International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

EVALUATION OF THE EFFECTS OF TERMINAL HEAT STRESS ON GRAIN TRAITS OF BARLEY (*Hordeum vulgare* L.) IN CHITWAN, NEPAL

[1]S. Pathak, [1]C. Poudyal, [2]B. R. Ojha and [2]S. Marahatta

[1]Institute of Agriculture and Animal Science, Rampur Campus, Chitwan, Nepal

[2]Agriculture and Forestry University, Chitwan, Nepal

*Corresponding Author

ABSTRACT

A field research was conducted at IAAS, Rampur, Chitwan from November, 2014 to April, 2015 to evaluate different barley genotypes for their response to terminal heat stress based on grain traits and heat stress indices. Altogether, 12 exotic genotypes and one landrace were sown in two dates (normal sowing: 29th November, 2014 and late sowing: 1st January, 2015) under two factor factorial RCBD with three replications during winter season of 2014/15. The various grain traits were found to be significantly influenced by terminal heat stress. As compared to normal sowing condition, grain yield reduced by 69.8% spike length by 7.9%, grain per spike by 57.69%, grain length by 3.86% in late sown condition. Similarly, dorsal grain width, ventral grain width and thousand grain weight reduced by 2.73%, 2.39% and 10.37% respectively in stressful environment, while sterility was found to be increased by 20.15%. The mean tolerance level, geometric mean productivity, stress susceptibility index and stress tolerance index of genotypes stood out to be 774 kg ha^{-1}, 523.9 kg ha^{-1}, -0.20 and 0.128 respectively. Due to stable production and high stress tolerance index Soluwa and SBYT 14-1 were observed to be promising in Chitwan, Nepal condition. New avenues can be opened for the further research and breeding of such heat tolerant barley lines.

Keywords: Barley, heat stress, stress tolerance

INTRODUCTION

Barley is the fourth most important cereals in the world (FAOSTAT, 2013). It constitutes the major source of food for the people of cooler semi-arids and the high altitude inhabitants. It is

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

cultivated in diverse landforms for its tolerance against alkaline soils, frost or drought (Mishra and Shivakumar, 2000). Barley, one of the first cultivated grains, is a source of three life-essential components: carbohydrates (74%), proteins (11.5%) and fiber (3.9%) alongwith fats (1.3%) and minerals (1.5%). In Nepal, barley is grown as a spring season crop in the High hills and Himalayas while in Terai region it is grown as a winter season crop. The numbers of environmental factors prevent the plant from expressing its maximum genetic potential. Severe grain losses are caused by higher or lower temperatures, drought, anaerobiosis and excess salt (Cattivelli *et al*., 2013) and heat stress is a severe threat to crop production worldwide (Hall, 2001).

Heat stress is the occurrence of temperatures usually 10 to 15°C above ambient causing irreversible damage to plant (Peet and Willits, 1998). There is an average yield loss of 1.7% per day, when sown beyond optimum time (Mohammadi, 2002). In Nepal, as barley is grown in both tropical and sub-tropical climate, post-anthesis heat stress is common. Also, barley is forced to grow under heat-stress due to the late maturing rice crops. High temperature limits the ability of the plant to accumulate carbohydrate necessary for grain growth due to accelerated development.

In addition, heat stress before flowering can cause floret sterility, causing yield losses due to reduces grain number. It is therefore deemed that the new research be directed to identifying and developing suitable genotypes for normal and stressed environments. So, this experiment was undertaken to evaluate different grain traits of given barley genotypes, to assess the effect of heat stress on individual genotypes and to identify the heat tolerant genotypes in Chitwan, Nepal condition.

MATERIALS AND METHODS

The field experiment was carried out at breeding research field (27° 37’ N latitude, 84° 25’ E longitude and 198m above sea level) of IAAS, Rampur in inner Terai region of Nepal from November, 2014 to April, 2015. Twelve exotic genotypes from ICARDA, Morocco and one landrace from HCRP, Kabre were used in the experiment (Table 1). Field layout was done in RCBD method. Barley was sown in two dates, viz. normal sowing (29^{th} November, 2014) and late sowing (1^{st} January, 2015). Thirteen genotypes were grown in three replications in each normal and late sowing condition. Three replicates each of 20m long including borders were made. 12 plots in each replication were prepared. Each plot consisted of 6 rows of 2.5m in length and 0.2 m row to row distance. 0.5m separation was made within each replication. Same layout was followed in late sowing condition. The normal and late sown crop was separated by 1m distance.

Table 1: List of barley genotypes used in the experiment along with their pedigree.

Genotypes	Cross/Pedigree
SBYT14-5	Avt/Attiki//M-Att-73-337-1/3/Aths/Lignee686/4/Lignee527/NK1272//JLB70-63
SBYT14-38	Rhn-03/AC_Bacon
SBYT14-9	Nadawa/Rhn-03//Saida
SBYT14-18	QB813-2/5/Aths/Lignee686/4/Rhn-03/3/Bc/Rhn//Ky63-1294
SBYT14-7	Rhn-03/Alanda
SBYT14-1	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI05761
SBYT14-39	Rihane-03
SBYT14-2	Zarjau/80-5151//OK84817
SBYT14-11	Aths/Lignee686/4/Avt/Attiki//Aths/3/Giza121/Pue
SBYT14-27	Alanda//Ssn/Lignee640/3/QB813-2
SBYT14-37	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Aths/CI16155
SBYT14-8	Clipper//WI2291*2/WI2269/7/Hml-02/5/Cq/Cm//Apm/3/12410/4/Giza134-2L/6/Clipper/Volla/3/Arr/Esp//Alger/Ceres362-1-1/4/Hml
Soluwa	NB 1054/Solukhumbu *(Landrace)*

The standard barley crop production practices were adopted. When the crop matured, spikes from each plot were counted, cut and threshed to obtain the grain yield. Grain yield hectare^{-1} was calculated by converting yield plot^{-1} into grain yield hectare^{-1} by using formula:

$$\text{Grain yield per hectare} = \frac{\text{Yield per plot}}{\text{Plot size in m}^2} \times 10000\ \text{m}^2$$

Spike length was determined with the help of ruler. Ten spikes were randomly selected from each plot and number of grains was calculated for each spike to calculate grain per spike. The grain length and width were measured with the help of digital vernier caliper from 10 randomly selected grains of each genotype. Thousand grain weight (TGW) was obtained by weighing 1000 sample grains of each genotypes of barley. The sterility percentage was obtained by counting the number of filled grains to the number of non-filled grains present in a spike. Ten spikes from each plot were sampled for calculating sterility.

Stress susceptibility index (SSI) was calculated by formula of Fischer and Maurer (1978) as:

$$SSI = \frac{1 - \frac{Y_{Si}}{Y_{Pi}}}{1 - \frac{Y_S}{Y_P}}$$

Where Y_{Si} and Y_{Pi} meant the grain yield or Thousand Grain Weight (TGW) of each cultivar in stress condition and Y_S and Y_P meant the mean grain yield or TGW of all genotypes in stress and optimum condition respectively.

Geometric mean productivity (GMP) was calculated as given by Fernandez (1992):

$GMP = \sqrt{Y_P \times Y_S}$, where Yp and Ys are grain yield of each genotype in normal and late sown condition respectively.

Stress tolerance index (STI) was calculated by following formula recommended by Fernandez (1992).

$$STI = \frac{Y_{si}.Y_{pi}}{Y^2\,p}$$

Where Y_{si} is the grain yield or TGW of each genotype in stress condition, Y_{pi} is the grain yield or TGW of each genotype in optimum condition and Y^2p is the mean square of grain yield of all genotypes in optimum condition. Data entry and processing was carried out using Microsoft Office Excel 2007 and analysis of variance was calculated using Genstat 15th Edition.

RESULTS AND DISCUSSION

The average temperature during the growth period of barley from November to February was favourable (upto 25°C). The average temperature rose to 30°C and beyond in March and April which was detrimental to the barley (Bavei et al., 2011). The weather pattern of the experimental period is given in the Figure 1.

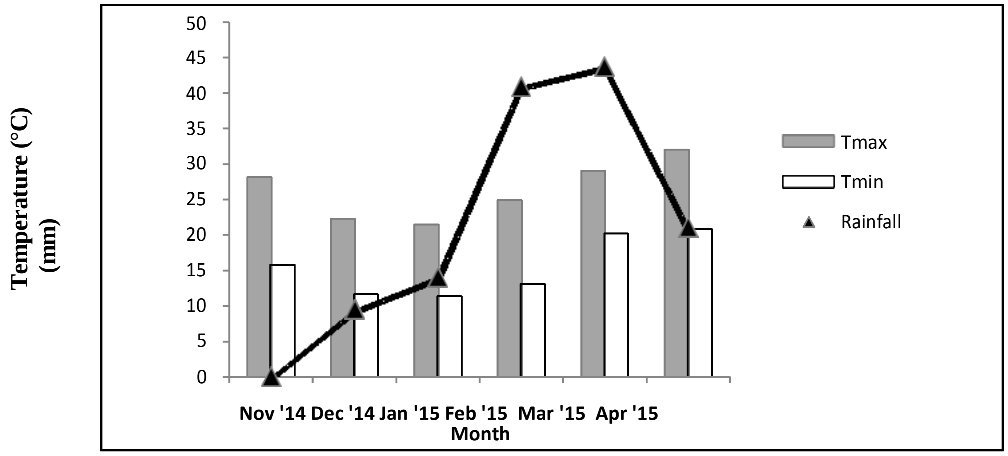

Fig. 1: Weather pattern of experimental site for crop growing period at IAAS, Chitwan in 2014/15.

The combined analysis of variance (Table 2) showed that the effect of genotypes, sowing time and their interaction were significant for all the grain traits except dorsal and ventral grain width in which the interaction effect was non-significant. The effect of sowing time was also non-significant for ventral grain width.

Table 2: Combined ANOVA of grain traits of 13 barley genotypes during 2014/15.

Source of Variation	d.f.	Grain Yield	Spike Length	Number of grain per spike	Grain length	Dorsal Grain Width	Ventral Grain Width	Thousand Grain Weight	Sterility
Replication	2	651047	0.4662	15.70	0.4484	0.00442	0.00900	12.78	81.60
Genotype	12	3476555**	3.0686**	619.12**	2.9851**	0.10683**	0.09079*	180.69**	2562.44**
Sowing time	1	11678470**	5.4617**	1985.66**	2.7478**	0.18144*	0.13592	340.21**	7911.09**
Genotype× sowing time	12	177619**	0.6423*	104.48**	0.3380*	0.03002	0.03356	55.90**	583.26**
Residual	50	392949	0.2979	24.15	0.1392	0.02690	0.02724	14.19	77.69

** represents significance at 0.01 level

* represents significance at 0.05 level

The different genotypes performed differently and sowing time had significant impact on various grain traits of barley. Similarly, it also indicated that the given genotypes responded in varying manner to different environmental conditions implying the need of evaluation of genotypes under different conditions to identify the best genotype for a particular condition. The interaction effect (Fig. 2 to Fig. 7) of sowing time and genotypes for various grain traits is shown below:

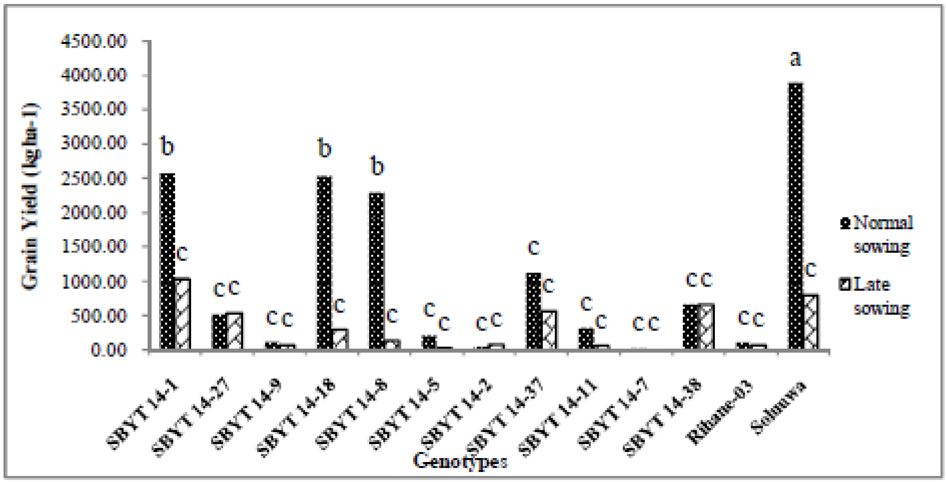

Fig. 2: The interaction between sowing date and different genotypes of barley for grain yield at IAAS, Chitwan in 2014/15.

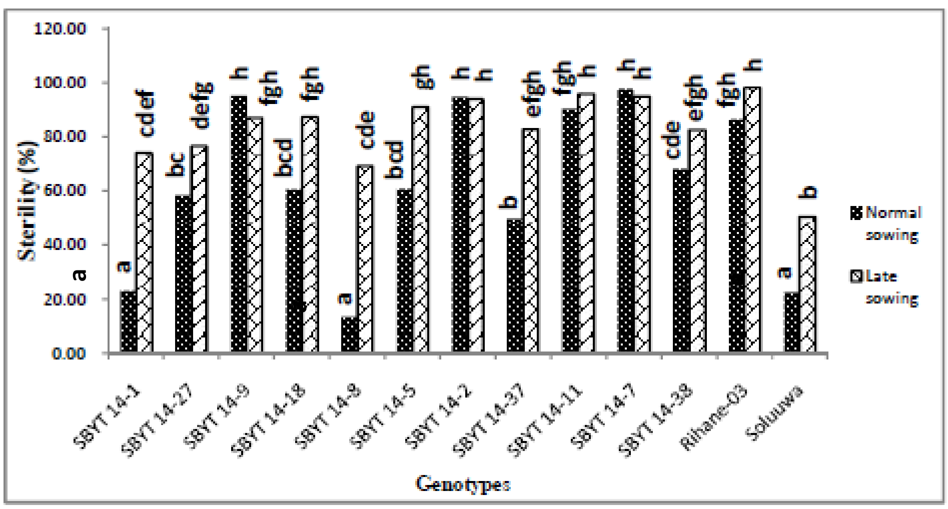

Fig. 3: The interaction between sowing date and different genotypes of barley for sterility at IAAS, Chitwan in 2014/15.

** Data labels in the figures followed by same letter are not significantly different at 5% level by DMRT.*

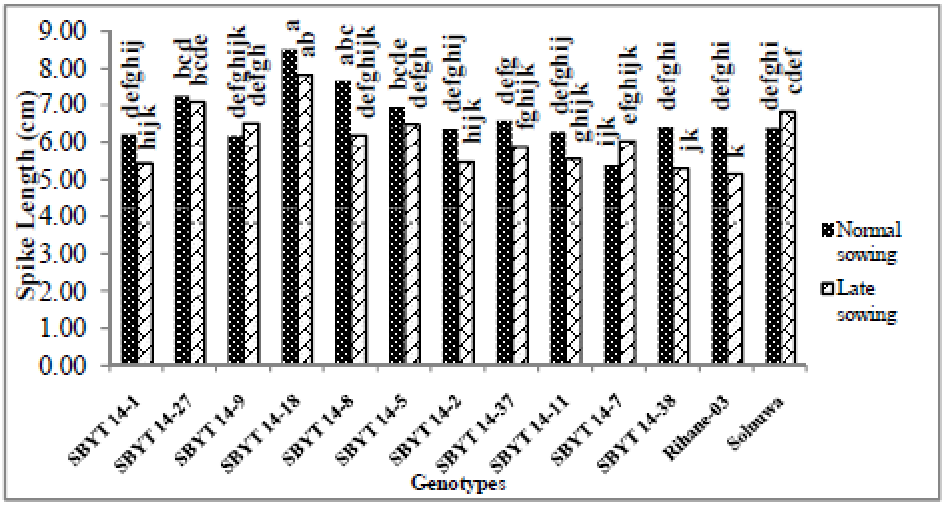

Fig. 4: The interaction between sowing date and different genotypes of barley for spike length at IAAS, Chitwan in 2014/15.

**Data labels in the figure followed by same letter are not significantly different at 5% level by DMRT.*

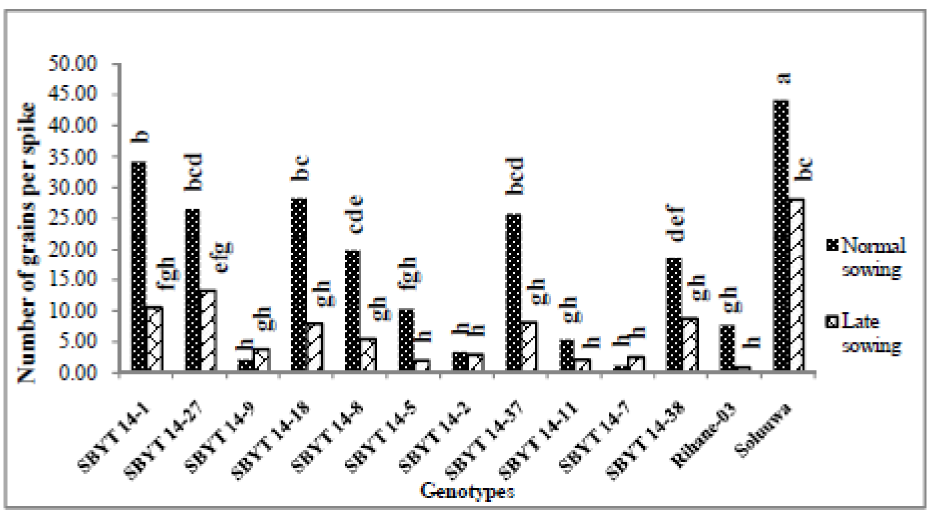

Fig. 5: The interaction between sowing date and different genotypes of barley for grain number per spike at IAAS, Chitwan in 2014/15.

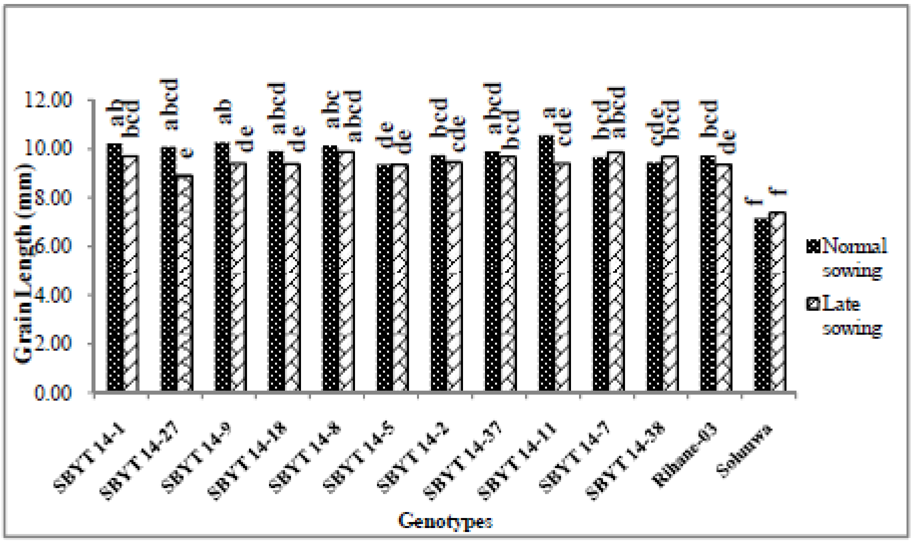

Fig. 6: The interaction between sowing date and different genotypes of barley for grain length at IAAS, Chitwan in 2014/15.

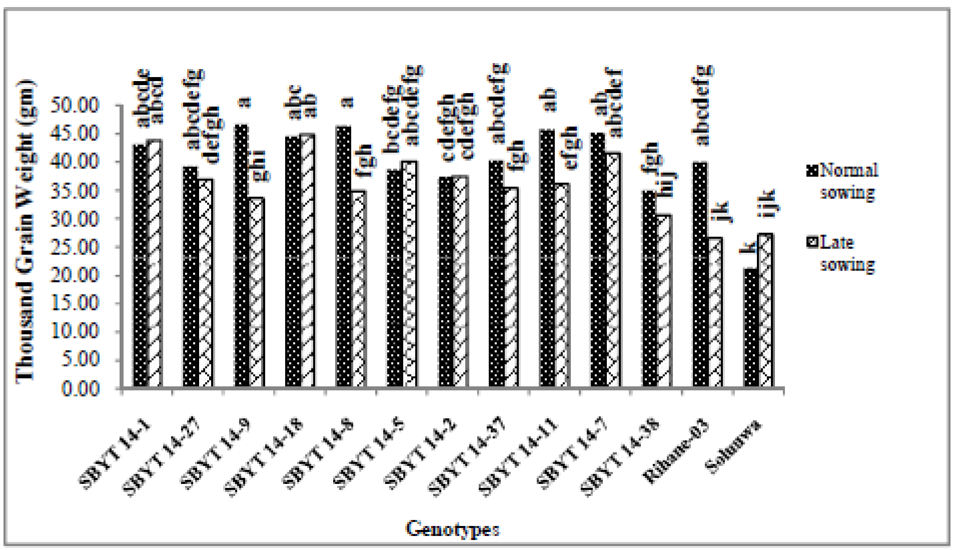

Fig. 7: The interaction between sowing date and different genotypes of barley for TGW at IAAS, Chitwan in 2014/15.

**Data labels in the figure followed by same letter are not significantly different at 5% level by DMRT.*

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

The table of means of various grain traits (Table 3) in terms of sowing time and genotypes resembled remarkable differences at normal and late sowing conditions. The average grain yield reduced by 69.8% from 1108 kgha^{-1} in normal sown condition to 335 kg ha^{-1} in late sown condition. The higher temperature during flowering and grain filling period of late sowing crop forced plant to divert resources to cope with heat stress thus making only limited photosynthates available for reproductive development which accelerated senescence, diminished seed set and seed weight, and reduced yield (Siddique *et al.*, 1999). In an average, grain number per spike reduced by 57.69% in late sown condition (7.40) as compared to the normal sown condition (17.49). Soluwa (36.10) had the highest grain number per spike and SBYT 14-7 (1.87) had the lowest grain per spike. Similar findings have been reported by Cooper *et al*., (1994) and Christen *et al*., (1995). Reproductive development of cereals being vulnerable to environmental conditions during anthesis delimits the grain formation in spike and grain yield. Heat stress speeds up the development of the spike reducing the spikelet number and thus the number of grain per spike (Porter and Gawith, 1999). Since, the present experimental site had high temperature during late planting, the number of grains per spike of all genotypes was significantly decreased in harvest after late planting.

The average spike length was altered by 7.9% in late sown condition as compared to the normal one (Table 3). The highest spike length was recorded for SBYT 14-18 (8.190 cm) and the lowest one was recorded for SBYT 14-7 (5.720 cm). Difference in spike length among the genotypes is due to genetic variability. The variation in spike length of the late sown genotypes might be due variation in temperature and sunshine availability (Acharya, 2015).

The average grain length differed by 3.86% between normal sown condition (9.715 mm) and the late one (9.340 mm). The longest grain length was observed in SBYT 14-8 (10.017 mm) while shortest grain length was recorded for Soluwa (7.280 mm). The average dorsal and ventral grain width reduced by 2.73% and 2.39% respectively in late sown condition when compared with the grain width of normal sown condition.

The thousand grain weight (TGW) also reduced by 10.37% from 40.29 g in normal sown condition to 36.11 g in late sown condition. The highest TGW was recorded for SBYT 14-18 (44.67 g) and the lowest TGW was recorded for Solu-Uwa (24.32 g). This reduction can be attributed to the lower rate of grain filling due to supression of photosynthesis and inhibition of starch synthesis in the endosperm leading to reduced growth and shorter period for the production of grains. This result is supported by the findings of Tashiro and Wardlaw (1990).

The average sterility in the experiment rose from 63.32% in normal condition to 83.47% in late sown condition. The lowest sterility was recorded

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

for Soluwa (36.59%) while highest sterility was recorded in SBYT 14-7 (96.34%). The increase in sterility is due to the inhibition of development of florets of barley due to higher ambient temperature just before or after anthesis (Siddique *et al*., 1999).

Table 3: Table of means of various grain traits as influenced by date of sowing and genotypes in IAAS, Chitwan in 2014/15.

Treatment	Grain Yield (kg ha^{-1})	Spike Length (cm)	Grain number per spike	Grain Length (mm)	Dorsal Grain Width (mm)	Ventral Grain Width (mm)	Thousand grain weight (gm)	Sterility (%)
SowingTime								
Normal	1108 ± 228.610	6.674 ± 0.147	17.49 ± 2.267	9.715 ± 0.144	3.513 ± 0.033	3.508 ± 0.032	40.29 ± 1.173	63.32 ± 4.778
Late	335 ± 66.463	6.145 ± 0.139	7.40 ± 1.248	9.304 ± 0.107	3.417 ± 0.031	3.424 ± 0.031	36.11 ± 1.018	83.47 ± 2.318
S.E.M(±)	100.4	0.0874	0.787	0.0597	0.0263	0.0264	0.603	1.411
LSD (0.05)	285.1	0.2483	2.235	0.1697	0.0746	.0751	1.713	4.009
Genotypes								
SBYT 14-1	1801^{de} ± 587.741	5.843^{a} ± 0.238	22.33^{c} ± 5.494	9.971^{cd} ± 0.175	3.468^{bcde} ± 0.010	3.468^{bcd} ± 0.018	43.50^{ef} ± 1.144	48.60^{c} ± 11.881
SBYT 14-27	527^{ab} ± 140.604	7.173^{d} ± 0.119	19.90^{c} ± 3.753	9.503^{bc} ± 0.299	3.462^{bcde} ± 0.062	3.461^{bcd} ± 0.067	38.10^{d} ± 0.684	67.67^{b} ± 5.522
SBYT 14-9	96^{a} ± 38.037	6.360^{abc} ± 0.314	2.97^{a} ± 1.144	9.843^{bcd} ± 0.314	3.547^{cde} ± 0.132	3.538^{cd} ± 0.136	40.12^{def} ± 3.603	91.16^{a} ± 3.713
SBYT 14-18	1417^{cd} ± 761.225	8.190^{e} ± 0.284	18.13^{bc} ± 5.766	$9.641b^{cd}$ ± 0.179	3.657^{e} ± 0.099	3.579^{d} ± 0.097	44.67^{f} ± 0.691	74.06^{b} ± 8.420
SBYT 14-8	$1217b^{cd}$ ± 519.044	6.937^{cd}±0.482	12.63^{b} ± 3.310	10.017^{d} ± 0.157	3.569^{de} ± 0.035	3.589^{d} ± 0.034	40.68^{def} ± 3.071	41.48^{cd} ± 12.649
SBYT 14-5	120^{a} ± 50.080	6.723^{cd} ± 0.190	6.17^{a} ± 1.885	9.365^{b} ± 0.131	3.546^{cde} ± 0.066	3.546^{cd} ± 0.063	39.41^{de} ± 1.125	76.11^{b} ± 6.908
SBYT 14-2	61^{a} ± 16.244	5.930^{ab} ± 0.289	3.14^{a} ± 1.249	9.604^{bcd} ± 0.140	3.369^{abcd} ± 0.072	3.402^{abcd} ± 0.076	37.40^{bcd} ± 1.903	94.52^{a} ± 1.777
SBYT 14-37	843^{abc} ± 191.539	6.237^{abc} ± 0.194	16.97^{bc} ± 0.495	9.776^{bcd} ± 0.114	3.443^{bcde} ± 0.024	3.456^{bcd} ± 0.024	37.89^{cd} ± 1.304	66.43^{b} ± 8.565
SBYT 14-11	190^{a} ± 100.900	5.940^{ab} ± 0.234	3.70^{a} ± 1.172	9.994^{cd} ± 0.288	3.570^{de} ± 0.078	3.590^{d} ± 0.069	40.94^{def} ± 3.170	93.18^{a} ± 2.219
SBYT 14-7	19^{a} ± 3.810	5.720^{a} ± 0.147	1.87^{a} ± 0.378	9.768^{bcd} ± 0.152	3.593^{e} ± 0.025	3.582^{d} ± 0.028	43.37^{ef} ± 1.178	96.34^{a} ± 0.744
SBYT 14-38	656^{abc} ± 204.189	5.860^{a} ± 0.267	13.63^{b} ± 2.787	9.557^{bcd} ± 0.122	3.220^{a} ± 0.056	3.220^{a} ± 0.064	32.83^{b} ± 1.946	75.55^{b} ± 4.114
Rihane-03	89^{a} ± 14.917	5.790^{a} ± 0.381	4.27^{a} ± 2.306	9.538^{bcd} ± 0.187	3.333^{abc} ± 0.090	3.344^{abc} ± 0.087	33.35^{bc} ± 3.117	92.44^{a} ± 3.956
Soluwa	2345^{e} ± 701.107	6.617^{bcd} ± 0.183	36.10^{d} ± 4.425	7.280^{a} ± 0.084	3.269^{ab} ± 0.051	3.281^{ab} ± 0.049	24.32^{a} ± 1.417	36.59^{d} ± 7.302
S.E.M (±)	255.9	0.2228	2.006	0.1523	0.0670	0.0674	1.538	3.598
LSD(0.05)	726.9	0.6329	5.699	0.4327	0.1902	0.1914	4.369	10.221
CV (%)	86.9	8.5	39.5	3.9	4.7	4.8	9.9	12
GM	722	6.409	12.45	9.527	3.465	3.466	38.20	73.40

**Means followed by same letters are not significantly different at 5% level by Duncan's Multiple Range Test (DMRT).*
** ± denotes Standard Error, SEM = Standard Error of Mean, LSD= Least Significant Difference, CV=Coefficient of Variation, GM= Grand Mean*

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

Heat Stress Indices:

In normal and late sown condition, the highest grain yield was shown by Soluwa (3888.10 $kgha^{-1}$) and SBYT 14-1 (1032.11 $kgha^{-1}$) repectively while SBYT 14-7 recorded the lowest yield in both conditions (Table 4). In genotypes like SBYT 14-1, SBYT 14-18, SBYT 14- 8 and Soluwa, significant reduction in the yield was observed in late sowing than the normal sowing condition while genotypes like SBYT 14-27, SBYT 14-37 and SBYT 14-38 showed better yield potential in stress condition reflecting wider adaptation to stressful environment which is similar to the findings of Sadiq *et al.* (1994). But, absolute reduction in grain yield gives no complete information on stress tolerance/susceptibility of genotypes. So, for the proper evaluation of tolerance and susceptibility parameters, some stress indices (Table 4) of each genotype have been assessed separately. Selection of genotypes with low Stress Susceptibility Index (SSI) is desirable but it may lead to the selection of low yielding genotypes (Bavei *et al*., 2011). Highest SSI was recorded for SBYT 14-8. The Geometric Mean Productivity (GMP) and Stress Tolerance Index (STI) was recorded highest for landrace Soluwa (GMP= 1718.9 kg ha^{-1}, STI = 0.6383) followed by exotic genotype SBYT 14-1 (GMP= 1517 kg ha^{-1}, STI= 0.5208) making them the best yielder in Chitwan condition as per this experiment. This selection based on STI allows selection of genotypes having higher yield in both stress and optimum condition (Fernandez, 1992). STI and GMP were recorded lowest for SBYT 14-7 followed by SBYT 14-2 (Table 4).

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

Table 4: Production, productivity and heat stress indices of 13 barley genotypes used in the experiment.

Genotypes	Yp	Ys	TOL	MP	GMP	SSI	STI
SBYT 14-1	2570.08[c]	1032.11[f]	1538.0[bde]	1801.1[ef]	1517.3[c]	0.704[b]	0.5208[b]
SBYT 14-27	521.27[a]	533.30[bcde]	-12.0[ab]	527.3[abc]	500.4[ab]	-0.187[b]	0.0656[a]
SBYT 14-9	117.57[a]	73.59[abc]	44.0[abc]	95.6[ab]	80.1[a]	-1.248[b]	0.0017[a]
SBYT 14-18	2537.80[c]	295.84[abcd]	2242.0[ef]	1416.8[de]	797.6[b]	1.072[b]	0.1629[a]
SBYT 14-8	2298.22[bc]	134.92[abc]	2163.3[ef]	1216.6[cde]	526.9[ab]	1.408[b]	0.0578[a]
SBYT 14-5	213.74[a]	26.70[ab]	187.0[abcd]	120.2[ab]	70.3[a]	1.304[b]	0.0012[a]
SBYT 14-2	38.88[a]	82.81[abc]	-43.9[a]	60.8[a]	48.4[a]	-6.707[a]	0.0006[a]
SBYT 14-37	1118.13[ab]	567.25[cdef]	550.9[abcd]	842.7[bcd]	788.2[b]	0.783[b]	0.1472[a]
SBYT 14-11	320.93[a]	59.56[abc]	261.4[abcd]	190.2[ab]	116.0[a]	0.770[b]	0.0031[a]
SBYT 14-7	24.76[a]	12.84[a]	11.9[ab]	18.8[a]	17.4[a]	0.594[b]	0.0001[a]
SBYT 14-38	657.02[a]	655.27[def]	1.7[ab]	656.1[abc]	546.0[ab]	-2.361[b]	0.0689[a]
Rihane-03	103.90[a]	73.57[abc]	30.3[ab]	88.7[ab]	83.2[a]	0.103[b]	0.0014[a]
Soluwa	3888.10[d]	802.14[ef]	3086.0[f]	2345.1[f]	1718.9[c]	1.179[b]	0.6383[b]
SEM(±)	238.20	153.80	461.7	233.5	165.20	1.245	0.0828
LSD (0.05)	1278.90	449.00	1347.5	681.6	482.20	3.635	0.2417
CV (%)	26.60	45.10	45.8	21.2	25.2	354.4	49.8
GM	1108.49	334.61	774	722	523.9	-0.20	0.128
F-probability	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001

**Means followed by same letter are not significantly different at 5% level by DMRT.*

**Yp and Ys: Grain yield in normal and stress condition respectively, ToL: Tolerance Level, MP: Mean Productivity, GMP: Geometric Mean Productivity, SSI: Stress susceptibility index, STI: Stress tolerance index, SEM: Standard Error Of Mean, LSD: Least Significant Difference.*

CONCLUSION

The higher temperature (30° and beyond) during the reproductive development of barley pose detrimental effect to the growth and development of barley. Since the rise in production of grain is the need of present time, the identification of heat tolerant lines and their subsequent development is the major challenge to the breeders. In this experiment, the landrace Soluwa overruned all the exotic genotypes in many parameters like yield, stress tolerance, grain per spike and so on. The performance of exotic genotype SBYT 14-1 also seemed to be noteworthy in Chitwan condition in terms of stress tolerance, grain yield, grain per spike and thousand grain weight. These promising barley genotypes obtained from this experiment can be further studied for their heat tolerance attribute in subsequent breeding programs.

ACKNOWLEDGEMENTS

The authors are thankful to ICARDA for funding this research and Dr. Sanjaya Gyawali for necessary research arrangements and guidance. We also kindly acknowledge the help rendered by Mr. Mahendra Tripathi (S1) and Asst. Prof. Suryamani Dhungana during post- research activities.

REFERENCES CITED

Acharya, R. 2015. Assessing the productivity of heat tolerant wheat cultivars under different establishment methods and climate change simulation using CSM–CERES-Wheat model at central Nepal. Thesis, M. Sc. Agriculture and Forestry University, Rampur. 120 p.

Bavei, V., B. Vaezi, M. Abdipour, M. R. J. Kamali and M. Roustaii. 2011. Screening of tolerant spring barleys for terminal heat stress: Different importance of yield components in barleys with different row type. Int. J. Plant Breed. and Genetics. 5 (3): 175-193.

Cattivelli, L., G. Delogu, V. Terzi, and A. M. Stanca. 2013. Progress in barley breeding. In: Genetic improvement of field crops (ed.), G. A. Slafer. Marcel Dekker Inc., New York. pp. 95-181.

Christen, O., K. Sieling, H. Richter-Harderand and H. Hanus. 1995. Effects of temporary water stress before anthesis on growth, development and grain yield of spring wheat. Eur. J. Agron. 4: 27-36.

Cooper, M., D. E. Byth and D. Woodruff. 1994. An investigation of the grain yield adaptation of advanced CIMMYT wheat lines to water stress environments in Queensland. Aust. J. Agric. Res. 45: 965-984.

FAO. 2013. Statistical yearbook. Food and Agricultural Organization of the United Nations, Rome, Italy. Fernandez, G. C. J. 1992. Effective selection criteria for assessing plant stress tolerance. In: C. G. Kuo (ed.),

Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress. Taiwan. pp. 257-270.

Fischer, R. A. and R. Maurer. 1978. Drought tolerance in spring wheat cultivars. I. Grain yield response. Aust. J. Agric. Res. 29: 897-907.

Hall, A. E. 2001. Crop developmental responses to temperature, photoperiod, and light quality.

ISSN: 2455-6939

Volume:03, Issue:02 "March-April 2017"

In: E. Anthony (ed.), Crop responses to environment. CRC Press , Florida. pp. 83-87.

Mishra, B. N. and B. G. Shivakumar. 2000. Barley. In: P. S. Rathore (ed.), Techniques and management of field crop production. Agrobios (India), Jodhpur.

Modhej, A., R. Farhoudi and A. Afrous. 2015. Effect of post-anthesis heat stress on grain yield of barley, durum and bread wheat genotypes. Journal of Scientific Research and Development. 2(6): 127-131.

Mohammadi, M. 2002. Effect of heat stress on grain yield components and identification of tolerant wheat (*Triticum aestivum* L.) cultivars. Seed Plant. 17:400–411.

Peet, M. M. and D. H. Willits. 1998. The effect of night temperature on greenhouse grown tomato yields in warm climate. Agric. Forest Meteorol. 92:191–202.

Porter, J. R. and M. Gawith. 1999. Temperatures and the growth and development of wheat: A review. European Journal of Agronomy 10(1):23-36.

Sadiq, I. I. S., K. A. Siddiqui, C. R. Arain and A. R. Azmi. 1994. Wheat breeding in a water-stressed environment. I. Delineation of drought tolerance and susceptibility. Plant Breed. 113:36-46.

Tashiro, T. and I. F. Wardlaw. 1990. The effect of high temperature at different stages of ripening on grain set, grain weight and grain dimensions in the semi-dwarf wheat banks. Ann. Bot. 65:51-56.

