Research Article

Comparative Response of Seedlings of Heat Tolerant and Sensitive Maize Genotypesregarding Early Growth Traits against Heat Stress

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Abstract | Ten maize *(Zea mays)* commercial hybrids were screened for checking their comparative response against high temperature / heat stress at Botany Department, Agriculture University, Faisalabad. Germinated maize seedlings / plants were placed in the glass fitted canopies, where canopy temperature was found 7-10°C higher than ambient temperature along with light reflection was enough for optimum photosynthesis. The plants were raised under heat stress environment for 15 days and harvested. Data regarding seedling parameters were recorded and analyzed. The study revealed that SB-11 and 32-F-10 were able to produce longer shoots under heat stress while SB-11 and ND 6339 produced longer root under heat stress. The hybrids like SB-11, Hycorn-984 were able to retain greater shoot and root water contents as evident from their increased fresh weight. The hybrid including Hycorn-984, ND6339 and SB-11 manifested greater shoot dry matter yield, while none of the hybrids displayed greater root dry weight under heat stress than root respective controls. The Hybrid SB-11 incurred a minimal loss of leaf area followed by Hycorn-11 and Hycorn-984 while hybrids ICI-984 and SB-11 were the most affected. These data indicated that like conventional synthetic maize varieties, the hybrids also respond differentially to the prevailing high temperature stress condition. The results also showed that hybrids capable of producing greater root mass were better able to withstand the heat stress than those with a lesser root volume. In the current screening effort, the hybrid SB-11 emerged as heat tolerant while ICI-984 was ranked as heat sensitive hybrid based on the investigated growth parameters.

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Introduction

Changing environmental conditions, catastrophic events and abiotic stresses decreased food production and every nation of the world is experimenting management practices and making use of innovative technologies to explore more means for fulfilling the food requirements of the bulging population (Mahajan and Tuteja, 2005). Maize *(Zea mays),* third most important crop of Pakistan has multiple uses in the country as well as throughout the world. Its grains are used as staple food for human beings, fodder for livestock, feed for poultry and raw material in many agro-based industries.

Crop production and yields can be increased either by expanding the agricultural land or by enhancing crop productivity per unit area. Historically in early decades of the 20th century, it was known that extending crop growing area was a prime factor for enhanced crop production (Sadava, 2003). During later decades, cultivation of high yielding crops imposed positive impact on agricultural crop yields per hectare (Evenson, 2005; Araus *et al*., 2008).

Environmental factors adversely alter metabolism, growth and finally plant yield (Lichtenthaler, 1998; Monclus *et al*., 2006; Arshad *et al*., 2008). Salinity, water scarcity, flooding, pollutants, radiations and extremes of temperatures all restrict crop productivity (Lawlor, 2002; Ali *et al*., 2017; Suralta and Yamauchi, 2008). Of these, high ambient temperature is recognized as most suitable appraisal of the damaging stresses under changing global climate. A 0.2°C rise in temperature per decade will be responsible for 1.8-4.0°C rise in air temperature till 2100 (IPCC, 2007). Plants being sessile in habit cannot escape from the negative influence of high thermal stress (Lobell and Field, 2007; Innes *et al*., 2015).

High temperature affects the plant growth and developmental processes by bringing morphological, physiological and biochemical changes. There is a rise of 0.2°C in average temperature globally per decade in the coming years (IPCC, 2007), which is likely to change the growing time and geographical distribution of cultivated crops (Porter, 2005).

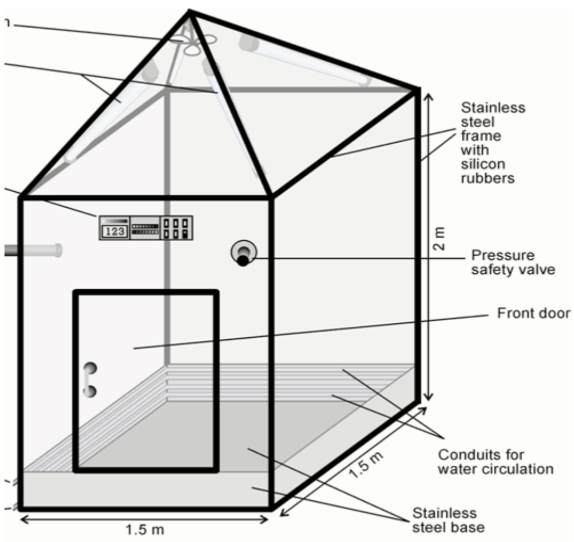
Heat stress caused major impacts on germination percentage reduction, plant emergence, weakened and irregular seedling, and cut down plumule and radicle growth (Toh *et al*., 2008; Kumar *et al*., 2011; Piramila *et al*., 2012). High temperature causes induction of ABA, which leads to prohibition of seed germination (Essemine *et al*., 2010). At very high temperature (45°C) inhibited seed germination rate of bread wheat occurred followed by embryo and cell death and also reduction in seedling establishment rate (Cheng *et al*., 2009), reduction in tiller numbers, plant height and total biomass yield in paddy genotypes (Mitra and Bhatia, 2008).

High thermal stress (40°C) can lead to twigs scorching, sunburn to branches and leaves, leaves abscission and senescence , shoot and root expansion inhibition , fruit staining and destruction and reduction of crop yields (Hasanuzzaman *et al*., 2013; Innes *et al*., 2015). Reduction of stem growth and intermodal length under elevated temperature led to the premature plants death (Hall, 1992), immature leaf dropping, and overall productivity attenuation (Ebrahim *et al*., 1998).

Therefore, currently main focus of the crop breeders, physiologists and ecologists is to find ways and means to boost the crop yields under prevailing climatic conditions (Nelimor, 2019). The development of hybrids exploiting the principle of hybrid vigor in different plant races and species under temperature stress is a step forward in fetching better yields (Farooq *et al*., 2013; Guan-fu *et al*., 2015; Singh *et al*., 2017). Thus, study published through this manuscript was conducted to screen highly heat tolerant and sensitive varieties by comparative response of maize seedlings to heat stress.

Materials and Methods

The Research was conducted in the experimental area of Botany Department, Agriculture University, Faisalabad. Seeds of ten maize hybrids [ICI-984, hycorn-8288 (ICI Seed Co(pvt)ltd), 32-F-10, SB-292 (Kissan Seed Co(pvt)ltd), SB-11(Kissan Seed Co(pvt)ltd), SB-13 (Kissan Seed Co(pvt)ltd), ND-6339, HYCORN-984 (ICI Seed Co(pvt)ltd), SB-989 (Kissan Seed Co(pvt)ltd) and HYCORN-11 (ICI Seed Co(pvt)ltd)) were used to screen out the sensitive hybrids from tolerant hybrids against heat stress. Healthy seeds were sown in washed river sand plastic pots which were placed under green net. After germination, the seedlings wee raised for 15 days and were supplemented with Hoagland's nutrient solution on five day interval. One triplicate set of 5 plants from each hybrids was transferred to open door PlexiGlass Fitted Canopies where the temperature was 7-10°C above ambient during day time (as shown below). The other set of 5 plants was kept in the net house under natural conditions. The plants were grown under both



the conditions for 15 days and then harvested. Data was recorded for shoot length and root length, fresh weights and dry weights, shoot and root dry weight ratio and leaf area. The fresh weights of detached shoots and roots of harvested plants were taken with analytical balance. The plants were oven-dried at 70°C for five days and then reweighed for the getting values of root and shoot dry weights. Length and width of selected plant leaves were measured using meter rod. Leaf area was calculated by multiplying leaf width, leaf length and maize leaf correction factor (0.75).

CRD (Completely randomized Design) in triplicated arrangement was used for statistical data analysis. Analyses of variance (ANOVA) for all seedling traits were performed and DMRT (Duncan's Multiple Range Test) at $P<0.05$ was applied to determine the differences among hybrids; and their interactions with heat stress (Steel *et al*., 1996; Ali *et al*., 2017). Alphabets were used for marking treatment means when the means were found significant and left unmarked if non-significant.

Results

Shoot length

Results reflected highly statistically significant differences among maize hybrids ($P<0.01$) as well as for heat treatments ($P<0.01$) while significant ($P<0.05$) interactions of both the factors (variety and temperature) for shoot length. An evaluation of hybrids data reflected that shoot length was generally higher in control condition with the exception of hybrids 32-F-10 and SB-11. Under control condition, a highest shoot length was recorded in SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was the lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest shoot length (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11 and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 1).

Root length

Although there were no significant ($P>0.05$) differences in hybrids and no significant interaction ($P>0.05$) of these factors but significant ($P<0.01$) effects were noted for heat treatments for root length. Graph presented in Figure 2 showed that maize hybrids responded differential behavior to treatments. In comparison to control treatment, root length increased in ND-6339 (-11%) and SB-11 (-7%), remained similar in 32-F-10 but decreased in rest of the hybrids in response to heat stress and a highest reduction was found in SB-989 (-8%). Overall, SB-11 produced the longest roots while SB-13 the shortest roots under either conditions (Figure 2).

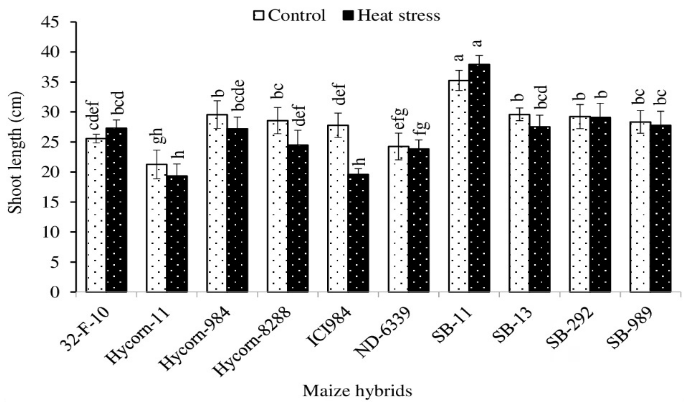


Figure 1: *Comparative changes in shoot length of maize hybrids under heat stress.*

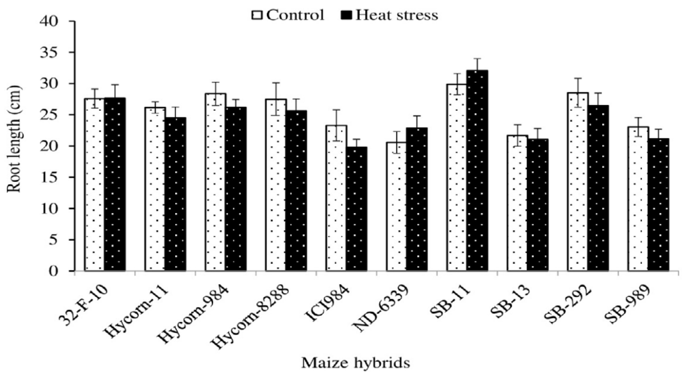


Figure 2: *Comparative changes in root length of maize hybrids under heat stress.*

Shoot fresh weight

Statistical analysis with respect to shoot fresh weight showed highly significant differences/ variation in maize hybrids ($P<0.01$) and heat treatments ($P<0.01$) along with significant ($P<0.05$) interaction of both the factors. Graph presented in Figure 3 showed that root length was on upper side in control condition treatment with exception of hybrids 32-F-10 and SB-11. Under control environment treatment, maximum shoot fresh weight was observed in genotype SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was found lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest root length (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11, ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 3).

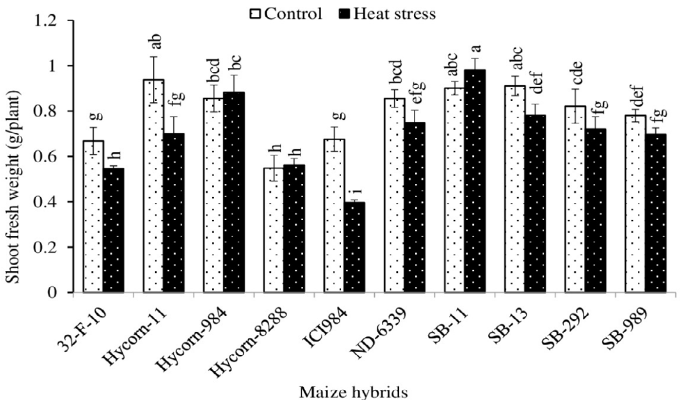


Figure 3: *Comparative changes in shoot fresh weight of maize hybrids under heat stress.*

Root fresh weight

Significant differences were recorded in maize hybrids (P<0.01) and heat treatments (P<0.01) along with significant (P<0.05) interactions of both the factors for root fresh weight. Figure 4 revealed that that shoot length was generally higher in control environment treatment with exception of hybrids 32-F-10 and SB-11. Under control treatment, maximum root fresh weight was observed in genotype SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was found lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest root fresh weight (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11 and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 4).

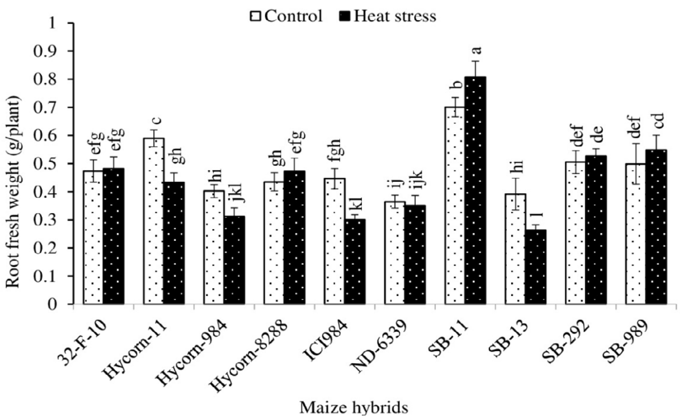


Figure 4: *Comparative changes in root fresh weight of maize hybrids under heat stress.*

Shoot dry weight

Results showed highly significant differences/variation in maize hybrids (P<0.01) and heat treatments (P<0.01) and significant (P<0.05) interaction of both the factors for shoot dry weight. Graphs in Figure 5 depicted that shoot dry weights were overall on upper side than in control environment treatment with the exception of hybrids 32-F-10 and SB-11. Under control environment treatment, maximum shoot dry weight was observed in SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was found lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest shoot dry weight (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11 and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 5).

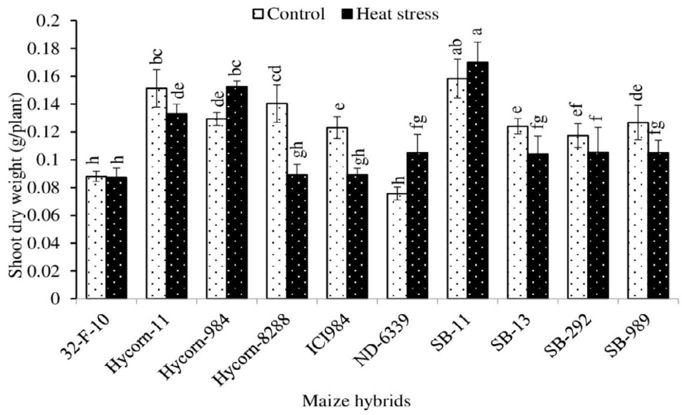


Figure 5: *Comparative changes in shoot dry weight of maize hybrids under heat stress.*

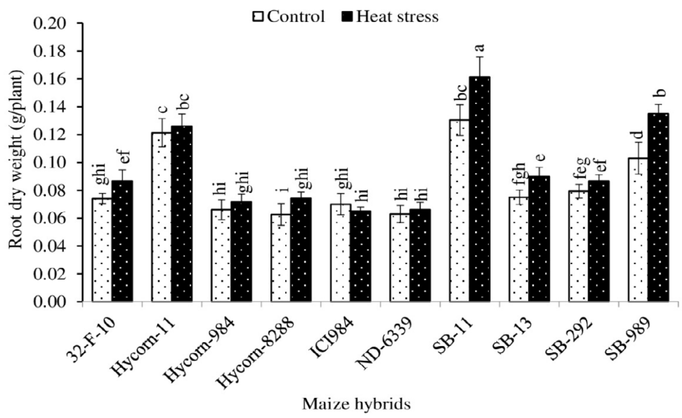


Figure 6: *Comparative changes in root weight of maize hybrids under heat stress.*

Root dry weight

Results reflected highly significant differences/variation in maize hybrids (P<0.01) and heat treatments (P<0.01) and significant (P<0.05) interactions of both the factors for root dry weight. Graph on Figure 6 indicated that hybrids showed that root dry weights were overall on upper side in control treatment condition with the exception of hybrids 32-F-10 and SB-11. Under control environment treatment, maximum root dry weight was founded in maize hybrids SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was the lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest root dry weight (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11 and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 6).

Leaf area

Results indicated highly significant highly differences/variation in maize hybrids (P<0.01), heat treatments (P<0.01) and significant (P<0.05) interaction of both the factors for leaf area per plant. A comparison of hybrids data showed that leaf area per plant was generally higher in control condition with the exception of hybrids 32-F-10 and SB-11. Under control environment treatment, maximum leaf area per plant was founded in maize genotype SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was the lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest leaf area per plant (-7.6 and 6.8% higher than control, respectively) while it was the lowest hybrids Hycorn-11 and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 7).

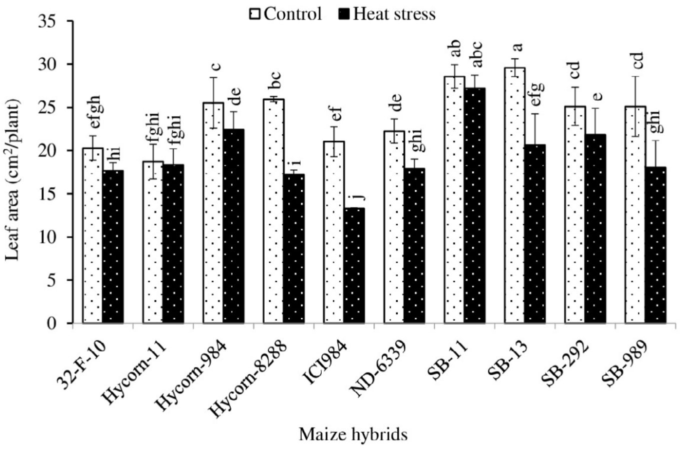


Figure 7: *Comparative changes in leaf area plant of maize hybrids under heat stress.*

Shoot/root ratio

Results showed highly significant differences/ variation in maize hybrids (P<0.01) and heat treatments (P<0.01) while significant (P<0.05) interaction of both the factors for shoot/root ratio. A comparison of hybrids data showed that shoot/root ratio was on upper side in control condition with the exception of hybrids 32-F-10 and SB-11. Under control condition, a highest shoot/root ratio was recorded in SB-11 followed by Hycorn-984, SB-13 and SB-292 while it was the lowest in Hycorn-11. Under heat stress on the other hand, hybrids SB-11 and 32-F-10 indicated the highest shoot/root ratio (-7.6 and 6.8% higher than control, respectively) while it was the lowest in hybrid Hycorn-11and ICI-984 (-14 and 29%, respectively) than the other hybrids (Figure 8).

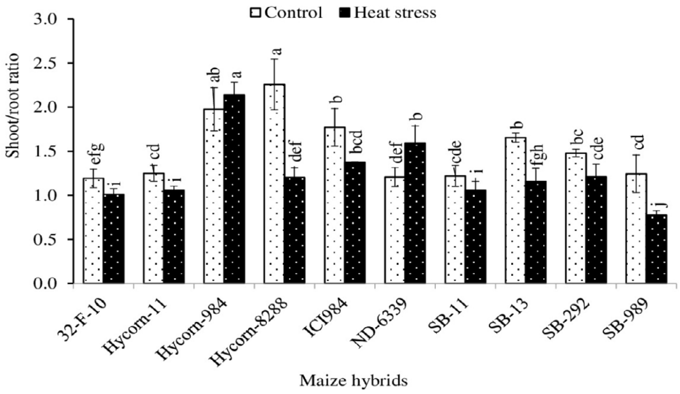


Figure 8: *Comparative changes in specific leaf weight of maize hybrids under heat stress.*

Discussion

High temperature stress in plants is greatly devastating malaise and therefore affects the growth and development to a significant extent (Johkan *et al*., 2011). However, plant species and varieties show great genotypic variability for their responses to high temperature stress (Javid *et al*., 2011). In the current era of high demand meeting the food requirements of burgeoning population, the hybrid production technology has been successfully employed for getting higher yields (Mahajan and Tuteja, 2005). It is however, important to note that the commercially available hybrids are not largely tested for their comparative responses to suboptimal growth condition like high temperature.

In this study, screening of commercially available hybrids revealed substantial differences based on early growth traits particularly shoot length and root length, their fresh weight and dry weight, leaf photosynthetic area in their responses to heat tolerance. The data revealed that although high temperature reduced the shoot length and root length in most of the hybrid some hybrids such as SB-11 and 32-F-10 were able to produce longer shoots under heat stress. Similarly, SB-11 and ND 6339 produced longer root under heat stress. The hybrids like SB-11and Hycorn-984 were able to retain greater shoot and root water contents as evident from their increased fresh weight. Janni *et al.* (2020) also found that heat stress has highly adverse affect on plant root system as these roots maintain not only high nutrients and water uptake but also transport to other organs.

The hybrid including Hycorn-984, ND6339 and SB-11 manifested greater shoot dry matter yield, while none of the hybrids displayed greater root dry weight under heat stress than root respective controls. A similar was the case for leaf area per plant, where SB-11 incurred a minimal loss of leaf area followed by Hycorn-11 and Hycorn-984, while ICI-984 and SB-11 were the most affected. For specific leaf weight which is the expression of ratio between leaf weight and leaf area was increased in most of the hybrids except Hycorn-11 and Hycorn-8288.

Data showed that like conventional synthetic maize varieties the hybrids also respond differentially to the prevailing high temperature stress condition. This is important with the perspective of hunting the environmentally resilient maize materials for growing in the relatively warmer areas of the country. Singh *et al*. (2017) also screened maize inbred lines through Temperature induced response (TIR) technique and revealed that tolerant maize inbred lines expressed more root and shoot dry weights than susceptible inbred lines. Thus, in order to produce heat resilient genotypes, it is a regular program of researchers to identify and screen suitable cultivars and traits for high temperature stress (Yousaf *et al*., 2018). These findings further provided the support that suitable strategies can be adopted for improving the high yielding maize materials for heat tolerance and showing satisfactory yields in a cost effective manner (Slafer, 2003; Khan *et al*., 2010; Tiwari and Yadev, 2018).

Conclusions and Recommendations

Maize hybrids, in this study showed significantly variable responses to applied heat stress, while the hybrids, capable of producing greater root mass were better able to withstand the heat stress than those with a lesser root volume. In the current screening effort, the hybrid SB-11 emerged as heat tolerant while ICI-984 was ranked as heat sensitive hybrid, based on the investigated growth parameters. These findings suggested that search for the hybrids with a prolific root system will be desired for their cultivation in the warmer areas.

Authors Contribution

Asima Batool performed experiment and made full contribution in research work and Ghulam Abbas did critical review of manuscript, helped in materials and methods and in data collections and analysis. Zuhair Hasnain added technical input at every step of the manuscript preparation. Muhammad Naeem Akhtar and Nasira Perveen gave technical input in critical review and reorganization of manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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