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Agronomic performance of maize under high temperature condition

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Abstract: Maize (*Zea mays* L.) is second most important crop in Nepal and its production is greatly affected by high temperature stress. Improving heat tolerance in maize has become one of the top priorities for maize breeding program in the country. In order to identify high grain yielding maize genotypes under high temperature condition, field experiments were conducted at Parwanipur (Bara), Nepalgunj (Banke) and Rampur (Chitwan) during summer season of 2010. The forty four genotypes were evaluated in randomized complete block design with three replications. The pooled analysis over locations showed that TLBRSO7F16 produced the highest grain yield with shorter anthesis silking interval (ASI) and bigger ear length (2809 kg/ha, 3 days, 14.4 cm) followed by RPOP-4 (2417 kg/ha, 2 days, 13.6 cm), TLBRSO7F14 (2316 kg/ha, 3 days, 14.2 cm), BLSBSO7F10 (2159 kg/ha, 2 days, 14.4 cm), Manakamana-3 (2108 kg/ha, 2 days, 14.7 cm) and Upahar (2108 kg/ha, 4 days, 14.3 cm). Therefore it was concluded that TLBRSO7F16, RPOP-4, TLBRSO7F14, BLSBSO7F10, Manakamana-3 and Upahar were good genotypes under high temperature conditions at terai region of Nepal.

Keywords: Anthesis-silking interval, grain yield, high temperature, maize

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Maize has high production potential among the primary maize growing countries in the world, Italy (9322 kg/ha) was first for higher productivity (Narang and Gill, 2004) but in Nepal its productivity is only 2500 kg/ha (MOAC, 2011/12). The productivity of maize in the hill is stagnant and low. Because of rapidly growing population and decreasing food productivity, food crisis in Nepal especially in hilly regions is rising day by day. There is a need to improve the productivity of maize in order to increase food security in the hills. Among the different measures to increase maize production under adverse climatic conditions, development of high temperature tolerant maize varieties is good option to increase and maize production under heat stress condition. The high temp-erature (heat) stress is considered to be the major environmental factor limiting crop growth and yield. It induces many biochemical, molecular, and physiological changes and responses that influence various cellular and whole plant processes that affect crop yield and quality. High temperature around flowering has negative effects on maize grain yield. That temperature is an important source of yield reduction in maize and its effects depend upon the growth stage when it takes place. It directly influences seed-filling duration, leading to smaller seed size and lower yields. High temperature impairs the flow of carbon assimilation processes in cereals and causes distinctive yield loses (Stone, 2001). It has been suggested that each 1°C increase in temperature above optimum (25°C) results in a reduction of 3 to 4% in grain yield (Shaw, 1983). At rise in temperature (+30°C), pollen shedding starts much ahead of silks emergence while silking is delayed, so that silking period does not correspond to anthesis/tasseling, resulting in poor synchronization of flowering (asynchrony). Further rise in temperature reduces the

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pollen viability and silk receptivity resulting in poor seed set and reduced yield. 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.

Global warming is becoming major issues for agriculture; the days are heating more and more so high temperature tolerant crop varieties should be developed to increase and stabilize crop production. Maize is a tropical plant species, it shows variable response to prevailing temperatures (Hussain et al, 2006 and 2010), the genetic makeup of a species may play important role in reducing the deleterious effects of high temperature. So these studies were conducted during heat period of summer season in 2010 at Parwanipur, Nepalgunj and Rampur under rainfed condition to develop high yielding high temperature tolerant maize genotypes in terai region of Nepal.

MATERIALS AND METHODS

Genetic Materials and Experimental Site

Forty four maize genotypes namely RL-84, RL-30-1, PUTU-13, Pool-17, Arun-1EV, Arun-4, Pool-16, Narayani, Upahar, Across-9331, S97TLYHGAYB (3), Rampur Composite, Manakamana-4, Arun-2, OEHPW, P501SRCO/P502SRCO, BGBY POP, S99TYQAB, S99TYQ-HGB, Posilo Makai-1, SO1SIWQ-3, S99TLYQ-B, RampurSO3FO2, RampurSO3FO4, RampurSO3FO6, RampurSO3FQ-02, BLSBSO7F10, BLSBSO7F12, TLBRSO7F14, TLBRSO7F16, RPOP-1, RPOP-2, RPOP-3, RPOP-4, NML-1/NML-2, RML-4/NML-2, RML-8/Rampur Composite, Manakamana-3, Rampur-2, Deuti, Pop-446, Khumal Yellow, Gulmi-2, Resunga Composite were used in these experiments. The location of experiments were Parwanipur, Nepalgunj and Rampur. The year and season were 2010 and summer respectively. Monthly mean temperature data (maximum and minimum temperature) was recorded during the crop growing season at Parwanipur, Nepalgunj and Rampur. At Parwanipur the maximum temperature ranges 30.4 to 35.5°C and minimum temperature varies from 19.7 to 25.1°C. Similarly at Nepalgunj the maximum temperature ranges from 32.4 to 38.5°C and minimum temperature varies from 21.5 to 29.7°C. At Rampur the maximum temperature ranges 31.4 to 35.4°C and minimum temperature varies from 22.8 to 26.9°C. An average precipitation at tested locations is negligible (less than 315.5 mm) during crop growth.

Experimental Design and Crop Husbandry

The experiments were laid out in randomized complete block designs with three replications. Planting was done in 20th May at each location. The plot size was 4 rows of 5 m length with spacing of 75 cm x 25 cm (RR x PP). The net harvested ares is 2 rows of 5 m (7.5 m^2) Organic matter at the rate of 10 ton FYM/ha was applied during the field preparation. All plots were fertilized with 120:60:40 N:P_2O_5:K_2O kg/ha in the form of urea, di-amonium phosphate (DAP), and murate of potash (MoP). Of this 50 % of nitrogen, full 100% of phosphorous and potassium fertilizers were applied as basal and remaining 50 % of nitrogen was split first at knee high stage (side dressing) and second at tasseling stage (side dressing). Thinning was done at 25th day after sowing (DAS) to maintain a single plant per hill. Furadon (3 % C.G) 2-3 granules per plant of maize was applied against the stem borer to the uppermost whorls of leaves at the grand growth stage (40 DAS). Two manual weedings were done throughout the maize growing period, first at knee-high (25 DAS) and second at tasseling stage (55 DAS). Irrigations was done two times during the growing period of maize hybrids, first at grand growth stage (40 DAS) and second at tasseling stage (60 DAS).

Data Recording, Measurements and Analysis

The observation on days to 50% tasseling, days to 50% silking, ASI, plant height, ear height, ear length, ear diameter and grain yield was taken. Ten plants in each subplot (harvested plot) after harvesting were randomly selected; their ear lengths were measured with the help of measuring tape. The plant height and ear height were measured with tape. Ear diameter was recorded using Vernier caliper. The data generated were averaged to record ear length. Ears harvested for grain yield were used for the determination of number of grains/ear by selecting ten ears randomly from each net plot, dried (around 15% moisture) and shelled (80% shelling) for grains/ear. Data regarding thousand grains weight were recorded by counting randomly selected 1000 grains from each net plot and weighed with sensitive electronic balance. The grain yield (kg/ha) was recorded by weighing the grains shelled from the ears obtained from the central two rows of each net plot and converted it into kg/ha using the formula:

$$\text{Grain yield}\left(\text{kg/ha}\right) = \left\{\text{Grain yield}\left(\text{kg}\right)/\text{Area harvested}\left(7.5\text{m}^2\right)\right\} \text{x} 10000$$

Data were analyzed using the statistical package MSTAT-C (Russel and Eisensmith, 1983) and the significant differences between treatments were determined using least significant difference (LSD) test at probability level of 0.01 or 0.05 where the effects of the treatments were significant at 1% or 5% level of probability, respectively.

RESULTS AND DISCUSSION

Data on 50% tasseling days, 50% silking days, plant height, ear height and grain yield were found highly significant at each location where ASI was highly significant at Parwanipur but non significant at Nepalgunj and Rampur (Table 1). The ear length and ear diameter were significant at Nepalgunj and Rampur and highly significant at Parwanipur. At Parwanipur, the highest grain yield was produced by Rampur SO3FQ-02 (1277 kg/ha) followed by OEHPW (1223 kg/ha) and Upahar (1210 kg/ha). The variation in grain yield was due to differential genetic response of

Table 1 Pooled analysis on grain yield and other agronomic traits of maize tested under high temperature condition of three different locations (Parwanipur, Nepalgunj and Rampur) during summer season of 2010

S. N.	Genotypes	Days to 50 % tasselling	Days to 50 % silking	ASI (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (kg/ha)
1	RL-84	57	61	5	187.6	79.3	12.7	3.4	937
2	RL-30-1	61	62	1	165.7	88.6	14.5	3.6	827
3	PUTU-13	58	66	8	164.5	66	10.7	3.4	367
4	Pool-17	45	47	2	139	70.1	12.5	3.6	1172
5	Arun-1EV	47	50	3	160.6	78.5	13.0	4.0	1117
6	Arun-4	46	48	1	166.6	75	14.5	3.9	1820
7	Pool -16	50	52	2	171.1	78	12.6	3.6	1086
8	Narayani	51	55	4	164.8	85.5	13.9	4.0	1615
9	Upahar	56	59	4	170	90.1	14.3	4.1	2108
10	Across-9331	53	56	3	189.6	90.3	13.5	4.0	1918
11	S97TLYHGAYB (3)	52	54	2	173	77	12.4	3.6	1393
12	Rampur Composite	55	57	2	173.3	88	12.9	3.9	1570
13	Manakamana-4	56	58	2	185.8	86.8	13.8	3.6	1575
14	Arun-2	49	53	4	181.8	84.5	12.5	3.9	1391
15	OEHPW	58	61	3	172.5	97.1	15.4	4.0	2149
16	P501SRCO/P502 SRCO	60	64	4	203.1	68.5	12.8	3.8	1096
17	BGBY POP	60	65	4	171.5	93	15.5	4.1	1963
18	S99TYQAB	58	60	2	183.5	81.3	15.3	4.0	1628
19	S99TYQ-HGB	56	57	1	174.6	84	13.1	3.9	2050
20	Posilo Makai-1	59	64	5	187	89.6	14.9	4.2	2071
21	SO1SIWQ-3	64	66	2	163.6	67.3	12.5	3.8	716
22	S99TLYQ-B	61	66	5	177.3	77.8	12.9	3.8	1443
23	RampurSO3FO2	56	59	3	190.1	96.3	15.0	4.0	1589
24	RampurSO3FO4	56	59	4	168.8	77.5	14.2	3.6	1803
25	RampurSO3FO6	57	60	3	191.5	91.5	14.2	4.1	1765
26	RampurSO3FQ-02	62	65	4	182.5	82.3	13.9	3.8	1612
27	BLSBSO7F10	54	56	2	174.1	86.67	14.4	3.8	2159
28	BLSBSO7F12	57	60	2	183.1	89.33	13.8	3.7	1969
29	TLBRSO7F14	55	58	3	190.3	86.5	14.2	4.0	2316
30	TLBRSO7F16	56	60	3	187.6	102	14.4	4.1	2809
31	RPOP-1	55	57	2	190.8	93.17	13.3	4.2	2032
32	RPOP-2	50	53	3	196.1	100.5	13.2	3.9	1944
33	RPOP-3	53	56	3	177.8	93.3	14.2	4.0	1704
34	RPOP-4	51	53	2	190.6	98.5	13.6	3.9	2417
35	NML-1/NML-2	56	57	1	187.1	97.1	15.0	4.0	1792
36	RML-4/NML-2	65	68	4	165.6	75.5	14.5	3.8	1351
37	RML-8/Rampur Composite	49	51	3	183.6	85.6	14.4	4.1	2057
38	Manakamana-3	58	60	2	190.5	98	14.7	3.9	2108
39	Rampur-2	51	53	3	171	76	14.2	3.9	1538
40	Deuti	59	64	4	192	94	14.9	3.8	1991
41	Pop-446	50	53	3	153.5	62.3	11.5	3.7	744
42	Khumal Yellow	51	55	4	176.5	86.3	12.7	4.0	2065
43	Gulmi-2	54	56	3	233.5	122	14.9	4.0	2036
44	Resunga Composite	54	57	3	200.1	93.6	14.3	3.8	2031
	Grand mean	54.9	57.9	3	179.1	86.0	13.8	3.9	1678
	$LSD_{0.05}$	6.27	7.18	2.70	36.76	25.31	3.41	0.66	1645.4
	CV, %	5.8	6.3	46.4	10.4	14.9	12.5	8.6	49.6
	Genotype (G)	**	**	**	**	**	**	**	**
	Location (L)	**	**	**	**	**	**	**	**
	F-test (G x L)	**	**	NS	NS	NS	NS	NS	NS

maize genotypes to prevailing high temperature. The reduction in grain yield under high temperature was due to increased percentage of shriveled seed and decreased seed size. The 50% tasseling days varied from 48.5 days (RML-8/Rampur Composite) to 66 days (RML-4/NML-2). Similarly highest 50% silking days varied from 47 days (Pool-17) to 71 days (RampurSO3FQ02). ASI was lowest in NML-1/NML-2 (1 day) and highest in PUTU-13 (8 days). The plant height varied from 125.5 cm (Pool-17) to 221cm (Gulmi-2). The highest ear height was observed in Gulmi-2 (97.5 cm) and lowest in Pop-446 (51 cm). The ear length varied from 9.6 cm (PUTU-13) to 17.6 cm (Deuti). The biggest ear diameter was found in RampurSO3FO6 (4.6 cm) and smallest in RL-84 (3.5 cm). The average values of 50% tasseling days, 50% silking days, ASI, plant height, ear height, ear length and ear diameter were 56 days, 59 days, 3 days, 177.9 cm, 76.9 cm, 15.2 cm and 4.0 cm respectively.

At Nepalgunj, the highest grain yield was produced by Khumal Yellow (3675 kg/ha) followed by RML-8/Rampur Composite (3519 kg/ha) and TLBRSO7F16 (3348 kg/ha). The 50% tasseling days varied from 46 days (Pool-17) to 70 days (RML-4/NML-2). Similarly highest 50% silking days varied from 47 days (Pool-17) to 76 days (RML-4/NML-2). ASI was lowest in Pool-17 (1 day) and highest in PUTU-13 (8 days). The plant height varied from 139 cm (PUTU-13) to 243 cm (Gulmi-2). The highest ear height was observed in Gulmi-2 (136.5 cm) and lowest in SO1SIWQ-3 (59 cm). The ear length varied from 9. 5 cm (PUTU-13) to 15.9 cm (TLBRSO7F16). The biggest ear diameter was found in TLBRSO7F16 (4.2 cm) and smallest in RL-84 (2.8 cm). The average values of 50% tasseling days, 50% silking days, ASI, plant height, ear height, ear length and ear diameter were 56 days, 59 days, 3 days, 174.5 cm, 88 cm, 12.2 cm and 3.5 cm respectively.

At Rampur, the highest grain yield was produced by Khumal Yellow (3675 kg/ha) followed by RML-8/Rampur Composite (3519 kg/ha) and TLBRSO7F16 (3348 kg/ha). The 50% tasseling days varied from 46 days (Pool-17) to 70 days (RML-4/NML-2). Similarly 50% silking days varied from 47 days (Pool-17) to 76 days (RML-4/NML-2). ASI was lowest in Pool-17 (1 day) and highest in PUTU-13 (8 days). The plant height varied from 139 cm (PUTU-13) to 243 cm (Gulmi-2). The highest ear height was observed in Gulmi-2 (136.5 cm) and lowest in P501SRCO/P502SRCO (60 cm). The ear length varies from 9.3 cm (Pop-446) to 15.9 cm (TLBRSO7F16). The biggest ear diameter was found in TLBRSO7F16 (4.2 cm) and smallest in RL-84 (2.8 cm). The average values of 50% tasseling days, 50% silking days, ASI, plant height, ear height, ear length and ear diameter were 56 days, 59 days, 3 days, 174.5 cm, 88 cm, 12.2 cm and 3.5 cm respectively.

The pooled analysis of forty four genotypes tested at Parwanipur, Nepalgunj and Rampur during summer season showed that the parameters on 50 % tasseling days, 50% silking days, plant height, ear height, ear length, ear diameter and grain yield were found highly significant for tested genotypes and locations but only days to 50% tasseling and 50% silking were highly significant for genotype × location (G × L) interaction. The rest of all characters were non significnant for G × L interaction. In pooled analysis over locations the highest grain yield was produced by TLBRSO7F16 produced the highest grain yield (2809 kg/ha) followed by RPOP-4 (2417 kg/ha), TLBRSO7F14 (2316 kg/ha), BLSBSO7F10 (2159 kg/ha), Manakamana-3 and Upahar (2108 kg/ha).

The reduction of grain yield in maize was due to heat stress. This findings was similar with the work of Cicchino *et al.* (2010) who observed the reduction in maize grain yield due to negative effects of heat stress on plant growth. The 50% tasseling days varied from 45 days (Pool-17) to 65 days (RML-4/NML-2). Similarly 50% silking days varied from 47 days (Pool-17) to 68 days (RML-4/NML-2). ASI values varied from 1 day (RL-30-1) to 8 days (PUTU-13). The variation in flowering in maize genotypes might be due to genetic variation among different maize genotypes and difference in their adaptation to high temperature which affects the growth and development of the crop. In this experiments heat stress delayed silking which was similar with previous evidences in maize summarized by Yan and Hunt (1999). Similarly Cicchino et al. (2010) found that heat condition increased the ASI in maize.

The final plant height reflects the growth behavior of a crop, besides genetic characteristics, availability of essential nutrients, space, water and environmental condition under which it is grown. Increase in temperature affects the plant growth which ultimately influences the plant height. Under high temperature condition maize genotyoe Pool-17 had the lowest plant height of 139 cm and Gulmi-2 had the highest plant height 233.5 cm. Ear height is considered one of the important characters in maize hybrids. Normally as the ear height increased, it received more photosynthates from the leaves which ultimately affect the individual grain weight and final yield of the crop. The highest ear height was observed in Gulmi-2 (122 cm) and lowest in Pop-446 (62.3 cm). The ear length varied from 10.78 cm (PUTU-13) to 15.5 (BGBYP). The biggest ear diameter was found in Poshilo Makai-1 (4.2 cm) and smallest in RL-84 (3.4 cm). The average values of 50% tasseling days, 50% silking days, plant height, ear height, ear length and ear diameter were 55 days, 58 days, 179.1 cm, 86.0 cm, 13.41 cm and 3.9 cm respectively.

This figure 1 indicated that the genotypes namely TLBRSO7F16, RPOP-4, TLBRSO7F14, Manakamana-3, Upahar, BLSBSO7F10 produced higher grain yield above the average grain yield (1678 kg/ha) and shorter ASI (2-4 days).

Conclusion

High grain yield under high temperature was associated with a short anthesis silking interval (ASI). Superior yield performance under high temperature

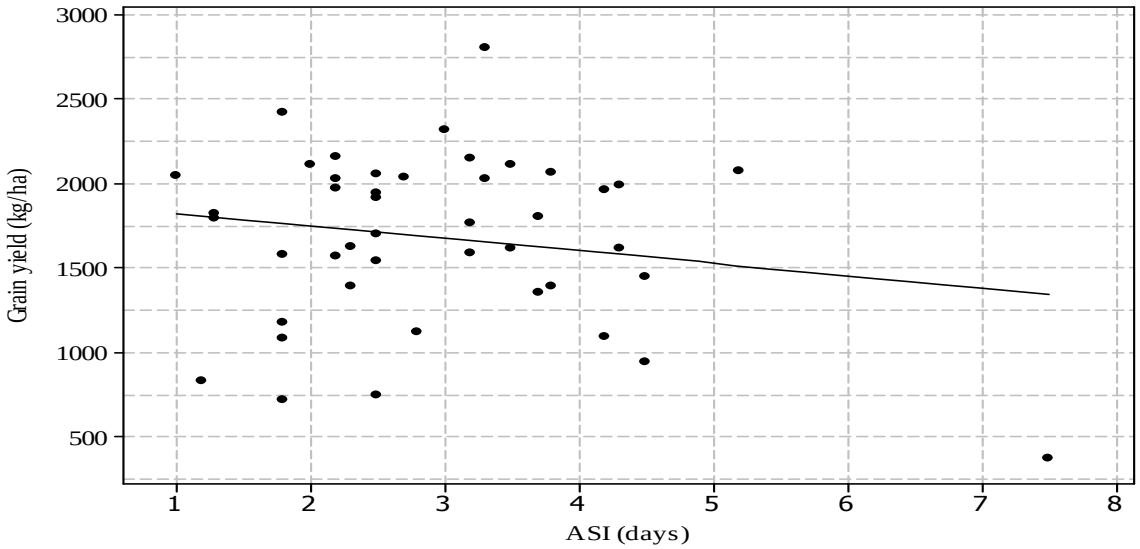

Figure 1 Grain yield (kg/ha) versus ASI (days) derived from combined analysis of maize at Rampur (Chitwan), Parwanipur (Bara), and Nepalgunj (Banke) during summer season of 2010

is an important and reliable secondary index of high temperature tolerance. The maize genotypes namely TLBRSO7F16, RPOP-4, TLBRSO7F14, BLSBSO7F10, Manakamana-3 and Upahar performed equally better in all tested locations and their grain yields were found higher with shorter ASI (1-4 days), hence they were promising genotypes under high temperature growing conditions at terai region of Nepal.

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