Int. J. Biol. Res., **12 (1-2): 29-48, 2024.**

Physiological and photochemical screening of distinct wheat genomes for drought and salinity stress tolerance

Farwa[1], Basit Ali[1*]

[1]Stress Physiology Lab., Department of Botany, University of Karachi, Pakistan
*Corresponding Author: basitalibot@gmail.com

Abstract

Wheat (Triticum aestivum L.) is the cereal cash crop cultivated globally and the economy of most agricultural countries like Pakistan depends on wheat cultivation. However, drought and salinity are the two major obstacles against wheat cultivation. Due to the continuously changing climatic conditions and anthropogenic activities, the hazardous risks of land water scarcity and soil salinity have markedly increased and will probably increase more in the future which will result in less crop cultivation and economic hindrance. Breeding is one of the admissible solutions to this issue. Varietal screening is the process of screening plants using different morphological physiological methods under stressed conditions and is one of the effective strategies for providing the best-suited crops for plant breeders and for affected areas. Six different wheat genotypes (Amin - 2000, Inquilab - 91, Parula - 73, Laylpur - 73, Dirk, and Blue Silver) were screened to check their tolerance under drought and salinity using different physiological and morphological tools. Different phenotypical and physio-chemical parameters were determined. The genotype Blue silver response was found to be better performing than others improved plant biomass accumulation (such as root and shoot lengths and fresh and dry matter contents), improved leaf pigments and photosynthetic traits (such as chlorophyll content index, PSII quantum yield, and photosynthetic apparatus performance index), maintained leaf water status (RWC-%), and reduced membrane damage index and oxidative damages, the crop produced more in terms of spike length, number of grains, and grain mass, making it a genotype that is best suited to regions that are subject to drought and salinity stress and hence could be effective in salt and drought-affected areas and can be further used for plant genomic and breeding purposes. However, the Amin genotype was found to be a sensitive and least-performing crop under abiotic stressors.

Keywords: Breeding, Physiological, Growth, Agricultural, Cultivation.

Introduction

Wheat (*Triticum aestivum* L.), belongs to the family Poaceae, is considered the king of cereal crops and is cultivated all across the world and hence consumed by one-third of the global population (Rahman et al. 2008; Abdelsalam et al., 2019). Wheat being the world's most dominant and important cereal crop grows in large areas because of its nutritious value for humans and animals. It is considered a stable food because of its quite accessible procession, transportation, refining, and consumption as unprocessed food (Elias, 203). Nutritionally, wheat seeds contain 1.8% fiber, 9.4% protein, 69% carbohydrates, and 2.5% fats (Ken, 2004). About 20% of calories and 55% of carbohydrates are provided by wheat across the globe (Taha et al., 2021). The cultivation of wheat originates from the South Western Asia and occurs in almost all parts of the world. However, in Pakistan, the annual production of this major cereal crop (wheat) takes place in an area of 9.2 million hectares with a net production of about 25.52 million tonnes. So the contributive role of wheat in the GDP of Pakistan (Economic Survey of Pakistan, 2019) is about 2.2%. Pakistan attains 6th position in the world in wheat-growing countries. Whereas under open environmental field conditions, the yield production of wheat is influenced negatively because of the encounter of various biotic and abiotic stresses (Saddiq et al., 2021, Abdelsalam et al., 2019).

Several biotic and abiotic factors affect the quality and quantity of yield of crops and hence reduce the economy. Among abiotic stresses, the two major stress conditions are physical dryness (drought) and physiological dryness (salinity). Drought has become a hectic issue all across the world especially in arid and semi-arid regions like Pakistan because it has a negative influence on the morphological and physiological traits of crop plants especially wheat (Raza et al., 2012). Recently, drought has become the most challenging and competitive issue for agricultural productivity and also for the sustainable means of agriculture thoroughly in agricultural countries because it affects the nutritional status of crops like wheat, maize, and rice (Azeem et al., 2022). In wheat, drought-caused effects have already been studied like the negative influence of drought on spikelet fertility and grain filling which reduce crop yield and lead to reduced agricultural output (Grzesiak et al., 2019; Abid et al., 2018). Drought stress affects overall plant biomass and productivity because it directly or indirectly affects its

Photosynthesis, critical physiological and biochemical activities, and causes oxidative damage to the plant by excessive ROS production in the plant body which results in membrane damage and disordered macromolecules metabolism like proteins, carbs, DNA and pigments (McDowell et al., 2022; Pepe et al., 2022). Morphologically, drought stress symptoms include shortness of plant height, reduced leaf biomass, reduced relative root length, shoot length, fresh weight, and late germination (Queiroz et al., 2019). However, the physiological impact of physical dryness on wheat plants includes Reduce Relative water content, turgor loss, and stomatal closure (Wagaw et al., 2019).

Salinity and salt stress are the conditions of physiological dryness for plants because in this condition the water is available in the soil but the plant is unable to absorb or use it because of the high salt content and osmotic difference. At the global level, the salinity is continuously and gradually increasing, and at present 20% soil is saline affected. As for Pakistan, land irrigation is reduced by approximately 14% and 64% of yield and productivity losses occur due to saline conditions. Salinity affects plant health status and reduces plant productivity, especially in crop plants. As for the major crop, Wheat (*Triticum aestivum L.*), according to the Food and Agriculture Organization (FAO), 397 million hectares of wheat yield nutrition is a threat under salinity (WHO, 2019). Visible effects caused by salinity on plants include reduced seed germination, alteration in growth and reproductive behavior, and crop yield (Hussain et al., 2021). Moreover, physiological dysfunctions also occur in plants under severe salinity stress. These include ion toxicity, nutritional imbalance, disruption in RWC, enzymatic activities, photosynthesis, membrane structure, hormonal balance, water, and nutrient uptake, and induces oxidative stress like more H_2O_2 and lipid peroxidation(Hajihashemi et al., 2009; Huang et al., 2010).

The morphological and physiological examination or testing of crop plants for specific stress conditions is termed screening. In screening, the evaluation of physical, physiological, biochemical, and molecular changes is determined (Zafar-ul-Hye et al., 2007). Screening of plant genotypes or plant varieties can be done by modern tools and non-invasive methods under standard conditions and it requires less time, it is known as varietal screening in which plant varieties are grown under different environmental conditions. This study aims to the morphological and physiological screening of the wheat genotypes for their tolerance level under drought and salinity stress conditions for the futuristic approach to the sustainable wheat crop in arid and semi-arid regions of Pakistan and plant breeding and genomic purposes.

Material and Methods

Experimental maneuver and plant setup

The Experiment was carried out at the Phenomics Center Lab, Department of Botany, University of Karachi, Pakistan. The big rectangular pots were prepared for the screening experiment(length = 19.5 inches × breath = 5.7 inches × height= 6 inches). These rectangular pots were filled with 7 kg of soil and the plants growing in these pots were led to grow till the grain-filling stage. The soil used for this experiment had a loamy texture and contained a fertilizer ratio of 9:1, which was suitable for wheat crops. The soil pH was measured at 6.91, and soil electrical conductivity was 193 µS (micro Siemens). Six different wheat (*Triticum aestivum* L.) genotypes were used namely, Amin - 2000, Inquilab-91, Parula - 73, Laylpur - 73, Dirk, and Blue Silver (BS). This experiment comprised two different treatments, a drought at 55-60% field capacity (FC) against control which was at 90-100% field capacity, and salinity at 200mM NaCl through gradual implementation against untreated control. The seeds were sown at the end of October which is considered as the best sowing date for wheat crops. The plants were grown under open field conditions to meet the open environmental demands. After germination, the genotypes were grown into pots for up to 3 weeks (21 days) before the imposition of 2 weeks of stress of both salinity and drought, while the stress continued in the few rectangular pots till the fruiting stage harvesting for yield parameters. After the completion, 2 weeks of stress plant biomass and growth parameters and leaf area were also calculated.

Cultivation practices and Replicates

The seeds were sown according to the cultivation needs for wheat crops. The plant-to-plant distance was 6-7cm each in small pots and at least 8-10 cm in rectangular pots. The small pots contain 5-6 plants per pot while for rectangular pots, there are 14-16 plants per pot for each genotype. All other cultivation practices were kept uniform except for treatments for each genotype. There were 3 replicates per treatment.

Relative Water Content (RWC-%)

Calculation of leaf RWA was done using the method of Schonfled (Schonfeld et al., 1988). Right after the completion of 2 weeks of the stress of both drought and salinity, leaves from each treatment were harvested and cut into equal patches to take fresh weight. After taking the (FW), the patches were imbibed in deionized water for 12h and after 12 h of imbibition, Turgid weight was noted (TW). Then, the same leave samples were dried using the oven at 70°C for 72 hours and then dry mass were recorded. The final leaf RWC was calculated by using the formula.

RWC (%) = [(fresh weight − dry weight)/(turgid weight − dry weight)] × 100

MDA content

MDA content was measured using the method of Velikova et al. 2000. MDA is an end product of lipid peroxidation which is determined by using leaves of plants. Leaves (500 mg) were crushed and homogenized in 5 ml 0.1% (w/v) trichloracetic acid (TCA) solution and then centrifuged at 10,000×g for 15 min. The supernatant (0.5 ml) was added to 1 ml 0.5% (w/v) TBA in 20% TCA. The solution was incubated in boiling water for 30 min and then kept in an ice bath to stop the reaction, following centrifugation at 10,000×g for 5 min. The absorbance of the supernatant was read at 532 nm.

H_2O_2 content

Leaf tissues (500 mg) were homogenized in an ice bath with 5 ml of 0.1% (w/v) TCA. The homogenate was centrifuged at 12,000×g for 15 min, and 0.5 ml of the supernatant was added to 0.5 ml 10 mM potassium phosphate buffer (pH 7.0) and 1 ml 1M KI. The absorbance of the supernatant was read at 390 nm. The H2O2 content was determined using a standard curve. (Velikova et al., 2000).

Osmolality

For ion content measurement or osmolality determination, crushing and ‘hand squeezing ' techniques were used. Fresh plant leaf samples were frozen, crushed, and then squeezed using a muslin cloth piece until all the sap was extracted from the shoot leaf sample. The Osmolyte or ion content was measured using the Osmometer type 6 (Loser Messtechnik, Germany**).**

Leaf membrane stability index (MSI)

The MSI was determined by using the Premachandra method (Premachandra et al., 1990) while having the modification of Sairam, 2004. In 10ml of DW, add 0.1g of leaf sample and boil it at 40°C for 30 minutes, and note the first conductivity (C1) using the conductivity meter. The same set was again boiled for 15 mins but this time at 100°C and then conductivity was noted again (C2).

MSI = [1 – (C1/C2) × 100]

CCI and Chlorophyll-a fluorescence parameters

The chlorophyll content index (CCI) of wheat genotypes with or without stress was calculated from the middle leaf part using a chlorophyll content meter (Model CL-01, Hansatech, UK).

Chlorophyll fluorescence was obtained using the Chlorophyll fluorescence meter (OS-30p+, Opti science, USA). The analysis was performed on the youngest and fully opened leaves between 9: 00 AM – 11: 00 AM with special care for shading and angle of leaf. Leaves were dark adapted for 30 minutes using leaf clips. The test protocol was conducted in weak modulated red light (0.5 µ mol m-1s-1) with pulses of saturating light 1.6 s (6.8 µ mol m-1 s -1 PAR). To check the efficiency of the photosynthetic apparatus of plants under stress Fv/Fm and PI values were recorded.

Experimental design and statistics

The experiment was carried out in the Completely Randomized Design. According to Steel et al., 1997 method, the significant differences among treatment means were compared using the least significant difference (LSD) test ($p < 0.05$), by applying the Statistics version 8.1 (Analytical Software ©, 1985–2005).

Results

Results of different performed tests have shown that under salinity and drought stress the morphological, physiological, and photochemical are negatively affected, however, Blue silver and Parula wheat genomes performed well under stressed conditions in terms of better growth and plant establishment, maintaining good photosynthetic apparatus and hence good crop productivity.

Plant growth biomass assay

Under salinity and drought stress the plant growth and biomass production were negatively affected among all wheat genomes(Fig.1). Under drought conditions, BS had the highest value of shoot fresh weight (SFW=0.39gm), and shoot dry weight (SDW=0.09 gm), while Inquilab had the highest value(0.25gm) root fresh weight (RFW). Root dry weight (RDW), BS had the highest (0.06 gm) while Amin was the lowest. In the case of salinity, BS has the highest shoot and root fresh weight (SFW=0.51gm, SDW=0.14gm, RFW=0.2gm, RDW = 0.047gm) while Amin has the lowest(SFW=0.17g, SDW=0.04gm, RFW=0.08gm, RDW=0.017gm) (Fig. 2).

Under salinity stress the highest Shoot length (SL) and Root length (RL) were recorded in Parula (S=27.51 cm, R=17.65 cm), while the lowest Shoot length was recorded in Inqilab(19.54 cm) and the lowest Root length was recorded in Amin(14.02). Under drought stress, the highest Shoot length was recorded in Parula(23.18 cm) while the lowest was Amin(17 cm), the highest root length was recorded in Dirk(17.5 cm), and the lowest RL was recorded in AminS(11.73). While under saline conditions, the highest SL was recorded in Parula (26 cm) and the lowest was in Amin(14.58 cm). For RL, the highest was in Parula (17.9 cm) and the lowest was in Dirk(12.71 cm) (Fig. 3).

Under drought stress, BS has the largest leaf area(5.68 cm^2) and Amin has the lowest(4.88 cm^2). In saline conditions, BS showed similar patterns and had the largest leaf area (6.54 m^2) and Amin had the smallest (3.97 m^2) as shown in Fig.3.

Leaf RWC(%), CCI and cholorophyll flourescence traits

RWC is a sensitive parameter and found to be affected under abiotic stress. Under drought, Parula has the highest RWC (80.64%) and Amin has the lowest(63%). Also in salinity, BS has the highest RWC (64.54%) and Amin has the lowest(57.11%) (Fig. 4).

The CCI was higher in Dirk and lowest in the Amin genotype under normal conditions. For drought, it is higher in BS and lowest in Amin. In salinity, it is higher in Dirk and Parula and lower in Amin. (Fig. 4).

In all cases, whether stress, the fv-fm ratio which shows the quantum yield of PSII of photosynthetic apparatus and PI that is the performance index of photosynthetic apparatus was greater in BS and Parula genotypes and lower in Amin and Laylpur while Amin had the lowest (Fig.4).

Plant Stress markers and osmolality

H_2O_2 content is an indication of oxidative stress and under abiotic stressors, it is found to increase in all wheat genomes. However, the lowest H_2O_2 content was recorded in Dirk, BS, and Parula and the highest was in Amin. (Fig.5) . Similarly under moisture stress (drought stress) conditions, the lowest lipid peroxidation (MDA content) was noted in BS while in saline, both Parula and BS had low MDA content values. The highest MDA values (lipid peroxidation) were observed in genotype Amin under all conditions. (Fig.5). MSI (Membrane stability index) was observed as highest in BS and lowest in Amin due to excessive production of H_2O_2 under abiotic stresses later than former genotypes. In drought, MSI was recorded highest in Dirk and Parula and lowest in Amin. In salinity, MSI was noted as high in BS and Parula and least in Amin. (Fig.5)The osmolyte concentration was highly increased in Amin and Laylpur during both stresses while in BS and Dirk, it significantly declined (Fig.5).

Fruiting stage parameters

Different fruiting stage parameters (harvesting parameters) of wheat genomes under drought and salinity stress are shown in Table. 1. Under drought stress, BS had the largest (55cm) plant length and Parula had the smallest (30cm). In Saline, again BS had the largest plant length with (57cm), and Amin had the least with (27cm). The number of tillers under both stress conditions BS shows the maximum values. The number of nodes was alternatively variable among all genotypes and not significantly affected by stress whereas the node-to-node distance was slightly affected by stress in all genotypes. The highest spike length was observed in D, BS, and L (7.4-7.4cm) and the smallest was Inquilab (5.5cm) under control. Under drought, BS had the highest spike length (6.9cm) and Amin had the lowest (3.9cm), similarly under salinity stress, BS had the highest (6.3cm), and Inquilab had the lowest (5.2cm) spike length recorded. In terms of the number of grains, BS was found the best among all genotypes. In drought, Amin and Inquilab were the worst (6-7) while in salinity, Inquilab had the lesser grains (6-8) than other genotypes and Amin had few to no grains. Grains mass in control conditions was observed in BS (0.73gm / 10grains) and less was observed in Amin (0.36 gm / 10 grains). The drought followed the same trend as control however in salinity, Inquilab was worst followed by Amin and Parula was the best (0.61gm).

Discussion

Drought and Salinity are challenging abiotic stresses for the whole world that reduce crop yield and ultimately affect the economy. Morphological, physiological, and biochemical responses of plants may vary at exposure to these stresses. Breeding techniques may be an effective solution to overcome stress and develop tolerant genotypes and their mechanism of tolerance should be studied (Ashraf et al., 1992). To determine the future crop yield production, different stages of the plant life cycle are important, especially seed germination and plant growth. Under controlled screening tests, BS has the highest growth and biomass accumulation which can be correlated with improved and well-maintained RWC-% while Amin and Inquilab were the smallest and Amin contained the least biomass due to the least water relations under salinity stress.

Leaf Area is one of the plant features that describes plant health. Wheat genotype BS has the greatest leaf area under all conditions while Amin has the smallest. Water deficiency whether in the form of drought is mostly associated with late germination, delayed fruiting, and reduced growth. Screening of wheat genotypes developed by wheat plant breeders under drought stress is usually used to check and enhance the tolerance of wheat genotypes (Mickky and Aldesuquy, 2017). Water deficiency in soil under drought stress directly affects plant morphology. In our study, under drought, the Parula genotype has the highest length while Amin was the smallest in size. For biomass, BS was the best and Amin was the worst. In our study, the low water availability significantly affected the wheat morphological traits (like plant length, plant biomass content, leaf area, Spike and Spikelet size, No of tillers, grains, and grains mass) as well as physiological traits (including RWC, MSI, CCI and chlorophyll fluorescence) and biochemical parameters (MDA, H_2O_2 content, Osmolality, and Total Carbohydrates) in a negative manner in all genotypes screened which is related to the previous line studies (Maqbool et al., 2015; Naeem et al., 2016; Sayar et al., 2008). Under both stresses, the Parula has the highest leaf RWC while Amin has the lowest %. The BS has the greatest Chlorophyll content and has the best fluorescence ratio while Amin has the lowest CCI and fv/fm under both stress conditions which predict the future plant biomass and yield content. The drought caused an increase in ROS production which resulted in lipid peroxidation and increased H2O2 content which ultimately decreased plant biomass and final yield production (McDowell et al., 2022; Zandi and Schnug, 2022).

Salinity results in physiological dryness for the plant body which hinders seed germination, plant growth, flowering, and fruiting. In our study, for the height parameter, P was the best and A was the last. BS has the greatest biomass and Amin has the least under salinity. Salinity also causes osmotic stress in wheat. The oxidative stress wheat caused by Sodium concentration in soil imbalanced nutrient uptake in plants (Sayar et al., 2008; Quan et al., 2007). Physiological and molecular changes caused by salinity suppress plant photosynthetic performance which results in retarded plant growth(Van Zelm et al., 2020). Salinity also affects plant health by affecting its Chlorophyll content, light-harvesting complexes, and Fluorescence negatively (Park et al., 2016). Ion imbalance under salinity is the main cause of osmotic stress. Osmotic stress results in several changes for example reduced turgor pressure, shrinkage in plasma membrane, and cell wall alteration. Under salinity, Osmolytes like proline, polyols, and sugars accumulation is normal which helps in osmotic adjustment by reducing the cytosolic osmotic potential. Also, ABA accumulation, regulates plant growth under salt stress. Salinity causes ROS production like H_2O_2 and increases lipid peroxidation which has toxic effects on plant growth (Marusig et al., 2020). The least H_2O_2 and lipid peroxidation was recorded in BS during stress and high in Amin which results in a higher number of grains and grains mass in BS while it is low for Amin.

Conclusion

Comprehensive physiological and photochemical screening of wheat genomes shows that Blue Silver (BS) performs the best in salinity and drought out of the six genotypes. When it comes to improved plant biomass accumulation (such as root and shoot lengths and fresh and dry matter contents), improved leaf pigments and photosynthetic traits (such as chlorophyll content index, PSII quantum yield, and photosynthetic apparatus performance index), maintained leaf water status (RWC-%), and reduced membrane damage index and oxidative damages, the crop produced more in terms of spike length, number of grains, and grain mass, making it a genotype that is best suited to regions that are subject to drought and salinity stress. However, the Amin genotype was found a sensitive and least-performing crop under abiotic stressors.

References

Abdelsalam, N.R.; Kandil, E.E.; Al-Msari, M.A.; Al-Jaddadi, M.A.; Ali, H.M.; Salem, M.Z.; Elshikh, M.S. Effect of foliar application of NPK nanoparticle fertilization on yield and genotoxicity in wheat (Triticum aestivum L.). Sci. Total Environ. 2019, 653, 1128–1139.

Abid, M.; Ali, S.; Qi, L.K.; Zahoor, R.; Tian, Z.; Jiang, D.; Snider, J.L.; Dai, T. Physiological and Biochemical Changes during drought and Recovery Periods at Tillering and Jointing Stages in Wheat (Triticum aestivum L.). Sci. Rep. 2018, 8, 4615.

Ashraf, M.; Bokhari, H.; Cristiti, S.N. Variation in osmotic adjustment of lentil (Lens culinaris Medik) in response to drought. Acta Bot. Neerl. 1992, 41, 51–62.

Azeem, M.; Haider, M.Z.; Javed, S.; Saleem, M.H.; Alatawi, A. Drought Stress Amelioration in Maize (Zea mays L.) by Inoculation of Bacillus spp. Strains under Sterile Soil Conditions. Agriculture 2022, 12, 50.

Deng, X. P., Shan, L., Inanaga, S., and Inoue, M. (2005). Water-saving approaches for improving wheat production. J. Sci. Food Agric. 85, 1379–1388. Doi: 10.1002/jsfa.2101

Elias, D., 2003. Wheat, world commodity at Glance. Pp.1-10.

Grzesiak, M.T.; Hordy ´nska, N.; Maksymowicz, A.; Grzesiak, S.; Szechy ´nska-Hebda, M. Variation among Spring Wheat (Triticum aestivum L.) Genotypes in Response to the Drought Stress. Ii—Root System Structure. Plants 2019, 8, 584.

Hajihashemi, S., Kiarostami, K., Enteshari, S., Saboora, A. (2009). Effect of paclobutrazol on wheat salt tolerance at pollination stage. Russian Journal of Plant Physiology, 56, 251–257. DOI 10.1134/S1021443709020149.

Huang, Y., Bie, Z., He, S., Hua, B., Zhen, A. Et al. (2010). Improving cucumber tolerance to major nutrients induced salinity by grafting onto cucurbita ficifolia. Environmental and Experimental Botany, 69, 32–38. DOI 10.1016/j.envexpbot.2010.02.002.

Hussain, S., Ali, B., Ren, X., Chen, X. Et al. (2021). Recent progress in understanding salinity tolerance in plants: Story of Na+/K+ balance and beyond. Plant Physiology and Biochemistry, 160, 250–256.DOI 10.1016/j.plaphy.2021.01.029.

Ken, P. Forms of micronutrient fertilizer. Sask agriculture and food, Rigas Karamanos (Westco). Agric. Agri-Food Can. 2004, 1,1–10.

Maqbool, M.M.; Ali, A.; Haq, T.; Majeed, M.; Lee, D. Response of spring wheat (Triticum aestivum L.) to induced water stress at critical growth stages. Sarhad J. Agric. 2015, 31, 53–58.

Marusig D., Tombesi S. Abscisic Acid Mediates Drought and Salt Stress Responses in Vitis vinifera—A Review. Int. J. Mol. Sci. 2020;21:8648. Doi: 10.3390/ijms21228648.

McDowell, N.G.; Sapes, G.; Pivovaroff, A.; Adams, H.D.; Allen, C.D.; Anderegg, W.R.L.; Arend, M.; Breshears, D.D.; Brodribb, T.;Choat, B.; et al. Mechanisms of Woody-Plant Mortality under Rising Drought, CO2 and Vapour Pressure Deficit. Nat. Rev. Earth Environ. 2022, 3, 294–308.

Mickky, B.M.; Aldesuquy, H.S. Impact of osmotic stress on seedling growth observations, membrane characteristics and antioxidant defense system of different wheat genotypes. Egypt. J. Basic Appl. Sci. 2017, 4, 47–54.

Naeem, M.; Ahmad, M.; Shah, M.; Kamran, M.; Iqbal, M. Character association and path analysis of osmotic adjustment, growth and physiological traits in wheat. J. Anim. Plant Sci. 2016, 26, 680–685.

Park H.J., Kim W.-Y., Yun A.D.-J. A New Insight of Salt Stress Signaling in Plant. Mol. Cells. 2016;39:447–459. Doi: 10.14348/molcells.2016.0083.

Pepe, M.; Crescente, M.F.; Varone, L. Effect of Water Stress on Physiological and Morphological Leaf Traits: A Comparison among the Three Widely-Spread Invasive Alien Species Ailanthus Altissima, Phytolacca Americana, and Robinia Pseudoacacia. Plants 2022, 11, 899.

Premachandra, G.S.; Saneoka, H.; Ogata, S. Cell membrane stability, an indicator of drought tolerance, as affected by applied nitrogen in soyabean. J. Agric. Sci. 1990, 115, 63–66.

Quan R., Lin H., Mendoza I., Zhang Y., Cao W., Yang Y., Shang M., Chen S., Pardo J.M., Guo Y. SCABP8/CBL10, a Putative Calcium Sensor, Interacts with the Protein Kinase SOS2 to Protect Arabidopsis Shoots from Salt Stress. Plant Cell. 2007;19:1415–1431. Doi: 10.1105/tpc.106.042291.

Queiroz, M.S.; Oliveira, C.E.S.; Steiner, F.; Zuffo, A.M.; Zoz, T.; Vendruscolo, E.P.; Silva, M.V.; Mello, B.F.F.R.; Cabral, R.C.;Menis, F.T. Drought Stresses on Seed Germination and Early Growth of Maize and Sorghum. J. Agric. Sci. 2019, 11, 310.

Rahman, M.; Soomro, U.; Haq, M.Z.-U.; Gul, S. Effects of NaCl salinity on wheat (Triticum aestivum L.) cultivars. World J. Agric. Sci.2008, 4, 398–403.

Raza, S.; Saleem, M.; Khan, I.; Jamil, M.; Ijaz, M.; Khan, M. Evaluating the drought stress tolerance efficiency of wheat (Triticum aestivum L.) cultivars. Russ. J. Agric. Socio-Econ. Sci. 2012, 12.

Saddiq, M.S.; Afzal, I.; Iqbal, S.; Hafeez, M.B.; Raza, A. Low leaf sodium content improves the grain yield and physiological performance of wheat genotypes in saline-sodic soil. Pesqui. Agropecu. Trop. 2021, 51.

Sairam, R. Effect of moisture-stress on physiological activities of two contrasting wheat genotypes. Indian J. Exp. Biol. 1994, 32, 594.

Sayar, R.; Khemira, H.; Kameli, A.; Mosbahi, M. Physiological tests as predictive appreciation for drought tolerance in durum wheat (Triticum durum Desf.). Agron. Res. 2008, 6, 79–90.

Schonfeld, M.A.; Johnson, R.C.; Carver, B.F.; Mornhinweg, D.W. Water relations in winter wheat as drought resistance indicators crop. Sci. 1988, 28, 526–531.

Steel, R.; Torrie, J. Principle and Procedure of Statistics: A Biometrical Approach; McGraw Hill Publication Co.: New York, NY, USA, 1997; p. 633.

Taha, R. S., Seleiman, M. F., Shami, A., Alhammad, B. A., Mahdi, A. H. A. (2021). Integrated application of selenium and silicon enhances growth and anatomical structure, antioxidant defense system and yield of wheat grown in salt-stressed soil. Plants, 10, 1040. DOI 10.3390/plants10061040.

Van Zelm E., Zhang Y., Testerink C. Salt Tolerance Mechanisms of Plants. Annu. Rev. Plant Biol. 2020;71:403–433. Doi: 10.1146/annurev-arplant-050718-100005.

Velikova, V., Yordanov, I., and Edreva, A. (2000). Oxidative stress and some antioxidant systems in acid rain-treated bean plants: Protective role of exogenous polyamines. Plant Sci. 151, 59–66. Doi: 10.1016/S0168-9452(99)00197-1

Wagaw, K. Isolation and Screening of ACC Deaminase-Producing Microbes for Drought Stress Management in Crops. Acad. Res. J. Agri. Sci. Res. 2019, 7, 87–99.

World Health Organization (2019). Preventing disease through healthy environments: exposure to highly hazardous pesticides: A major public health concern (No. WHO/CED/PHE/EPE/19.4.6). Geneva, Switzerland: World Health Organization.

Zafar-ul-Hye, M.; Zahir, Z.; Shahzad, S.; Irshad, U.; Arshad, M. Isolation and screening of rhizobia for improving growth and nodulation of lentil (Lens culinaris Medic) seedlings under axenic conditions. Soil Environ. 2007, 26, 81–91.

Zandi, P.; Schnug, E. Reactive Oxygen Species, Antioxidant Responses and Implications from a Microbial Modulation Perspective.Biology (Basel) 2022, 11, 155.

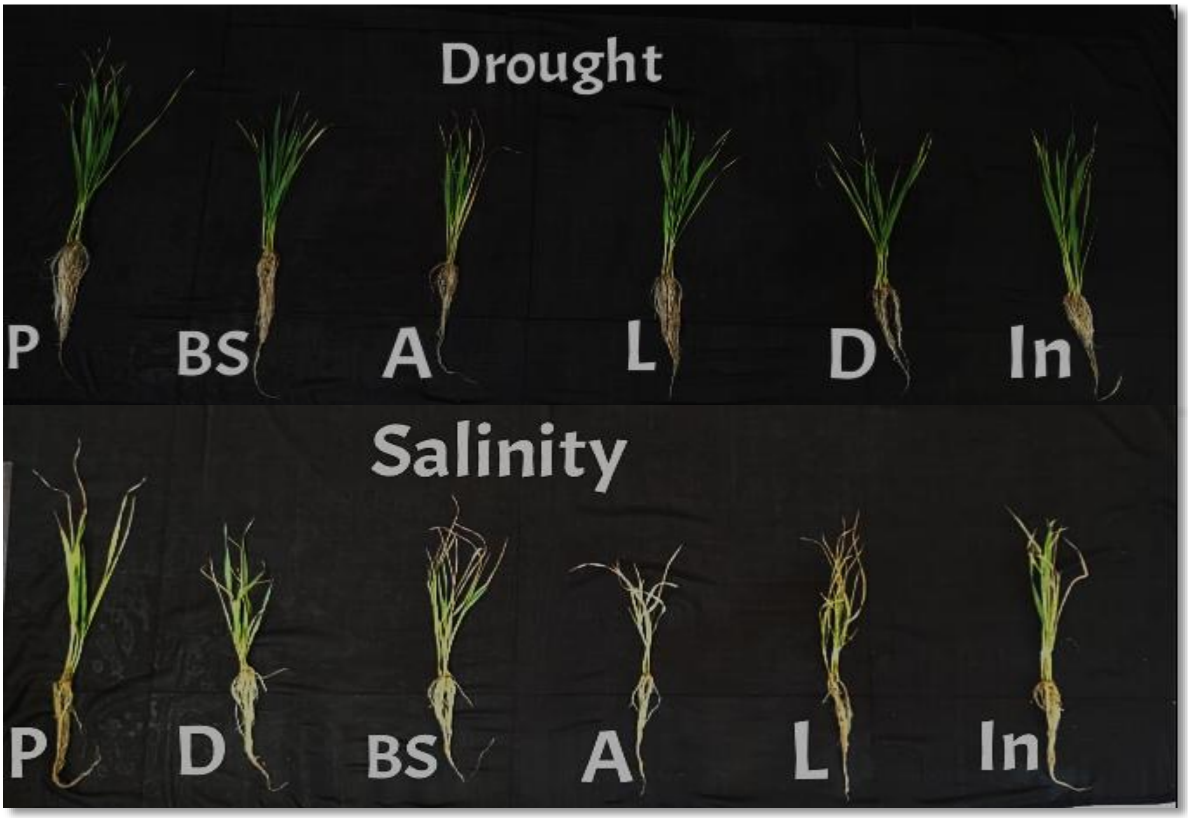
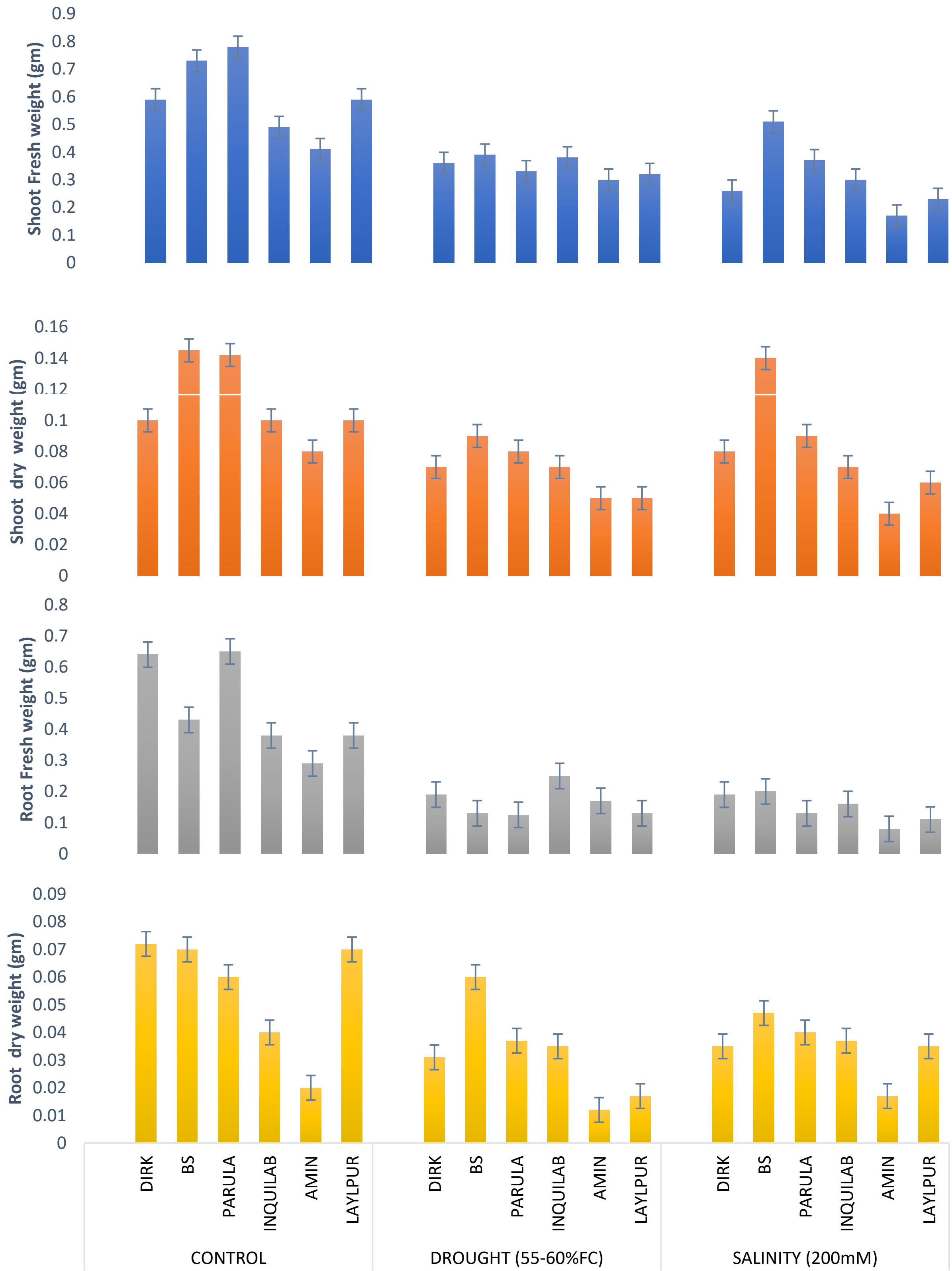


Fig. 1 Showing the growth status of different wheat genomes under salinity and drought stress. A= Amin - 2000, I = Inquilab - 91, P= Parula - 73, L = Laylpur - 73, D = Dirk, and B = Blue Silver.



Shoot Fresh weight (gm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Shoot dry weight (gm)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Root Fresh weight (gm)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Root dry weight (gm)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
DIRK
BS
PARULA
INQUILAB
AMIN
LAYLPUR
CONTROL
DROUGHT (55-60%FC)
SALINITY (200mM)

Fig. 2 Comparing the shoot and root fresh and dry weights of different wheat genomes under salinity and drought stress. Vertical lines on bar graph signify standard error (±) indicating non-significance at p≤0.05.

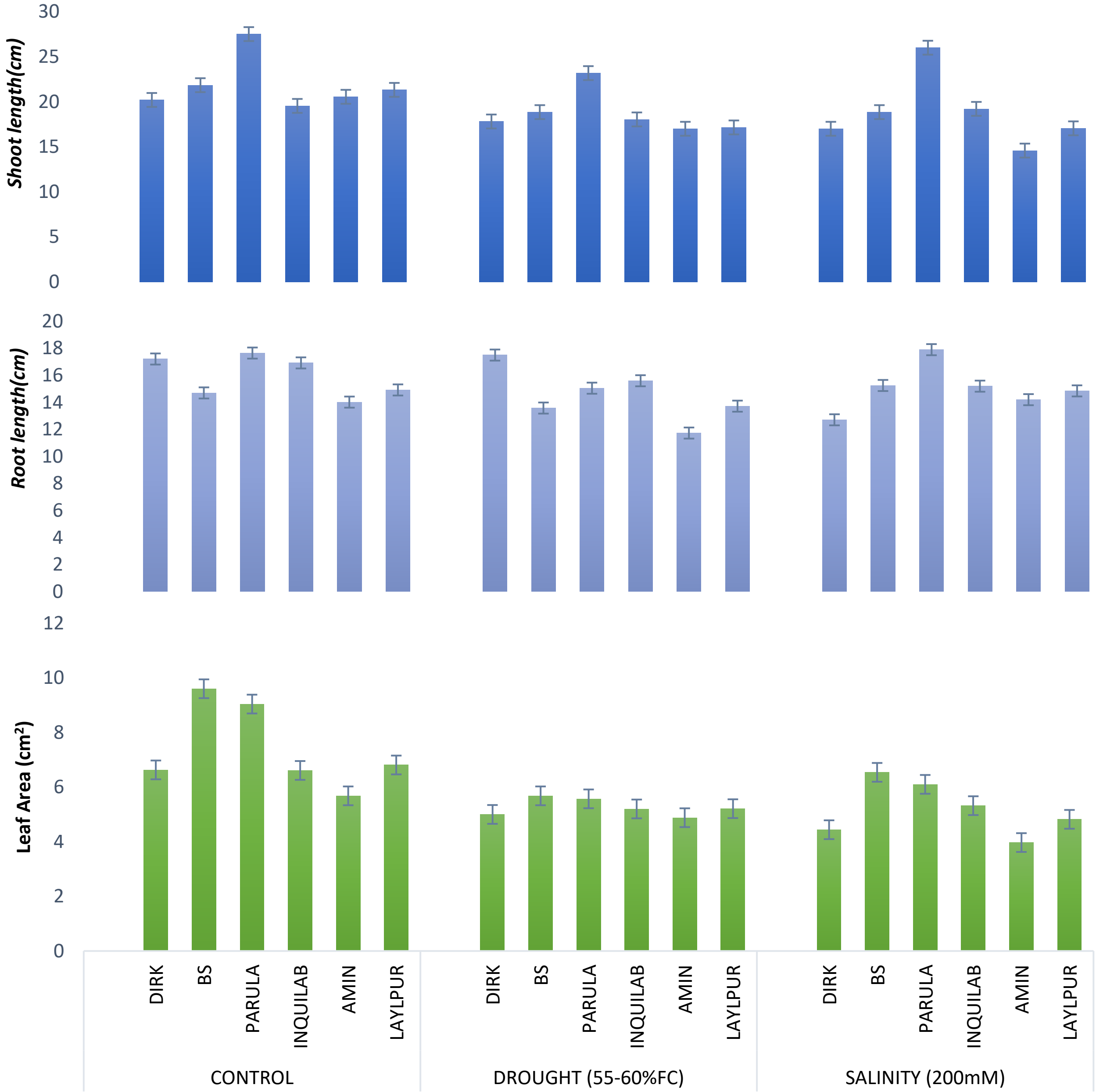


Fig. 3 Comparing the shoot length, root length and leaf area of different wheat genomes under salinity and drought stress. Vertical lines on bar graph signify standard error (±) indicating non-significance at p≤0.05.

Physiological and photochemical screening of distinct wheat genomes for drought and salinity stress tolerance

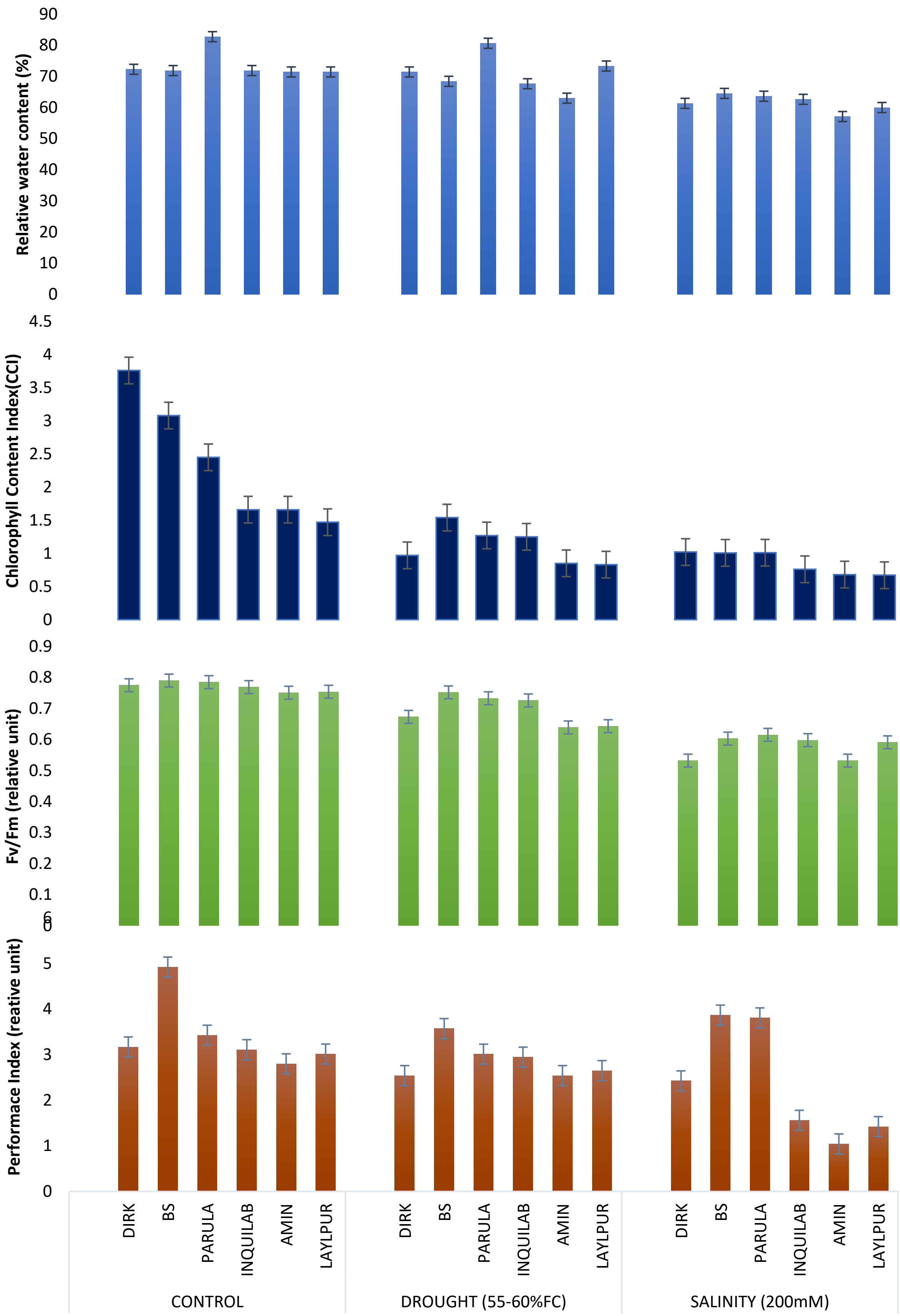
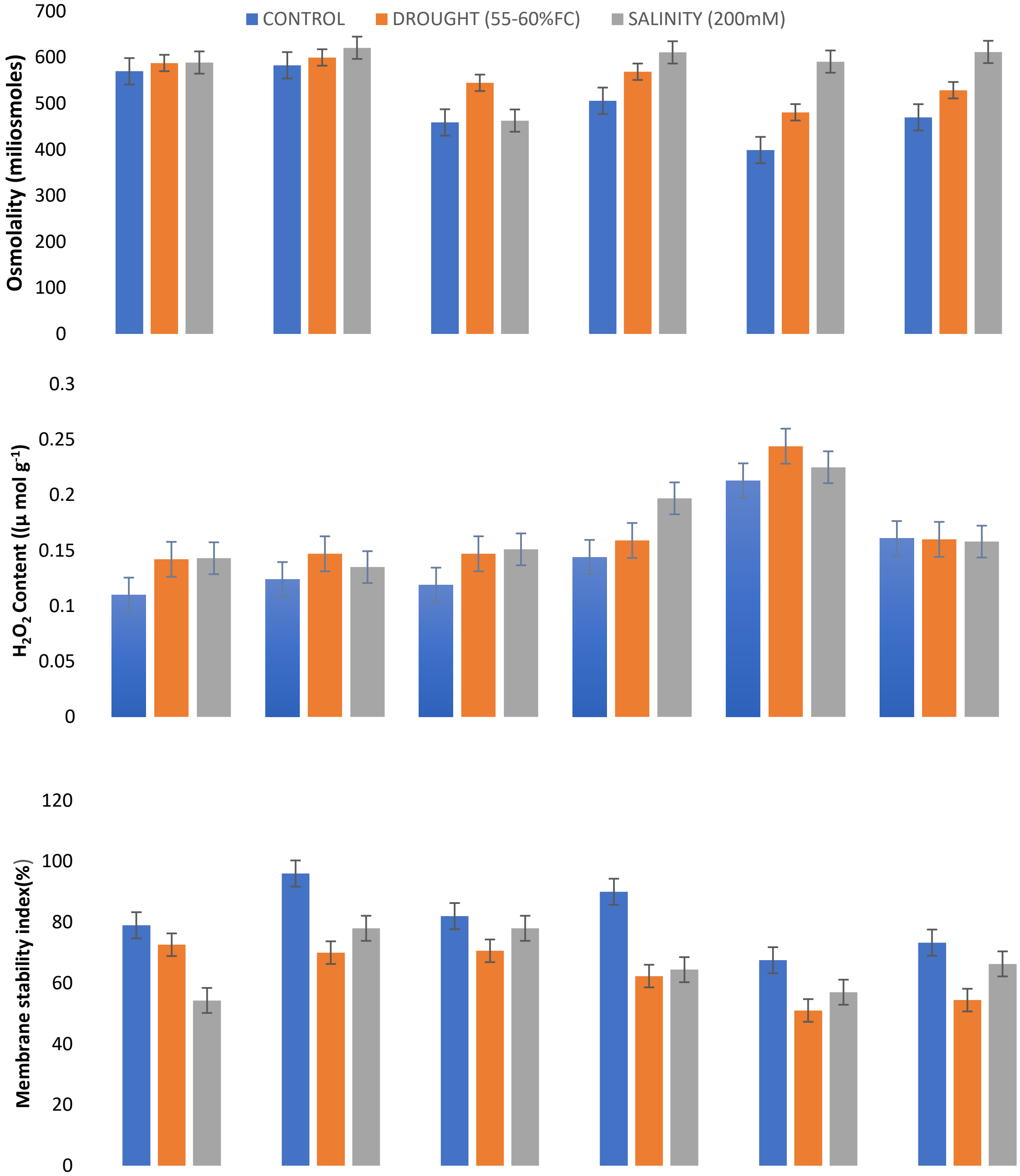


Fig. 4 Comparing the relative water content (%), CCI, Fv-Fm ratio and performance index of different wheat genomes under salinity and drought stress. Vertical lines on bar graph signify standard error (±) indicating non-significance at p≤0.05.



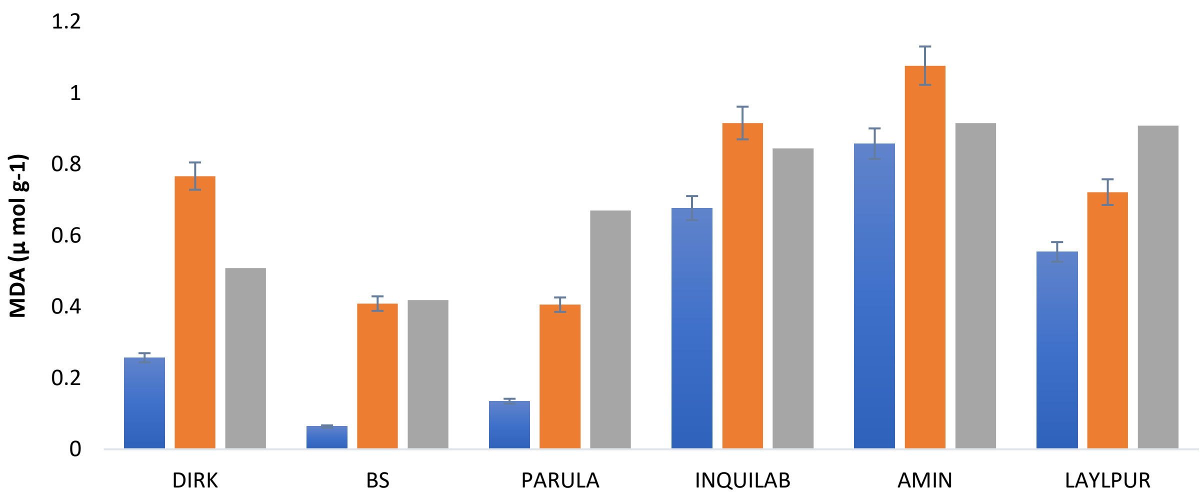


Fig. 5 Comparing the shoot osmolality, H_2O_2 content, membrane stability index (%) and MDA content of different wheat genomes under salinity and drought stress. Vertical lines on bar graph signify standard error (±) indicating non-significance at $p \leq 0.05$.

Table . 1 Fruiting stage parameters of wheat genomes under salinity and drought stress such as Height at grain filling stage, Number of tillers, Number of nodes, Node to Node distance(cm), Spike length(cm), Number of grains, Grain mass (gm) (Per 10 grains).

Treatments	Wheat Genotypes	Min Height	Max height	No of tillers	No of nodes	Node distance(max)	Spike.L(max)	No of grains(min-max)	Grain mass (gm)
CONTROL									
	DIRK	52	68	5	3 to 4	13.6	7.4	15--18	0.49
	BS	51	62	5	4	14	7.4	17--20	0.73
	PARULA	51	59	5	3 to 4	11.6	7	10--13	0.69
	INQUILAB	43	64	5	3	13	5.5	12--13	0.36
	AMIN	39	47	5	3	10.1	7	10--11	0.36
	LAYLPUR	49	67	5	3 to 4	13.5	7.5	9--12	0.66
DROUGHT (55-60%FC)									
	DIRK	30	42	4	3	9	5.6	7--8	0.46
	BS	47	55	5	3 to 4	12	6.9	9--15	0.56
	PARULA	21	30	4	3	11	5.1	6--8	0.38
	INQUILAB	27	39	5	3	10	4.3	6--7	0.31
	AMIN	29	38	4	2 to 3	8.4	3.9	6--7	0.3
	LAYLPUR	35	49	4	3 to 4	10.1	6.1	8--9	0.53
SALINITY (200mM)									
	DIRK	15	44	4	3 to 4	8.8	5.6	6--9	0.38
	BS	46	57	5	3 to 4	12.7	6.3	9--11	0.55
	PARULA	42	48	4	3 to 4	11.1	6.4	8--9	0.61
	INQUILAB	34	44	4	3	8.8	5.2	6--8	0.34
	AMIN	19	27	4	3	7.3	0	0	0
	LAYLPUR	37	44	5	3 to 4	8.1	6.3	9--10	0.39