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Morpho-physiological characterization of Indian wheat genotypes and their evaluation under drought condition

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To study the morpho-physiological and genetic diversity analysis of Indian wheat cultivars a total of 10 genotypes were collected namely: HD-2133, HUW-825, R-54, K-9533, V-110, V-70, HUW-213, V-23, VWTH-08-07 and HUW-37 to evaluate the genotypes under drought stress the seeds of 10 varieties were treated with polyethylene glycol (PEG) for inducing stress condition. Among the morphological characteristics of wheat genotypes under controlled and treatment condition the characters as; leaf area, numbers of productive tillers/plants, days of maturity were recorded at pre harvest stage and seeds per spike, length of spike and grain yield per plant were recorded at post harvest stage. In the present study, significant reduction in yield components like seeds per spike, number of filled and unfilled seeds per spike and final grain yield was observed in all the test genotypes when drought was imposed at seed stage by treating with PEG. After PEG treatment, the wheat variety V-110, performed better under artificially imposed drought condition and can be considered as drought tolerant variety.

Key words: Wheat, morphological parameters, physiological growth attributes, proline.

INTRODUCTION

Wheat (*Triticum aestivum)* belonging to family *Poaceae* (*Gramineae*) is the major cereal crop of the world. In last few years, climatic conditions have been drastically changed and most part of the world is under low water availability especially in South Asia and Africa. Drought imposes one of the commonest and most significant constraints to agricultural production, seriously affecting crop growth, gene expression, distribution, yield and quality (Zhu, 2002; Zheng et al., 2010; Almeselmani et al., 2011). Drought affects wheat productivity in dry and semi arid areas, and reduces plant yield more than any other environmental stress (Ali et al., 2013). The extent of modification depends upon the cultivar, growth stage, duration and intensity of stress (Araus et al., 2002). Hence, even at the same level of moisture stress condition, different genotypes show different responses as per their genetic potential for adaptation. Drought stress induces a range of physiological and biochemical responses in plants so that plants are able to develop tolerance mechanisms towards environmental stress (Shinozaki and Shinozaki, 2007*;* Gholamin et al., 2010). These responses include stomata closure, repression of cell growth and photosynthesis and activation of respiration, decreesed in the water relation, nutrient uptake and grain yield of the wheat cultivars (Fahimnavaz et al., 2012).

Morphological and agronomic traits of wheat have a

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special role in determining the importance of each trait in increasing yield; therefore, these traits were used in breeding programs which at least led to improving yield and introducing commercial varieties that can withstand seasonal drought stress condition (Ahmadizadeh et al., 2011). The biological yield, spike length, number of grains per spike and harvest index showed more direct positive effects on yield (Ahmadizadeh et al., 2011).

Improving drought tolerance and productivity is one of the most difficult tasks for researchers because under drought prone conditions, plant themselves adopts diverse strategies to combat drought stress depending on the timing, severity and stage of crop growth. In addition to this, the meager availability of drought resistant cultivars further adds to the problem. It is therefore, necessary to appraise and screen wheat genetic resources to identify the sources of the resistance for breeders to construct new wheat varieties. In this view, the major wheat varieties grown in Western Uttar Pradesh were evaluated for their performance in response to drought with a special focus given to morphological, physiological and biochemical parameters.

MATERIALS AND METHODS

Ten (10) major grown varieties of wheat (*T. aestivum*) in the area of Western Uttar Pradesh were selected for the present study. For this, seeds of all varieties viz. HD-2133, HUW-825, R-54, K-9533, V-110, V-70, HUW-213, V-23, VWTH-08-07 and HUW-37 were collected and treated with polyethylene glycol (PEG) for imposing drought condition (Figure 1a). Thirty (30) seeds of each variety were placed on the moist Whatman germination papers in Petri dishes and 5 ml of 15% PEG solution was applied on each day up to seven days along with control. After seven days, the germinated seeds were transferred into field for overall comparative study of morpho-physiology of wheat. The crop was maintained in the field using conventional agronomic practices to keep the crop in good condition (Figure 1b) and data was recorded timely.

Morphological evaluation of wheat genotypes

Observations for morphological parameters were recorded from randomly selected five plants from each introgression lines in each replication at maturity. The data was recorded for pre-harvest characters like number of productive tillers (at 30 to 45 days after sowing depending upon the growing condition), leaf area (length and width of flag leaf), and days to maturity (number of days taken from sowing to the browning of ears). For post harvest characters, the data was recorded for length of spike (ear length is measured in centimeter from tips of apical spikelet (excluding awns) to the bases or collar of ear), number of grains per spike (mean number of seeds counted from 10 randomly sampled spikes at maturity), and grain yield per plant (weight of seed per plant expressed in grams).

Physiological evaluation of wheat genotypes

To study the physiological changes after imposing the drought condition, the data for related water content and chlorophyll content was recorded. The relative water content (RWC) of flag leaf was measured following the method of Turner (1981). Fresh weight (FW) of flag leaf was determined immediately after harvest, and then allowed to float in distilled water until fully rehydrated and weighed for turgid weight (TW). The turgid leaf was dried in a hot oven at 80°C to constant weight, and dry weight (DW) was recorded. The RWC of the first leaves, coleoptiles and roots was calculated as: RWC (%) = (FW - DW) / (TW - DW) * 100.

Chlorophyll meter (SPAD 520) was used to measures the relative chlorophyll content of the leaves. Five readings were taken from single plant leaves and their average was considered for determination of chlorophyll content. The chlorophyll content was recorded in terms of percentage.

Biochemical evaluation of wheat genotypes

Prolone is a major biochemical signal of drought tolerance. For estimation of Proline content, 100 mg of fresh leaf tissue was taken from normal plants and treated plants. Grind the leaf tissue in aqueous sulphosalisylic acid (3%) and centrifuged at 7000 rpm for 5 min. The supernatant was mixed with equal volume of Glacial acetic acid and 0.5 ml of ninhydrin was added. The tubes were incubated for 30 min in boiling water bath and placed for 5 min in ice bath for cooling. To stop the reaction, 2 ml of toluene was added in each tube. The reaction mixture was mixed properly and aqueous phase was transferred in new tube. The reaction mixture was warm at 25°C and chromophore was measured at 520 nm.

Statistical analysis

The experimental data were compiled by taking mean values over randomly selected plant from both replications and subjected to the statistical analysis. The analysis of variance for the design of the experiment was carried out according to the procedure outlined by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Morphological characteristics of wheat genotypes under controlled and treatment condition

PEG is an osmotic agent, which plays an important role in the regulation of mineral elements harmones, protein metabolism and effects on signal transduction. The main function of PEG is to slow down the moisture rate of impact and export seeds, which benefit to reduce membrane system injury in process of seed imbibitions and repair impaired membrane system. Therefore in the present study, the PEG has been used in seed priming and simulated water stress to study the effect of drought on various aspects like photosynthesis (Guo et al., 2004).

Pre harvest characteristics

Leaf area of flag leaf is directly related to higher photosynthesis and high chlorophyll content. For measuring the leaf area of flag leaf, five plants of each variety was taken and their mean is presented in Table 1. The leaf area was varied from 30.88 to 62.71cm^2 of genotype R-54 and V-23, respectively. Total leaf area of flag leaf of wheat genotypes was decreased significantly after PEG

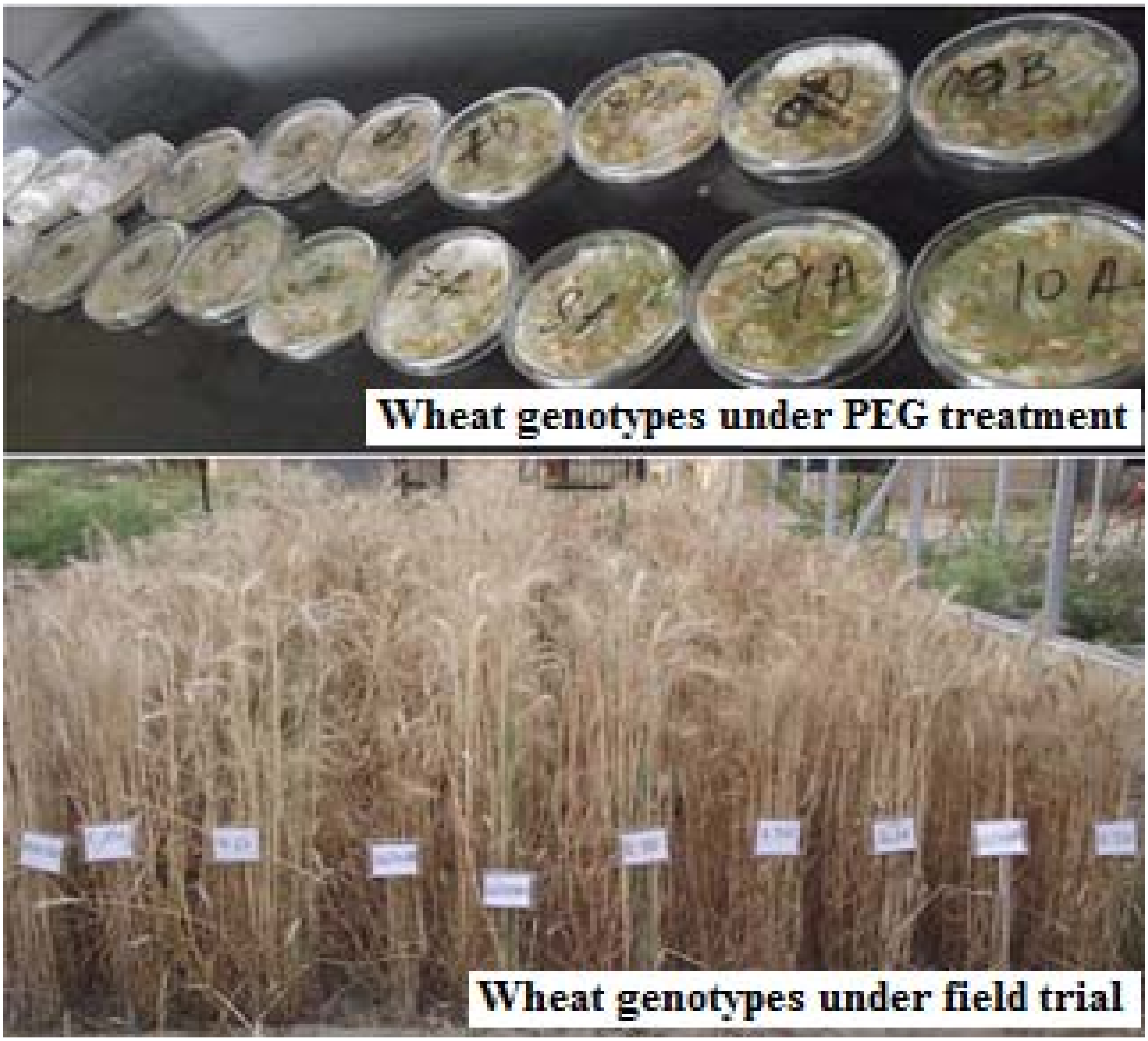

Figure 1. Wheat genotypes under PEG treatment and mature crop under field trial.

treatment. However, genotype V-110 and V-70 showed a least decline in leaf area and considered to be of better performance under drought condition (Figure 2).

The numbers of productive tillers per plants were noted at the time of maturity (Table 1). The number of productive tillers per plant was varied from 5 in HD2133 to 8.8 in V110 in controlled plants. The treatments of PEG, reduces the number of productive tillers per plant. After the treatment, the number of productive tillers reduced and varied from 3.6 to 8.5. The genotype V-110 and V-70 showed lesser effect of PEG treatment and performed better under artificially induced drought conditions; whereas the genotype HD-2133 showed a significant effect of PEG treatment.

All the wheat genotypes were maintained in good condition using recommended agronomic practices; although, all the varieties took different time to reach maturity. The days of maturity of each variety were noted down at the time of 50% grain maturity. Overall, the genotypes took 105 to 130 days to reach maturity in field (Table 1). Under artificially imposed drought condition by treating them with PEG, the crop took longer time in field to reach maturity as compared to controlled plants. How-ever the genotype V-110 shows the less effect of PEG treatment and matures along with the controlled plants.

Post harvest characteristics

In the present study, the significant differences were reported in total yield per plant and numbers of grains per spike amongst different varieties under simulated drought

Table 1. Morphological characteristics of wheat genotypes under normal and treatment of PEG

Genotype	Leaf area $(cm)^2$		No. of tiller		Days To maturity		Length of spike		N. of grain/ spike		Grain yield/ Plant (gm)	
	C	T	C	T	C	T	C	T	C	T	C	T
HD-2133	55.77	54.90	5.00	3.60	130	134	7.10	6.50	45.00	42.00	11.32	9.18
HUW-825	35.81	28.24	6.80	6.10	115	119	9.50	9.60	51.00	50.40	13.36	12.62
R-54	30.88	29.59	6.60	6.80	118	122	9.20	8.94	52.80	48.60	13.89	12.98
K-9533	51.95	39.61	6.40	6.60	116	117	8.60	8.74	49.80	45.30	11.42	10.82
V-110	58.23	58.29	8.80	8.50	105	104	10.50	10.00	61.40	63.00	16.37	16.32
V-70	53.16	52.81	8.10	8.00	108	108	9.04	9.04	54.00	53.10	15.23	15.02
HUW-213	43.04	38.01	6.80	5.90	115	113	9.04	8.97	51.00	48.00	13.36	13.01
V-23	62.71	58.65	7.80	7.00	110	115	8.93	8.52	60.00	58.80	15.71	14.62
VWTH-08-7	47.66	42.61	6.40	5.20	120	119	7.04	8.20	52.20	51.30	14.52	13.95
HUW-37	40.54	35.78	7.20	7.10	108	112	8.70	8.70	53.20	51.00	15.26	15.13

C, Control; T, treatment.

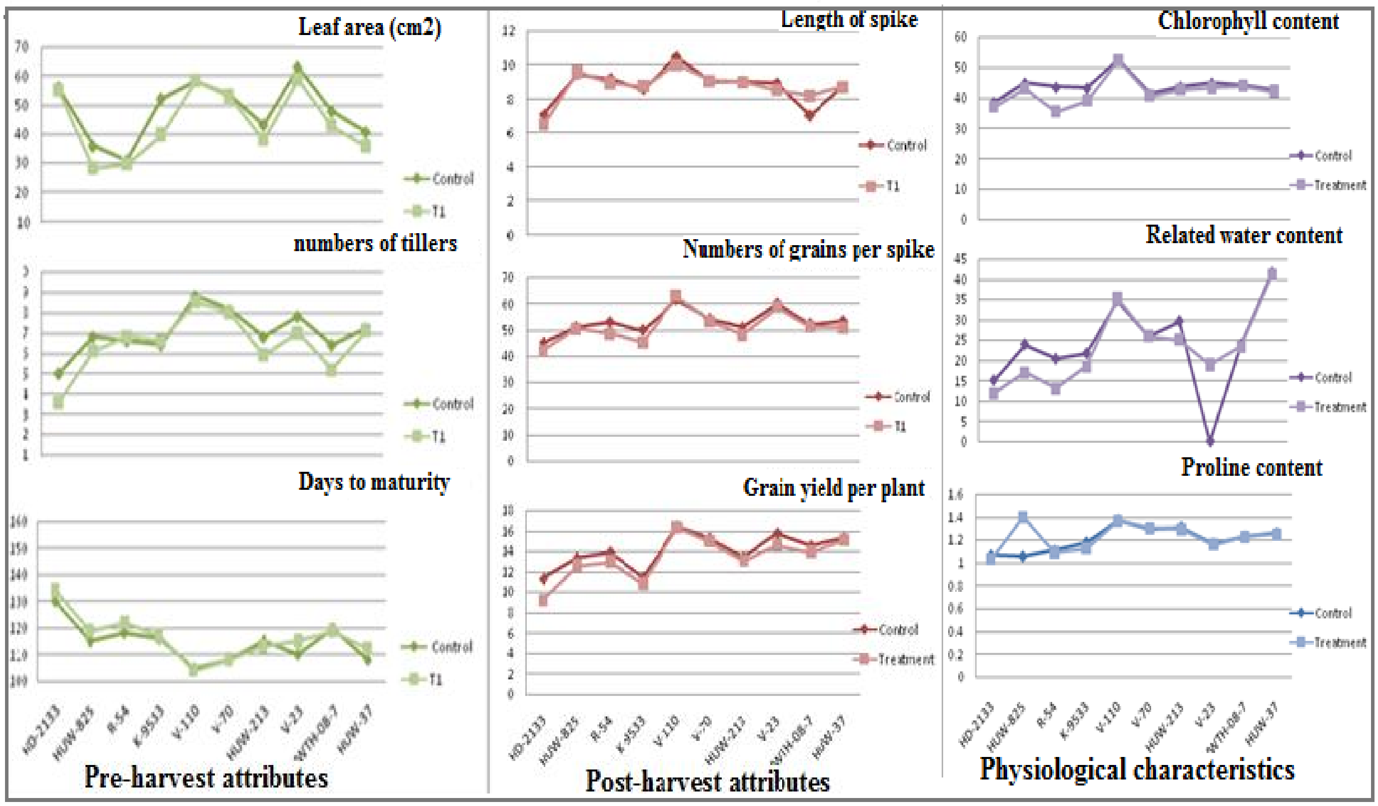

Figure 2. Pre-post harvest and Post-harvest growth attributes of wheat genotypes.

stress condition. Drought stress negatively affect length of spikelet yield per plant and number of grains per spike. The length of spikelets is directly contributed to yield component. The result shows that the length of spike varied from 7.04 cm in VWTH-08-7 to 10.5 cm in V-110 genotype (Table 1). The treatment of PEG affects the length of spike a little in all the genotypes except genotype V-110 (Figure 2).

Seeds per spike are a direct measure of yield/plant, hence it is an economically important post harvest characteristic. Number of seeds/spike varied from a lower value of 45 in HD-2133 to a higher value of 61.4 in V-110

Table 2. Physiological performance of wheat genotypes under normal and treatment of PEG.

Genotype	Chlorophyll		RWC		Proline	
	Control	Treatment	Control	Treatment	Control	Treatment
HD-2133	38.484	36.82	15.02	12.00	1.07	1.03
HUW-825	44.776	42.98	23.90	17.05	1.06	1.40
R-54	43.464	35.40	20.33	13.10	1.11	1.09
K-9533	43.152	39.000	21.66	18.61	1.18	1.13
V-110	52.420	52.31	34.66	35.21	1.37	1.37
V-70	41.228	40.54	25.87	26.00	1.30	1.30
HUW-213	43.584	42.53	29.62	25.09	1.31	1.29
V-23	44.776	43.28	20..49	19.01	1.17	1.16
VWTH-08-7	44.200	43.83	23.86	23.37	1.23	1.23
HUW-37	42.558	41.98	41.56	40.98	1.26	1.25

(Table 1). The number of seeds per spike was decreases after PEG treatment in almost all the genotypes except genotype V-110 where it increases from 61.4 to 63 after the treatments of PEG (Figure 2).

The grain yield per plant of each genotype were recorded and found to be varied from 11.32 in HD-2133 to 16.37 in V-110 in controlled plants (Table 1). After the treatment of PEG, the HD-2133 genotype showed a remarkable decrease in grain yield per plant (Figure 2). On the other hand, the grain yield of rest of the genotypes showed a little effect of PEG treatment.

This is also supported by Chander and Singh (2008) and Ali et al. (2013) that numbers of grains per spike were decreased under drought stress. Water stress has been reported to affect all the yield components, mainly the number of grains per spike and the number of pikes per plant (Giuanta et al., 1993; Simane et al., 1993). It has been recognized that decrease in yield and yield component under drought stress is a key concern in developing countries of the world (Guo et al., 2004).

Physiological characteristics of wheat genotypes under controlled and treatment condition

The chlorophyll content showed variation in control and in both treatments of PEG. Among all the genotype, V-110 shows highest chlorophyll content; that is, 52.42 µg and lowest in HD-2133; that is, 38.48 µg (Table 2). The treatment of PEG reduces the total amount of chlorophyll as compared to control and varied from 35.40 µg in R-54 to 52.31 µg in V-110 (Figure 2).

The plant free proline massive accumulated when the plants was subject to drought stress, the reason is, proline dehydrogenase activity is decreased and made the proline oxidation weakened; drought suppressed the protein synthesis, proline utilization is decreased and to increased accumulation in plants (Zhan et al., 2011). Therefore, the proline content is positively correlated with drought resistance in wheat seedling; hence the accumulation of proline contents could be use as physiological indicators of stress resistance (Gabor et al., 2004). In this view the total proline content was estimated among the studied genotypes. The proline content is present in significant amount in the leaf of wheat genotypes and varied from 1.06 µg/gfw in HUW-825 to 1.37 µg/gfw in genotype V-110 (Table 2, Figure 2). Proline content increased under treatment of PEG; this is quite understandable as proline is known to be produced in higher amount under stress condition as it helps in resisting plants against stress condition.

The RWC of the leaves indicate the water condition of the cells and have important correlation with biotic and abiotic stress tolerance (Almeselmani et al., 2011). It has been reported that, RWC of the leaves has strong association with drought tolerance (Kaur et al., 2011) and it is a good indicator of drought stress than other physiological and biochemical characteristics of the crop plants (Colom and Vazzana 2003). Our results reveal significant differences in RWC among varieties at three different stages and showed that, retention ability of the plant was significantly different at different growth stages. The relative water content (RWC) was estimated for the present 10 wheat genotypes under controlled condition and after the treatment of PEG (Table2). The RWC in controlled plants varied from 15.02% in HD-2133 to 41.56% in HUW-37. The higher RWC was estimated after PEG treatment in cultivar HUW-37(41.56%) and V-110 (35.21%) and thus can be considered as drought tolerant. The lowest RWC estimated after PEG treatment were obtained in K-9533 (12.00%) and can be considered as drought sensitive (Figure 2).

This variation in RWC of leaf may be due to the ability of the tested wheat genotypes to absorb more water from soil and also to control water loss through the stomata (Sinclair and Ludlow1985). It may also be due to the variation in the ability of wheat genotypes to avoid stress by maintaining tissue turgor osmotically. These results were supported by Schonfeld et al., (1988) and Ali et al., (2013) that RWC may be used as a selection criterion in breeding for improved drought resistance in wheat genotypes (Schonfeld et al., 1988).

Results showed significant variation among the genotypes, traits and their interactions. Artificial induction of drought by treatment of PEG caused a substantial reduction in growth related attributes in most of the wheat genotypes except in V-110 genotype. In the present study, significant reduction in pre-harvest and post-harvest characteristics which are directly related to yield like leaf area, number of productive tillers, days to maturity, length of spike, number of filled and unfilled seeds per spike and final grain yield per plant was observed in all the test genotypes when drought was imposed at seed stage by treating with PEG. Overall the genotype V-110sows least effect of PEG treatment in term of leaf area, number of tillers and maturity time, therefore can be considered as drought tolerant genotype. On the other hand the variety HD-2133 shows lesser leaf area, less no of productive tillers and stays a long in field to get mature after the PEG treatment and therefore said to be sensitive against drought condition. Bayoumi et al. (2008) observed that water stress caused 43% reduction in grain yield of wheat varieties and subjecting the seeds of wheat varieties to artificial osmotic stress condition in the laboratory (treating with PEG solution) is an adequate tool for the presumption of their thriving against water stress field condition. The parameters related to plant growth envisaged as prominent characteristics for drought resistant screening process of wheat varieties (Foito et al., 2009).

This study allows us to recognize those physiological characteristics that are associated with drought stress, and screen out appropriate wheat genotypes, which can be introduced in arid area to produce high yield in drought conditions and can be further used in breeding programs to produce a stress tolerant genotype.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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