
Rio Grande	8.20**	0.79**	0.17*	0.17**	-41.60	-693.26	0.38	-0.44	0.06
Tima	-3.45	-0.05	-0.003	0.01	9.47	157.87	0.14	-0.47	0.71
Tropimech	-2.52	-0.01	-0.05	-0.01	-81.36	-1355.95	-6.54**	0.06	0.03
Petomech	0.30	0.10	-0.05	0.07	-31.43	-523.83	-4.42*	-0.10	-0.24
Roma Savana	-1.03	0.31**	-0.02	0.06	7.03	117.23	-3.31	-0.37	-0.11
SE(g <sub>i</sub> )±	0.091	0.056	0.032	25.570	426.160	1.525	1.265	0.270	0.270

**Table 3:-** continued.

Parents/crosses	AFW	FRL	FRD	FRSI	FRYPP	PFRS	LCC	CTD
Icixina × Rio Grande	-0.86	-0.44**	-0.17	-0.08	119.99	12.61**	2.28	0.14
Icixina × Tima	0.48	0.13	-0.17	0.07	-5.41	-0.08	-2.16	-0.34
Icixina × Tropimech	-1.55	0.06	0.18	-0.01	-6.58	-9.60**	-1.83	0.35
Icixina × Petomech	4.64	-0.04	0.14	-0.08	-101.45	-3.37	-1.43	-0.01
Icixina × Roma Savana	-2.71	0.29	0.01	0.10	-6.55	0.45	3.14	-0.15
Rio Grande × Tima	-1.30	0.39*	-0.03	0.11	40.02	-0.59	-4.21	0.33
Rio Grande × Tropimech	-5.37	0.10	-0.09	0.09	-35.75	1.62	2.09	0.15
Rio Grande × Petomech	-0.67	-0.12	0.17	-0.12	-31.146	-3.06	-1.06	-0.38
Rio Grande × Roma Savana	8.19*	0.07	0.11	0.01	-93.11	-10.59**	0.89	-0.24
Tima × Tropimech	2.73	0.01	0.07	0.020	46.38	4.35	2.09	-0.03
Tima × Petomech	-2.39	-0.17	0.08	-0.11	-30.95	-3.04	1.46	-0.33
Tima × Roma Savana	-0.36*	0.04	-0.09	-50.04	-834.06	2.82	0.37	0.37
Tropimech × Petomech	-0.08	0.19	-0.12	-4.90	-81.65	-2.76	-0.11	-0.11
Tropimech × Roma Savana	-0.25	0.03	-0.21**	-8.95	-149.13	-5.11	-0.59	-0.59
Petomech × Roma Savana	0.26	-0.19	0.18**	158.65	2644.08	-1.73	0.61	0.61
SE(s <sub>ij</sub> )±	0.207	0.126	0.073	57.986	966.440	2.869	0.612	0.612

AFW: Average fruit weight, FRL: Fruit length, FRD: Fruit Diameter, FRSI: Fruit shape index, FRYPP: Fruit yield per plant, FRY/ha: Fruit yield per hectare, PFRS: Percentage fruit set, LCC: Leaf chlorophyll content and CTD: Canopy temperature depression. \*\* and \* are significantly different at 1% and 5% levels of probability, respectively.

**Table 4:-** Average temperature and rainfall for the experimental sites

Month	Bagauda			Samaru		
	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
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

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

### Conclusion:-

The present study revealed SCA variance components were higher than GCA variance components for the major traits, suggesting the preponderance of non-additive gene action. Considering GCA to SCA ratios and average degree of dominance values, hybrid vigor could be exploited to develop high yielding heat tolerant hybrid tomato that can thrive well under rainy season. The parent Icrixina was considered as the best general combiner for the major traits. Hybrids Icrixina × Rio Grande and Petomech × Roma Savana were considered as the most desirable Cross combinations for fruit yield per plant and percentage fruit set.

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