



Evaluation of viable selection criteria at the seedling stage in corn genotypes to forecast water stress tolerance

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Key words: Corn, Root, Shoot, Principle component analysis

<http://dx.doi.org/10.12692/ijb/18.1.46-52>

Article published on January 20, 2021

Abstract

Drought is the only factor which causes a more drastic effect on crop plant. Corn is a drought-sensitive crop their yield is influenced at every single phase of growth and development by limited water availability. Corn. A total of 90 accessions were screened and evaluated at different water levels 100% (T₁), 40% (T₂) and 30% (T₃) of field capacity (FC). Evaluation of corn genotypes was done against six seedling parameters (root length, shoot length, fresh root weight, fresh shoot weight, dry root weight and dry shoot weight). The analysis of variance indicated that all the traits under all water levels revealed significantly and the principal component analysis depicted diverse results for different treatments. The results showed that the genotypes Lala Musa, Akbar, Sahiwal-2002, Sultan, Pearl, 15005,15077,14972,15110 under 100% FC level performed well and genotypes 14933,15023,14968,15055, 15005, MMRI yellow, Lala Musa, Pearl, Akbar, Akhgoti, 15067 and Sultan under 40% FC and the genotypes Desi Fsd, 15075, Lala Musa, 14930, 14976, 15132, 15048, Sultan and 15005 performed best in 30% FC. Some corn genotypes Akhgoti, Lala Musa, Sultan, and 15005 performed better under all three water levels. The information on seedling parameters is best suited to screen viable genotypes for baseline information for on-ward corn breeding and research programs on water stress tolerance.

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Introduction

The cereal crops are cultivated on a larger scale throughout the globe due to its consumption ability. Corn (*Zea mays* L.) has attained the third position in cereals after wheat and rice. (Noorka and Heslop-Harrison 2019) It is a cash grain crop and belongs to the grass family (Myers *et al.*, 2000). It exists in the tribe Maydeae which is small but extremely specialized. Worldwide corn and wheat are cultivated and produced on a large scale because it is the staple food of many countries like wheat in Pakistan and North Africans, similarly corn in America, Venda and South Africa (Noorka and Taufiq Ullah, 2015).

In the same manner, the consumption of corn as feed also increased. Corn is monoecious and having separate male and female inflorescence. Their grains are produced from flank branches rather than the radical branches. There is a lot of misperception of the origination of corn. Many worldwide researchers anticipated the corn was evolved by the domestication of *Zea Mexicana* (teosinte a wild grass), which is native to Central America, Honduras, and Mexico. Still, there is a large distinction between these two species with their general character upon that some scientists suggested that corn has been evolved by such a wild pod corn species that has been extinct now (Noorka *et al.*, 2017 and 2020). There are about 7000 years' old corn cobs which are still preserved which were identified from the ancient caves of Mexico (Doebly, 2004). Corn is a rich source of phosphorus, magnesium, zinc, copper, iron, and selenium that has a small amount of potassium and calcium (Noorka, 2019). To search out the performance of the corn genotypes against water stress the current study was planned.

Materials and methods

The present study was conducted in the greenhouse in the Department of Plant Breeding and Genetics College of Agriculture University of Sargodha, Pakistan. The screening experiment was carried out as a 1st experiment of Ph. D thesis, using Completely Randomized Design (CRD) with three replications under three water levels.

Ninety genotypes were grown in sand media under Sargodha city, environmental conditions. The seeds were sown in a plastic pot measuring 35x50 cm with river sand with complete randomized design (CRD) with three replications under normal and water-deficient conditions. The data was analyzed with R studio software.

The sixty-eight genotypes emerged in normal irrigation conditions (100% FC) while underwater stress condition (40% FC) only 56 genotypes emerged. Under water stress conditions (30%FC) only fifty genotypes emerged. To balance the treatments and to check the genotypic behavior against water stress, only fifty emerged genotypes data was collected from all treatments and replications. The forty excessive and missed genotypes within treatments and replications remained as leftovers. The data was recorded at the three-leaf stage and analyzed with the R software.

Data collection and analysis

The data was collected for different seedling traits viz; fresh root length (FRL), fresh shoot length (FSL), fresh root weight (FRW), fresh shoot weight (FSW), dry root weight (DRW), dry shoot weight (DSW). The length was measured in cm and their weight is measured in grams. The data obtained were subjected to analysis of variance (Steel *et al.*, 1997). Principal component analysis (Sneath, 1973) was used to compare the relationship among different seedling traits.

Results and discussion

Analysis of variance

The analysis of variance (ANOVA) revealed for all the traits under the study of different water levels. The results indicated that there was a highly significant variation among root length, shoot length, fresh root weight, fresh shoot weight, dry root weight and dry shoot weight. All of the traits performed significantly in our genotypes and our experimental results agree with the earlier researchers (Noorka and Khaliq, 2007; Ma *et al.*, 2010; Comas *et al.*, 2013; Aslam, 2014; Jin *et al.*, 2018;) (Table 1).

Table 1. Analysis of variance (ANOVA) for seedling traits under different water treatments.

S.O.V	d.f	RL	SL	FRW	FSW	DRW	DSW
Genotypes	49	103.13**	22.56**	0.211**	0.14**	0.019**	0.001**
Residual	100	17.69	6.70	0.03	0.02	0.006	0.000

*Significant at $p < 0.05$, **Significant at $p < 0.01$, NS= Non-significant.

Where

RL = Root Length, FSW = Fresh Shoot Weight

SL = Shoot Length, DRW = Dry Root Weight

FRW = Fresh Root Weight, DSW = Dry Shoot Weight.

Principal component and biplot analysis for seedling traits under 100%, 40% and 30% field capacity levels

The principal component analysis was conducted separately for all the treatments.

The principal component analysis extracted six components based on the six traits and the only PC1 had a standard deviation greater than one in all the three water treatments. The cumulative proportion of PC1 is 0.646%, 0.651% and 0.628% for T1, T2 and T3

respectively (Table 2). In the overall variability, the trait performed differently under different treatments. Root length contributed 0.416%, 0.417% and -0.414%, variability in PC1 whereas this trait had contributed 0.383 %, 0.234% and 0.153%, in PC2 for T1, T2 and T3 respectively (Table 2). Shoot length contributed 0.375%, 0.382% and -0.353 %, variability in PC1 of T1, T2 and T3 respectively whereas this trait performed better in PC2 of T1 and T2 respectively which is 0.528% and 0.578 % (Table 2).

Table 2. Standard deviation, the proportion of variance and cumulative proportion of different factors based on the principal component analysis under different water levels.

	Treatment	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	100% FC	1.941	0.855	0.744	0.598	0.572	0.511
	40% FC	1.976	0.799	0.693	0.623	0.597	0.481
	30%FC	1.969	0.842	0.780	0.622	0.525	0.378
Proportion of variance	100% FC	0.628	0.122	0.092	0.060	0.055	0.044
	40% FC	0.651	0.106	0.080	0.065	0.059	0.039
	30% FC	0.646	0.118	0.101	0.065	0.046	0.024
Cumulative proportion	100% FC	0.628	0.750	0.842	0.902	0.956	1.000
	40% FC	0.651	0.757	0.837	0.902	0.961	1.000
	30% FC	0.646	0.764	0.866	0.930	0.976	1.000

The contribution of fresh root weight, fresh shoot weight, dry root weight, and dry shoot weight is -0.453%,-0.440%,-0.448% and -0.325 % in PC1 of 30%FC all of the traits contributed negatively and have negative correlations. But all of these four traits contributed positively to PC1 of T1 and T2 respectively (Table 2). Dry root weight performed very well in PC1, PC2 and PC3 under 100% field capacity level but their performance in low in PC1 and PC2 under 300% field capacity level. (Table 2). Dry shoot weight contributed positively which is 0.517% for PC2 in 100%FC and 0.865 % in PC2 in 30%FC but

their contribution is very low and has a negative correlation in PC3 that is -0.156 % under 30% field capacity level (Table 2). Biplot graphs were made using PC1 and PC2 of principal component analysis for all three water treatments separately.

The biplot is mainly based on the direction of angle and length of the vector the grouping of data is mainly based on that two factors which tell us the information about the correlation of the trait with each other and between the groups and these groups having similar performance.

Table 3. Principle Component Analysis (PCA) for agronomical traits at 100%, 40% and 30% of field capacity level.

Traits	100%FC						40%FC						30%FC					
	PC1	PC2	PC3	PC4	PC5	PC6	PC1	PC2	PC3	PC4	PC5	PC6	PC1	PC2	PC3	PC4	PC5	PC6
RL	0.416	0.383	0.194	0.785	0.194	0.161	0.417	0.234	-0.124	0.511	-0.703	-0.031	-0.414	0.153	0.228	0.852	-0.160	-0.045
SL	0.375	0.529	0.240	0.436	0.240	0.140	0.382	0.578	-0.431	-0.563	0.090	-0.094	-0.353	-0.396	-0.772	-0.320	-0.100	0.103
FRW	0.436	0.198	-0.051	0.178	0.051	0.754	0.444	0.013	0.402	-0.111	0.082	0.788	-0.453	-0.158	0.406	-0.039	0.013	0.777
FSW	0.424	0.086	-0.095	0.323	0.095	0.614	0.424	0.128	0.067	0.521	0.674	-0.272	-0.440	-0.116	0.373	-0.233	-0.611	-0.476
DRW	0.405	0.510	0.720	-0.220	0.720	0.046	0.416	-0.294	0.533	-0.369	-0.190	-0.533	-0.448	-0.183	0.155	-0.020	0.766	-0.393
DSW	0.389	0.517	-0.612	0.097	0.612	0.083	0.359	-0.713	-0.591	-0.046	0.043	0.100	-0.325	0.865	-0.156	-0.340	0.065	0.050

RL: Root Length, SL: Shoot Length

FRW: Fresh Root Weight, FSW: Fresh Shoot Weight

DRW: Dry Root Weight, DSW: Dry Shoot.

Biplot categorized the traits into two groups under 100% field capacity the group I had root length, shoot length and fresh root weight and group II had fresh shoot weight, dry root weight and dry shoot weight and within the groups, the trait had a strong correlation and among groups, the traits had weak correlations the traits like shoot length, root length and fresh root weight had a weak correlation with each other, the dry shoot weight and dry root weight had a very strong and significant correlation between them but it had a weak correlation with fresh shoot weight (Fig. 1).

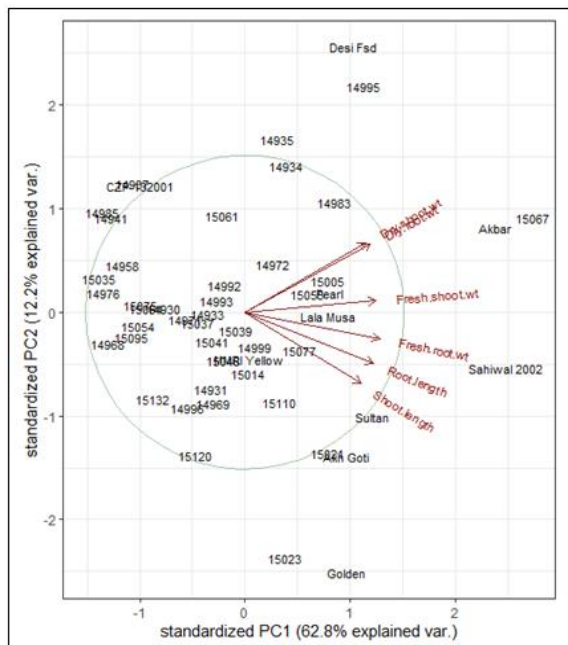


Fig. 1. Biplot graph for fifty corn genotypes at 100% FC.

In bio plot of 40% field capacity, it categorized the biplot into two groups the group I had dry root weight

and dry shoot weight and group II had root length, shoot length, fresh root weight and fresh shoot weight the traits like dry shoot weight and dry root weight had a weak correlation but the fresh root weight, fresh shoot weight and root length had a very strong and significant correlation between them but this trait had a very weak correlation with shoot length (Fig. 2).

In the biplot of 30% field capacity, it also made two groups based on the trait performance in group I had dry shoot weight and root length and in group II they had shoot length, fresh root weight, fresh shoot weight and dry root weight the traits like fresh shoot weight, fresh root weight and dry root weight had a very strong correlation with each other, we should use the dry shoot weight in our study to evaluate the corn genotypes because it has longer vector length, the dry shoot weight and root length had weak correlation, the shoot length is present in a separate category and it had a weak correlation with other traits, we should not use in our study (Fig. 3).

Under 100% and 40% field capacity the dry root weight and dry shoot weight had the discrimination power and should be used for evaluation of corn genotypes. Those genotypes had more distance from the center or origin, showed more diversity.

The genotypes fall in the positive were found, a good performer. The genotypes that fall in the negative found poor performer. Water deficient condition in any crop is a limiting factor in crop production globally.

The selection of water-tolerant corn germplasm plays a significant and major role in breeding programs. Mainly many techniques are being applied to evaluate and select the water-tolerant germplasm in corn (Molin *et al.*, 2013). Data mining is a very useful technique for large data set for selection, exploration and finds out useful information. In that technique, principal component analysis are in precision and more informative.

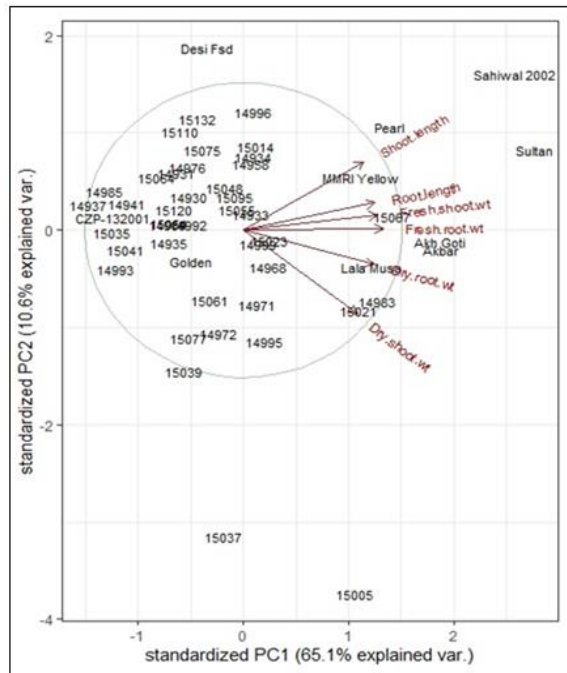


Fig. 2. Biplot graph for fifty corn genotypes at 40% FC.

Principal component analysis reduced the large dimensions of data set into small components. The principal component analysis generates useful information if the first factor explained many differences. The eigenvalue is also a very important selection criterion for principal factor and mainly 1 is used as a key indicator for the selection of principle factors. Eigenvalue >1 indicated that the factor having maximum variation and having useful information when compared to other variables (Gabriel, 1980).

In the current study, there is the only PC1 which have an eigenvalue greater than one but the first three-factor PC1, PC2 and PC3 which is also important because they also generate maximum variance and information. Root length (Terbea and CiocAzanu 1999), shoot length (Hussain, 2009), fresh root and

shoot weight (Efeoglu Ekmekci and Cicekk 2009), and dry root and shoot weight (Mehdi, Ahmad, and Ahsan, 2001) were repeatedly used by many scientists to evaluate the different crops. Our PCA results are similar to Qayyum *et al.*, 2012; Aslam, 2014. The genotypes like Lala Musa, Akbar, Sahiwal-2002, Sultan, Pearl, 15005, 15077, 14972, 15110 under 100% FC level performed well and genotypes like 14933, 15023, 14968, 15055, 15005, MMRI yellow, Lala Musa, Pearl, Akbar, Akhgoti, 15067 and Sultan under 40% FC and the genotypes like Desi fsd, 15075, Lala Musa, 14930, 14976, 15132, 15048, Sultan and 15005 performed best in 30% FC. In general, those genotypes which performed better under in the availability of 30% of field capacity is ideal for area areas with extremely rare water accessibility or rain fed areas or hilly areas and the genotypes which showed their performance good under 40% field capacity is generally appropriate for those areas which have normal accessibility to water and genotypes which performed better in 100% of field capacity reasonable for the areas of ideal accessibility to water.

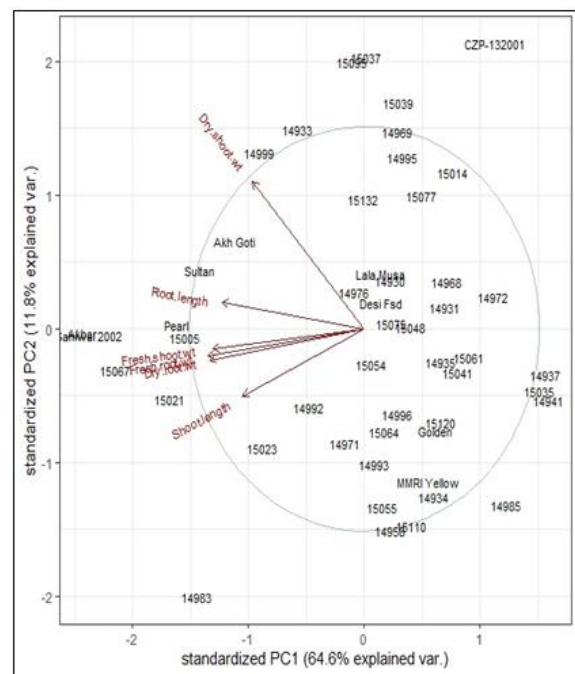


Fig. 3. Biplot graph for fifty corn genotypes at 30% FC.

We have to select certain genotypes from the above results that achieve a contrasting factor for each of three water treatments that suggested that these

chosen parents could be used for recombination breeding for further improvement of accessions resistant to drought. In all three water treatments, Akhgoti, Lala Musa, Sultan, and 15005 are the best performing genotypes, i.e. 100, 40 and 30 percent of field capacity.

Conclusion

The genotypes which performed better under a wide range of water availability indicated that these genotypes have a wide and resistant genetic background. The performance of the genotypes was diverse. I.e. if one genotype performed well for one trait but on another side, this performance is too worse for another trait. Genotypes were ranked for resistant and susceptible based on discriminating traits like root length, shoot length, fresh root weight, fresh shoot weight, dry root weight and dry shoot weight.

Acknowledgment

The authors have hereby acknowledged the services rendered by Maize and Millets Research Institute, Yousafwala, Sahiwal and National Agriculture Research Center (NARC) for the provision of maize materials. The financial and technical guidance through research project #: UOS/ORIC/2016/12. The manuscript is part of Ph. D dissertation of Mr. Zia Ud Din Khan.

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