GENETIC DIVERSITY FOR HEAT TOLERANT RELATED TRAITS IN MAIZE INBRED LINES

Kandel Manoj[*1], Surya Kant Ghimire[1], Bishnu Raj Ojha[1], Jiban Shrestha[2]
[1]Department of Genetic and Plant breeding, Agricultural and Forestry University, Rampur, Chitwan, Nepal: [2]Nepal Agricultural Research Council, National Commercial Agriculture Research Program, Pakhribas, Dhankuta, Nepal
**Corresponding author: manojkandel24@gmail.com*

Abstract. The present investigation was carried out at research field of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during February to June 2016. The objective of this investigation was to estimate genetic variability and identify suitable maize inbred lines under heat stress condition. Twenty maize inbred lines were evaluated in alpha lattice design with two replications under normal and plastic house condition. Several secondary traits, namely yield attributes such as - ears per plant, cob length, cob diameter, number of kernels row^{-1}, number of kernel rows cob^{-1}, number of kernel ear^{-1}, shelling percentage, thousand kernel weight and morpho physiological traits such as anthesis silking interval, plant height, ear height, silk receptivity, leaf senescence, tassel blast, leaf area index and leaf firing exhibited significant genotypic and phenotypic association with grain yield under heat stress. Maize inbred lines RL-140, RML-76, RML-91 and RML-40 were exhibited shorter anthesis silking interval, lowest value of tassel blast, leaf firing, and leaf area index with highest value of cob diameter and length, ear per plant, number of kernel row ear^{-1}, number of kernel ear^{-1} and number of kernel row^{-1},shelling percentage, silk receptivity and grain yield in heat stress condition.High heritability along with genetic advance as well as significant positive correlation with grain yield recorded for traits grain yield with number of kernel ear^{-1}, silk receptivity, shelling percentage, and thousand kernel weight indicates presence of additive gene effect early selection and could be used as target traits to improve maize grain yield under heat stress condition. But significant negative association grain yield as well as moderate heritability with low genetic advance for traits anthesis silking interval, tassel blast, leaf firing and leaf area index showed significant negative association with grain yield, and these traits could be improved through the use of hybridization and hybrid vigour.Therefore maize inbred lines RML-91, RL-140, RML-76 and RML-40 were can be used for development of hybrid for heat stress condition.

Keyword: Maize, Heat stress, Morphological trait, Genetic variability

INTRODUCTION

Maize being nutritionally an important crop has multiple functions in the traditional farming system; being used as food and fuel for human beings & feed for livestock and poultry. In Nepal, it is grown in 8,91,583 ha producing 2.2 million tons, with an average yield of 2500 kg ha^{-1} (MOAD,2016).The reasons for low maize yield in Nepal are high temperature, drought, stalk rot infestation, maize borer and shoot fly infestation, poor crop management, high input rates and use of low quality, substandard seed. Heat and drought stress have emerged as a common problem worldwide which can reduce maize crop productivity (Ali *et al.*, 2015).Heat stress in the flowering and grain filling periods due to elevated temperatures drastically affect crop productivity. It is predicted that maize yield might be reduced up 70 % due to increasing temperatures (Khodarahmpour *et al.*, 2011).A report of the Asian Development Bank (2009) warns that if the current trends persist until 2050 major food crop yields and food production capacity of south Asia will significantly decreases by 17% for maize, 12% for wheat and 10% for rice due to climate change induced heat and water stress. To cope this situation genetic management would be low readily available and acceptable to all farmer as compared to agronomic management (Saxena and Toole,2002).Genetic diversity within the crop is pre requisite for genetic improvement of crop through selection. Correlation analysis used as effective tool to determine the relationship among different traits in genetic diverse population for enhancement of crop improvement process. Binodh *et al.,(*2010) character association in crop is important for effective and rapid selection in crop improvement. Heritability is measure of the phenotypic variance attributable to genetic causes provide extend of particular trait can be transmitted to successive generation. It helps to choose selection method would be most useful to improve character to predict gain from selection and to determine the relative importance of genetic effects. High genetic advance with high heritability determine reliability of crop improvement through selection of such traits. To improve heat stress tolerance maize can be achieved through effective selection of suitable parent materials of significant genetic variability. The objective of propose investigation study was to estimated correlation, genetic variation, heritability and genetic advance in maize inbred lines under heat stress and normal condition and evaluated suitable selection criteria for further breeding program of heat stress in maize.

MATERIALS AND METHOD

Genetic Materials and Experimental site. The research was conducted at National Maize Research Program (NMRP) of Rampur, Chitwan (27º 37’ North and 84 º 29’ East, 225m asl) during spring season from February 24, 2015 to July 31, 2016.The soil type at this location is sandy loam(sand:slit:clay:75.4:16.9:7.7), pH=5.5,Total nitrogen=0.09,organic matter(2.01%),phosphorous(89.70%)& potassium(308.2%).

Experimental design and crop husbandry. Twenty maize inbred lines collected from national maize research program were evaluated using a alpha lattice design with two replication under half of field was controlled heating imposed using two plastic (120gsm) houses were used just prior to the onset of reproductive period up to the crop maturity. Each plot contained single row with spacing 60×20 cm and consisted 15 hills, each of two seed were sown ,one of whose seedling were removed at the six leaves stage.

Table 1

Names and pedigree information of maize genotypes used for heat stress research at NMRP Chitwan (2016)

S.N.	Maize Inbred Lines	Pedigree	S.N.	Maize Inbred Lines	Pedigree
1	NML-2	CML-430	11	RL–101	UPAHAR-B-20-2-3-1-1
2	RML–4	CA00326	12	RML–24	CA00304
3	RML–32	CA00320	13	RML–40	CML-427
4	RML–95	PUTU-17	14	RML–57	CLQG6602
5	RML–86	PUTU-20	15	RL–107	UPAHAR-B-20-2-4-3-1
6	RML–17	CML-287	16	RML–20	CA-34503
7	RML–96	AG-27	17	RML–76	CLRCYQ007
8	RL–105	UPAHAR-B-20-2-4-1-1	18	RML–7	CML-413
9	RL–111	UPAHAR-B-31-1-1-1-1	19	RML–91	PUTU-19
10	RML–115	PUTU-17	20	RL–140	POOL-21-12-1-2-2-1-1

The irrigation was given according crop growth stage and fertilizer were applied prior to sowing at rate of 60 N kg ha^{-1} and 40 kg P ha^{-1} and additional side dressing of 30 N Kg ha^{-1} were applied at the six leaves stage of maize plants. Maximum mean temperature (46.2–43.28°C) & minimum (30.52-30.77°C) in with relative humidity 37.05 to 49.45% inside the tunnel during in April-May which coincide with the flowering, pollination & grain filling periods. To avoid any possible disease outbreak humidity inside the plastic tunnel was controlled by partial opening top side of tunnel.

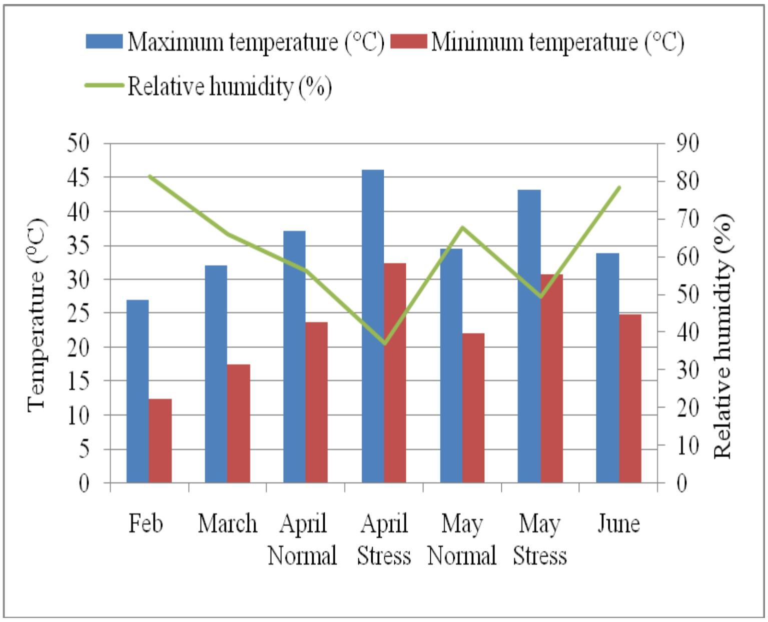

Fig. 1. Weather data recorded in NMRP, Rampur during Experimental period (24th Feb to June 2016)

Data Collection and Analysis. Data on days to 50% anthesis, days to 50% silking and ears per plot, leaf firing, tassel blast, leaf senescence were recorded on plot basis. Whereas, ear height (cm), number of kernels per cob, number of kernel row, number of kernel row per ear,SPAD reading,leaf area index, silk receptivity, thousand kernel weight (g)and shelling per cent were recorded on five selected representative plants. The sample cobswere shelled, cleaned and grain weight and shankweight were recorded to calculate the shelling percent. Thousand kernelweights was measured by counting 1000grains from the bulk of each plot after shelling andweighed in grams after the moisture was adjustedto 12.5%. Anthesis to silking interval (ASI) wascalculated by subtracting the number of days taken for 50% anthesis from the number of days taken to50% silk emergence. Leaf area index was calculated by total leaf area divided by land area and multiply by correction factor (0.75). Silk receptivity was recorded by total number of fertilized grains per ear divided by number of potential grain per ear. Leaf firing was obtained bythe counting the number of plants that showed leaffiring symptoms (younger leaves near tassel burntor dried) in the total number of plants in aparticular plot. Then the value was expressed inpercentage. Tassel blast was obtained by thecounting the number of plants that showed tasselblast symptoms (tassel dried with partial or nopollen shedding) in the total number of plants inparticular plot. Grain yield (kg/ha) at 15% moisture content was calculated using fresh ear weight with the help of the below formula:

Where,

F.W. = Fresh weight of ear in kg per plot at harvest
HMP = Grain moisture percentage at harvest
DMP = Desired moisture percentage, i.e. 15%
NPA = Net harvest plot area, m^2
S = Shelling coefficient, i.e. 0.8

This formula was also adopted by Carangal *et al.* (1971) and Shrestha *et al.* (2015) to adjust the grain yield (kg ha^{-1}) at 15% moisture content. This adjusted grain yield (kg ha^{-1}) was again converted to grain yield (t ha^{-1}).

Broad sense heritability (h^2_b) for the trait was estimated by using the variance components method suggested by Becker, (1984) as follows:

$$H^2b= \frac{\text{MSS due to genotype – MSS due to error}}{\text{Replication}}$$

Where, h^2b= broad sense heritability, r= number of replication

Genetic advance

The extent of genetic advance to be expected by selecting five percent of the superior progeny was calculated by using the following formula given by Robinson *et al.,* (1949).

$$GA= I\ \sigma_p H^2_b$$

Where,I = efficiency of selection which is 2.06 at 5% selection intensity ,σ_p= phenotypic standard deviation,H^2_b= heritability in broad sense.

Statistical analysis. The data recorded on different parameters from field were first tabulated in Microsoft Excel (MS- Excel, 2010), then Analysis of variance (ANOVA) for all data was statistically analyzed GENSTAT. The data obtained was subjected to Restricted Maximum Likelihood (REML) tool in GenStat to obtain ANOVA.Correlation coefficients of different traits were carried out using the formula given by Steel and Torrie,(1980) by using SPSS program.

RESULTS AND DISCUSSION

Association of chlorophyll content with grain yield was strong under heat stressed environments, suggesting it to be one of the major contributors to grainyield hence fully supported our results. Therefore, due to high heritability and low genetic advance as well as positively significant association between SPAD readings with grain yield at heat stress as compared to non-significant association in normal condition showed that high SPAD reading.Chen *et al,* (2010) reported that under high temperature stress condition leaf firing reduces photosynthetic apparatus which lead to reduction in grain yield.

Kaur *et al*. (2011) reported positivesignificant association between leaf firing and tassel blast and negative association ofboth with yield. While, the heritability of leaf firing and tassel blast under heat stressed environments for inbred lines were high the magnitude of damage observed and their association with grain yield was negatively significant, means they were strongly associated with reduction in the seed set of maize in heat stressed. Hence SPAD reading, tassel blast and leaf firing it might be representative secondary trait for yield improvement of maize under heat stress. Heat stress effect was most prominent on plant and ear height.

Table 3
Mean of 20 maize inbred lines for various traits evaluated under normal (N) and heat stressed condition (S) condition.

	DT		DS		ASI		LAI		LF %		TB %		LS %	
Inbred	N	S	N	S	N	S	N	S	N	S	N	S	N	S
NML 2	71	71.5	74	77	3	5.5	3.5	3.5	5.03	5.6	25.9	58.3	20	50
RL 101	71	71.5	73	75	2	3	3.04	2.61	6.97	14	31.1	36.7	50	60
RL105	73	74.5	75.5	79	2.5	4	2.93	2.84	9.4	39	39.1	46.2	25	65
RL107	68.5	71	70	74	1.5	2.5	2.43	2.42	9.95	11	17.1	27	30	60
RL111	70.5	71.5	73.5	77	3	5.5	2.74	2.29	6.67	24	16.7	48.1	30	50
RL 140	67.5	70	70	73	2.5	3	2.28	2.21	7.88	0	3.3	24	25	75
RML115	70	70.5	73	76	3	5.5	2.65	2.63	7.5	43	21.7	24.9	30	45
RML 17	70.5	71	73	73	2.5	2	2.8	2.7	7.18	14	13.8	17.1	35	80
RML 20	70.5	71.5	73	75	2.5	3	3	2.85	7.5	14	17.1	17.4	30	85
RML 24	71.5	72	70.5	77	-1	5	3.2	3.09	6.67	28	23.3	55.8	35	75
RML 32	68.5	71.5	71	75	2.5	3	2.44	2.33	8.33	18	18	22.7	30	60
RML4	71	71	74	77	2.5	5.5	2.66	2.65	7.74	28	30.4	52.3	25	50
RML 40	67	68	68	71	1	3	2.83	2.8	7.18	10	3.8	43.3	25	80
RML 57	69.5	71.5	71.5	74	2	2.5	2.5	2.33	8.12	10	9.1	37.6	25	60
RML 7	67	67	68.5	70	1.5	3	2.31	2.29	12.7	14	31.5	35.7	60	100
RML 76	70.5	70	72	75	1.5	4.5	2.09	1.75	7.18	13	0	23.3	40	45
RML 86	72	71.5	75.5	77	3.5	5.5	3.22	3.07	4.17	21	18.3	50	30	65
RML 91	68.5	70.5	71	74	2.5	3	3.17	3.15	6.9	0	3.6	16.7	35	40
RML 95	68.5	71	72	75	2.5	4	2.7	2.62	7.88	22	28.2	44.5	25	70
RML 96	70	72	72.5	75	2.5	3	2.91	2.86	6.67	14	6.7	31	35	60
G.Mean	69.9	71	72.1	75	2.2	3.8	2.77	2.64	7.58	18	18	35.6	32	63.8
F –test	NS	NS	*	*	*	*	*	*	NS	*	*	**	NS	**
CV%	2.25	2.85	2.17	2.45	37	21.9	14	12	38.01	52.3	40.3	22.93	32	12.4
LSD	3.4	4.37	3.39	3.97	1.7	1.8	0.88	0.70	6.22	20.8	15.68	17.64	22.1	17.2

All the genotypes showed significant reduction in plant and ear height as compared to in normalenvironmentas observed in present study. This reduction might be result of the effect of heat stress on internal –nodal elongation.Weaich *et al.*, (1996) & Cairns *et al.*, (2012) fully supported our finding. Strong correlation between plant height and ear height with leaf area index suggested that tall plants with high ear placement gave better yield under heat stress.

Table 4

Mean of 20 maize inbred lines for various traits evaluated under normal (N) and heat stressed condition (S) condition

	SPAD		PH (cm)		EH (cm)		PM (Days)		EPP		CD (cm)		CL(cm)	
Inbred	N	S	N	S	N	S	N	S	N	S	N	S	N	S
NML 2	46.65	41.59	176.3	147.8	96	81	115.5	106.5	1.436	1.042	3.41	0	10.92	0
RL 101	43.975	44.53	152.5	133.3	85.5	73.8	108	103	1.5	1.25	3.19	2.67	9.70	8.24
RL105	41.1	24.5	146.7	141.8	86.5	80	111.5	108	1.267	0.885	2.75	0	11.4	0
RL107	50.125	43.38	143.9	129.2	68	65.8	114.5	105	1.7	1.339	3.99	2.99	12.95	12.43
RL111	36.93	24.27	164.5	148.3	86.1	80.6	120	104.5	1.95	2.176	3.87	0	12.19	0
RL 140	41.215	37.45	136.8	127	72.2	60.2	121	107.5	1.406	1.14	3.9	2.67	13.30	12.4
RML115	38.42	35.72	108.3	102.6	61.6	54.5	121.5	109	1.042	0.862	3.69	0	7.27	0
RML 17	47.375	44.11	159.2	136.6	86.7	74.5	114	105.5	1.419	0.893	3.83	2.43	12.40	11.62
RML 20	44.26	39.87	133.8	118	68.2	52.8	114	103	1.550	1.488	3.56	2.89	14.10	12.84
RML 24	45.65	27.31	153.6	144.3	93.3	77.6	119.5	108	1.333	1.196	3.49	0	9.96	0
RML 32	48.14	43.18	120	113.4	46.5	43.5	114	108	1.250	1.045	3	2.83	13.05	11.96
RML4	44.7	40.25	125.6	116.7	72.4	54	118	109	1.435	1	3.1	0	10.75	0
RML 40	46.725	41.25	134.9	125.8	63.7	60.2	116.5	106	1.254	1.033	4.06	3.65	12.10	11.36
RML 57	48.24	45.56	134.1	128.2	66.5	60.9	116	104.5	1.350	1.143	3.29	2.45	12.95	0
RML 7	38.78	36.41	148.6	135.8	74.7	67.3	115	100.5	1.30	1	3.87	3.02	12.18	12.08
RML 76	44.88	41.1	123.9	115	56.8	51.4	115	108.5	1.3	1.1	3.44	2.32	11.13	9.53
RML 86	37.605	33.48	126.8	120.5	74.8	69.4	114	107	1.35	1	3.53	0	13.02	0
RML 91	40.33	42.45	159.8	150	95.5	83.4	120	109	1.55	1.3	3.16	3.08	13.85	13.27
RML 95	37.4	38.55	142.9	128	77	71.5	116	108.5	1.7	1.324	3.57	0	10.55	0
RML 96	41.53	38.32	155.4	134.8	75.8	69.6	119.5	108.5	1.533	1.143	3.73	2.54	12.60	11.83
GM	43.202	38.16	142.4	129.9	75.4	66.6	116.17	106.5	1.431	1.168	3.522	1.677	11.82	6.89
F –test	**	*	**	*	**	**	**	**	NS	*	*	**	*	**
CV%	1.17	14.22	5.2	7.91	9.25	8.13	1.45	1.5	14.2	15	7.5	14.66	8.16	12.97
LSD	1.0941	11.723	16.02	22.21	15.08	11.7	3.654	3.432	0.441	0.379	0.5708	0.532	2.086	1.931

The tall stature of plant provided space for more number of leaves which ultimate help in increases leaf area index with good orientation finally resulting high photosynthesis rate and which ultimately affect the individual grain weight and grain yield of crop. However, this trait seemed to be more complex as high heritability, genotypic coefficient of variation and genetic advance at 5 % was observed, while their association was non-significant with grain yield under heat stress condition. Therefore further study is needed to confirm the result about these traits might be representative trait for yield improvement of maize under heat stress condition. A number of factors could be responsible for reduction in number of silk receptivity under heat stress on corn kernel set, seasonal pollen production, silk elongation pattern and duration of silk receptivity.

The seasonal pollen production determine kernel per plant at pollen densities less than 3000 pollen grain per silk. It was found that a minimum pollen shed density per exposed silk is required to achieve maximum kernel set and grain yield reported by (Westgate *et al.*, 2003).Silk receptivity can be drastically reduced by as much as 80% during high temperatures due to sudden pollen shedding over a very short time (Fonseca *et al.*, 2005).Anderson *et al.*, (2004) found that kernel set and yield stability are impacted by variation among hybrid for silk elongation and senescence. Leaf area index of the decreases was observed after severe heat waves due to leaf growth pattern of maize increases in rang of temperature 0-35ºC with decline at 35-40ºC.Leaf area expansion is of great importance for light interception and for photosynthesis; it varies with the quantity of assimilates allocated to the production of leaves and the ratio of the leaf area produced per unit of leaf dry matter. Heat stress causes translocation of the photosynthetic products cannot fully match the increased rates of carbon fixation under the prevailing conditions, this results in the thickening of the existing leaves and the formation of thicker new leaves, and therefore in a sharp decrease of leaf area in the pre-anthesis period. It can also be noted that the LAI is maximum at tasselling or later and further slight decrease in leaf area is attributed to the senescence of the old (thinner) leaves, so that the younger thicker leaves remain on the stand a and longer growing cycle and normally a higher leaf area index and determine the overall leaf area index value.Karim *et al.*, (2000) reported that leaf area and day time leaf expansion rate were good thermo tolerance trait of tropical maize under heat stress condition.

Therefore, due to high heritability, GCV and genetic advance as well as positively significant association between silk receptivity with grain yield and negative association leaf area index However, limited literature isavailable on this trait in maize. Thus they might be representative secondary trait for yield improvement of maize under heat stress. In general, maize yields have been shown to have an optimum growing temperature of 29 °C and 30 °C, respectively; temperatures above this threshold result in yield decreases (Schlenker and Roberts, 2009).The major effect of high temperature is embryo abortion, which is related to the inhibition of photosynthesis and the subsequent reduction in assimilates available to developing kernels. Exposure to temperatures above 30 °C damaged cell division and amyloplast replication in maize kernels which reduced the size of the grain sink and ultimately yield (Commuri and Jones, 2001).The of the yield decrease up to 100%, larger than those estimated in previous studies (Lobell and Field, 2007; Schlenker and Roberts, 2009).Amongthe yield traits, a significant reduction in average ears per plant was observed underheat stress suggesting an increase in the frequency of barrenness due to high temperature. This is attributed to the fact that different vegetative andreproductive organs undergo active growth at the same stage, which incurscompetition for assimilates among organs.

The changes in distribution of assimilates might be cause for reduced reproductive growth, particularly ears per plant (Rattalino Edreira *et al*., 2011). Similar findings has been reported in previous studies (Cicchino *et al*., 2010b) in maize crop exposed to high temperature at flowering stage. However, this trait seemed to be more complex as high heritability, genotypic coefficient of variation but low genetic advance at 5 % was observed, while their association was non-significant with grain yield under heat stress while positively significant at normal condition. Therefore further study is needed to confirm the result about these traits might be representative trait for yield improvement of maize under heat stress condition.

Table 5

Mean of 20 maize inbred lines for various traits evaluated under normal (N) and heat stressed condition (S) condition

	NKRE		NKE		NKR		SR %		SP %		TKW (g)		GY (kg/ha)	
Inbred	N	S	N	S	N	S	N	S	N	S	N	S	N	S
NML 2	10.6	0	74.4	0	10.6	0	54.74	0	45.8	0	259	0	1457	0
RL 101	13.5	12.6	87	53	14.7	12.5	46.73	30.55	60.5	57.95	289	264.6	1469	551.9
RL105	13	0	92.5	0	13	0	47.01	0	17.4	0	257	0	366	0
RL107	12.30	10.6	165	50.2	15	12.8	70.44	22.35	51.9	18.48	288	270.6	1918	264
RL111	12.2	0	173.9	0	12.2	0	77.7	0	48.8	0	261	0	2153	0
RL 140	12.8	11.7	210.4	110.5	17	14.8	79.27	36.77	61.4	54.65	289.5	279.6	2352	702.9
RML115	12.2	0	92.4	0	12.2	0	53.35	0	30.2	0	269	0	818	0
RML 17	12.2	10	187.8	67.9	14.6	12.4	78.1	31.9	71.3	58.1	275	271.1	2201	565.3
RML 20	11.6	10.4	115.5	50.3	15.4	13.2	55.37	20	40.4	21.62	316	306.1	1213	273.6
RML 24	12.4	0	104.9	0	12.4	0	54.73	0	38.3	0	229	0	1196	0
RML 32	10.5	10	74.3	45.2	14.4	12.2	53.41	26.3	54.9	42.3	306	293	1130	536.7
RML4	11.2	0	92.5	0	11.2	0	62.06	0	39.3	0	269.5	0	1287	0
RML 40	11.	10.1	130.5	74.8	13.6	12.4	74.52	34.27	62.3	56.5	301	276	2018	643
RML 57	11.8	11.3	143.7	48.7	15.5	13.8	70.57	22.95	51.1	36.22	253	204.7	1903	342.6
RML 7	12.6	12.6	102.5	70	14.2	12	50.84	26.7	55.9	51.2	333	320	582	526.5
RML 76	14.2	10.8	124.6	94	16.5	14.3	68.19	34.57	79.0	52.12	272	255.7	1689	689.5
RML 86	12.4	0	108.2	0	12.8	0	61.75	0	44.3	0	257	0	1577	0
RML 91	12.8	12.8	275	130.2	16	13.8	79.39	38.2	60.4	40.3	289	276	2346	716.8
RML 95	11.2	0	143.4	0	11.2	0	76.8	0	54.1	0	169.4	0	1991	0
RML 96	12	10	118	46.2	14.4	12.2	77.25	20.06	56	46.3	289	277.9	2090	508
GM	12.24	6.64	130.8	42.1	13.8	7.82	64.61	17.23	51.2	26.79	273.3	164.8	1588	316
F –test	Ns	**	**	**	*	**	**	**	**	**	**	**	**	**
CV%	9.5	7.2	14.31	21	9.58	13.52	4.04	11.57	13.40	14.7	6.702	6	13.28	8.62
LSD	2.166	1.037	40.45	19.21	2.86	2.284	5.652	4.31	14.83	8.56	39.73	21.61	455.8	58.89

Apart from ears per plant, heat stress significantly affected other yield attributing traits, such as cob length, cob diameter, number of kernel row^{-1} and kernelof rows ear^{-1}, number of kernel ear^{-1}, shelling percentage, and thousand kernel weight. In general, most inbred lines showed lower trait value forthese traits as compared to normal condition.

Table 6

Genetic parameter and correlation analysis of maize inbred lines.

Traits	Heritability		GA at 5 %		Correlation	
	Normal	Stress	Normal	Stress	Normal	Stress
GY	0.88	0.98	1080.84	475.4	-	-
DS (day)	0.55	0.46	2.62	2.34	-0.221ns	-0.766**
DT(day)	0.36	0.06	1.48	0.24	-0.343ns	-0.492*
ASI (day)	0.49	0.62	1.13	1.73	0.096ns	-0.726**
LAI(cm2)	0.45	0.65	0.5	0.74	0.06ns	-0.445*
SPAD	0.98	0.47	8.34	7.13	0.085ns	0.560*
EH (cm)	0.76	0.8	22.02	20	0.124ns	0.249ns
PH (cm)	0.82	0.52	30.1	16.02	0.293ns	0.041ns
LF	0	0.6	0	2.07	-0.123ns	-0.692*
TB	0.62	0.72	2.5	1.86	-0.764**	-0.679*
LS	0.2	0.75	0.41	1.58	-0.24ns	0.167ns
PM (day)	0.78	0.64	5.8	3.53	0.327ns	-0.162ns
EPP	0.23	0.69	0.1	0.45	0.463*	-0.132ns
SR %	0.95	0.88	23.41	16.4	0.911**	0.98**
CD (cm)	0.57	0.44	0.47	1.53	0.439ns	0.896**
CL (cm)	0.62	0.62	2.25	6.25	0.51*	0.857**
NKRE	0.32	0.78	0.83	7.29	-0.2ns	0.917**
NKE	0.87	0.84	94.17	40.43	0.74**	0.941**
SP %	0.84	0.94	19.3	25.58	0.941**	0.963**
TKW (g)	0.75	0.99	56.25	286.65	-0.362ns	0.94**

These results are supported by previous findings of many authors wherenegative effects of high temperatures on cob growth rate and reduced biomasspartitioning to ear was reported (Cicchino *et al*., 2010b; Rattalino Edreira *et al*.,2011). A number of factors could be responsible for reduction in number of kernels per cob under heat stress, such as reduced pollen viability and receptivity of silk,increased frequency of kernel abortion, decreased cell division in endosperm, reducedsink capacity of developing kernels, reduced starch grain number and overall starchsynthesis, increased soluble sugar accumulation, duration of grain filling, kerneldevelopment and enzyme activities (Duke and Doehlert, 1996).Hussain *et al*., (2010) reported that, number of rows cob^{-1}, number of kernels row^{-1} and grain yield were much reduced in spring season due to heat stress. Moser *et al.*, (2006) reported that stress before and immediately after pollination may lead to failure of number of kernel development per ear. It was found that a minimum pollen shed density per exposed silk is required to achieve maximum kernel set and grain yield reported by (Westgate *et al.*, 2003).Silk receptivity can be drastically reduced by as much as 80% during high temperatures due to sudden pollen shedding over a very short time (Fonseca *et al.*, 2005).Anderson *et al.,* (2004) found that kernel set and yield stability are impacted by variation among hybrid for silk elongation and senescence.Rowhani *et al.,* (2011) reported that significant variation in shelling percentage under heat stress condition might be associated with lower grain yield traits such as pollen viability and fertilization under high temperature.

Rise in temperature beyond 30°C impacts the activity of *Rubisco* in maize, which in turn reduces photosynthesis and ultimately decreases grain filling period and grain size (Steven *et al.,* 2002).Kernel weight is influenced by source-sink relationships during grain fill with increased kernel weight being caused by irradiance level, grain-fill duration, and plant and kernel growth rate (Gambin *et al.,* 2006).Rowhani *et al.,* (2011) reported that significant variation in shelling percentage under heat stress condition might be associated with lower grain yield traits such as pollen viability and fertilization under high temperature. Rise in temperature beyond 30°C impacts the activity of *Rubisco* in maize, which in turn reduces photosynthesis and ultimately decreases grain filling period and grain size (Steven *et al.,* 2002).

Kernel weight is influenced by source-sink relationships during grain fill with increased kernel weight being caused by irradiance level, grain-fill duration, and plant and kernel growth rate (Gambin *et al.,* 2006).High heritability,GCV and genetic advance for all these yield attributing traits exhibited significant positive association with grain yield suggesting it to be an important parameter for selection index for maize crop improvement in heat stressed environment.

CONCLUSION

Heat stress significantly affected mean grain yield at all crop growth stages under heat stress. However, maximum losses was observed with flowering stage heat stress, followed by grain filling stage stress incomparison to mean grain yield of inbred lines under normal conditions. Significant genotypic variability was observed for grain yield, yield attributesand various morpho-physiological traits under heat stress at different growth stages. However, flowering stage heat stress showed maximum variation formost the traits studied. Heat stress affected flowering behavior, however, the effect was morepronounced on female inflorescence, which resulted in prolonged ASI. All inbred lines having low yielding (<1tonha^{-1}) under heat stress whereas, all genotypes gave higher yields under normal conditions. Several secondary traits, including yield attributes such as - ears per plant, coblength, cob diameter, kernels row^{-1}, kernel rows cob^{-1}, number of kernel ear^{-1} and morph physiological traits such as ASI, plant height, ear height, silk receptivity, leaf senescence, tassel blast, shelling percentage and leaf firing exhibited significant genotypic and phenotypic association with grain yield under heat stress.

Acknowledgements. The authors would also like to thank National Maize Research Program Rampur (NMRP), Rampur,Chitwan for the provision of reseach materials and National Agricultural Research and Development Fund (NARDF) for financial supports.

REFERENCES

1. Ali, F., Kanwal, N., Ahsan, M., Ali, Q., Niazi, N. K. (2015). Crop improvement through conventional and non-conventional breeding approaches for grain yield and quality traits in Zea mays. Life Science Journal, 12(4s).
2. Anderson, S. R., Lauer, M. J., Schoper, J. B., Shibles, R. M. (2004). Pollination timing effects on kernel set and silk receptivity in four maize hybrids. Crop Science, 44(2), 464-473.

3. Asian Development Bank (2009).The economics of climate change in Southeast Asia: A regional review. Retrieved 9 July 2017.
4. Becker, W. A. (1984). *Manual of quantitative genetics* (ed. 4). WA: Academic Enterprises.
5. Binodh, A. K., Manivannan, N., Varman, P. V. (2008).Character association and path analysis in sunflower. Madras Agric. J, 95(7-12), 425-428.
6. Carangal, V.R., Ali, S.M., Koble, A.F., Rinke, E.H., and Sentz, J.C. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. Crop Science, 11, 658-661. DOI: 10.2135/cropsci1971.0011183X001100050016x
7. Cairns, J. E., Sonder, K., Zaidi, P. H., Verhulst, N., Mahuku, G., Babu, R., Rashid, Z. (2012). 1 Maize Production in a Changing Climate: Impacts, Adaptation, and Mitigation Strategies. Advances in agronomy, 114(1).
8. Chen, J., Xu, W., Burke, J. J., Xin, Z. (2010). Role of phosphatidic acid in high temperature tolerance in maize. Crop science, 50(6), 2506-2515.
9. Cicchino, M., Edreira, J. I., Otegui, M. E. (2010a). Heat stress during late vegetative growth of maize: effects on phenology and assessment of optimum temperature. Crop science, 50(4), 1431-1437.
10. Cicchino, M., Edreira, J. I., Uribelarrea, M., Otegui, M. E. (2010b). Heat stress in field-grown maize: Response of physiological determinants of grain yield. Crop science, 50(4), 1438-1448.
11. Commuri, P. D., Jones, R. J. (2001). High temperatures during endosperm cell division in maize. Crop Science, 41(4), 1122-1130.
12. Crafts-Brandner, S. J., Salvucci, M. E. (2002). Sensitivity of photosynthesis in a C4 plant, maize, to heat stress. Plant Physiology,129(4), 1773-1780.
13. Duke, E. R., Doehlert, D. C. (1996). Effects of heat stress on enzyme activities and transcript levels in developing maize kernels grown in culture. Environmental and experimental botany, 36(2), 199-208.
14. Dupuis, I., Dumas, C. (1990). Influence of temperature stress on in vitro fertilization and heat shock protein synthesis in maize (*Zea mays L.*) reproductive tissues. Plant physiology, 94(2), 665-670.
15. Edreira, J. R., Carpici, E. B., Sammarro, D., Otegui, M. E. (2011). Heat stress effects around flowering on kernel set of temperate and tropical maize hybrids. Field Crops Research, 123(2), 62-73.
16. Fonseca, A. E., Westgate, M. E. (2005).Relationship between desiccation and viability of maize pollen. Field crops research, 94(2), 114-125
17. Gambín, B. L., Borrás, L., Otegui, M. E. (2006).Source–sink relations and kernel weight differences in maize temperate hybrids. Field Crops Research, 95(2), 316-326
18. Hussain, I. Q. B. A. L., Wahid, A. B. D. U. L., Ashraf, M. U. H. A. M. M. A. D., Basra, S. M. (2010). Changes in growth and yield of maize grown in the glasshouse. International Journal of Agriculture and Biology, 12, 9-12.
19. Hussain, T., Khan, I. A., Malik, M. A., Ali, Z. (2006).Breeding potential for high temperature tolerance in corn (Zea mays L.). Pakistan Journal of Botany, 38(4), 1185.
20. Kamara, A. Y., Menkir, A., Badu-Apraku, B., Ibikunle, O. (2003). Reproductive and stay-green trait responses of maize hybrids, improved open-pollinated varieties and farmers's local varieties to terminal drought stress. Maydica, 48(1), 29-38.
21. Karim, M. A., Fracheboud, Y., Stamp, P. (2000).Effect of high temperature on seedling growth and photosynthesis of tropical maize genotypes. Journal of Agronomy and Crop Science, 184(4), 217-223.
22. Kaur, R., Saxena, V. K., Malhi, N. S. (2010).Combining ability for heat tolerance traits in spring maize [zea mays L.)]. Maydica, 55(3), 195.
23. Kaur, R., Saxena, V. K., Malhi, N. S. (2010).Combining ability for heat tolerance traits in spring maize [zea mays L.)]. Maydica, 55(3), 195.
24. Khodarahmpour, Z., Choukan, R. (2011). Genetic Variation of Maize (Zea mays L.) Inbred Lines in Heat Stress Condition. Seed and Plant Improvment Journal, 27(4), 539-554.

25. Liu, X., Huang, B. (2000). Heat stress injury in relation to membrane lipid peroxidation in creeping bentgrass. Crop Science, 40(2), 503-510.
26. Lobell, D. B., Field, C. B. (2007).Global scale climate–crop yield relationships and the impacts of recent warming. Environmental research letters, 2(1), 014002.
27. Magorokosho, C., Tongoona, P. (2003).Selection for drought tolerance in two tropical maize populations. African Crop Science Journal, 11(3), 151-161.
28. MOAD, (2014/15).Statistical information on Nepalese agriculture.Agribusiness Promotion and statistics Division Singh Durbar, Kathmandu.Ministry of Government of Nepal.
29. Moser, S. B., Feil, B., Jampatong, S., Stamp, P. (2006). Effects of pre-anthesis drought, nitrogen fertilizer rate, and variety on grain yield, yield components, and harvest index of tropical maize. Agricultural Water Management, 81(1), 41-58.
30. Robinson, H.F., E. Comstock and P. H. Harvey. (1949). Estimation of heritability and degree of
31. dominance in corn. Agronomy Journal 41: 353- 359
32. Rowhani, P., Lobell, D. B., Linderman, M., Ramankutty, N. (2011).Climate variability and crop production in Tanzania. Agricultural and Forest Meteorology, 151(4), 449-460.
33. Saxena, N. P., O'Toole, J. C. (2002). Field Screening for Drought Tolerance in Crop Plants with Emphasis on Rice Proceedings of an International Workshop on Field Screening for Drought Tolerance in Rice 11-14 Dec 2000. International Crops Research Institute for the Semi-Arid Tropics.
34. Schlenker, W., Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. Proceedings of the National Academy of sciences, 106(37), 15594-15598.
35. Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., and KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. Journal of Maize Research and Development, 1(1), 21-27.
36. Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics, a biochemical approach. McGraw Hill, Inc. New York
37. Steven J.,C.Brandner, M. Salvucci (2002).Sensitivity of photosynthesis in C4 maize plant to heat stress. Plant Physiol 129:1773-1780.
38. Suwa, R., Hakata, H., Hara, H., El-Shemy, H. A., Adu-Gyamfi, J. J., Nguyen, N. T., Fujita, K. (2010). High temperature effects on photosynthate partitioning and sugar metabolism during ear expansion in maize (Zea mays L.) genotypes. Plant Physiology and Biochemistry, 48(2), 124-130.
39. Weaich, K., Bristow, K. L., Cass, A. (1996).Modeling preemergent maize shoot growth: II. High temperature stress conditions. Agronomy Journal,88(3), 398-403.
40. Westgate, M. E., Lizaso, J., Batchelor, W. (2003). Quantitative relationships between pollen shed density and grain yield in maize. Crop Science, 43(3), 934-94.