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Carbohydrate and Nitrogen metabolism in wheat (*Triticum aestivum L.)*in response to salinity in laboratory and field condition.

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Abstract

Wheat (*Triticum aestivum* L.) is second important crop being next only to rice andcontributesabout33percentofthetotalfoodgrainproductionofthiscountry,andsalinityisone oftheenvironmentalfactorthathaveacriticalinfluen ceonthegerminationofseedsand subsequent establishment of seedling in the soil. In order to investigate salinity stresson wheat germination indices, an experiment was carried out at A.N.D.U.A.T, (studentinstructional farm)and net house in department of MBB, (Kumarganj, Ayodhya) tocreate salinity stress at the level of T0(as control), 25, 75, 125 mM concentration of NaCl,andtenwheat(*TriticumaestivumL.*)cultivarsFLW-11,DBW-303,DBW-71,DBW-129,FLW-3, DBW-187, FLW-8, KH-65, HD-2858, KRL-3-4 were tested. For each treatmentrate of germination percent, fresh weight of seedling, dry weight of seedling seedlinglength, number of tillers, panicle length, plant height, and number of grain per spike, testweight and other biochemical were compared. In conclusion it was observed the increaseinsalinitylevel,ithampersthepla ntgrowthanddevelopment.However,wheatproductivity is adversely affected by salt stress, which is associated with a reduction ingermination, growth, altered reproductive behavior andenzymatic activity, disruptedphotosynthesis,hormonalimbalance,oxidativestress,andyieldreductions.Thus,abetter understanding of wheat (plant) behavior to salinity stress has essential implications todevise counter and alleviation measures to cope with salt stress. Different approachesincludingtheselectionofsuitablecultivars,conventionalbreeding,andmolecular techniquescanbeusedforfacingsaltstress tolerance.Asrateofsalinityincreasethereweresignificantreductioninplantgrowth.Byinvestigation it was found that the most salinity tolerant variety is KH65, KRL3-4, DBW187, and least tolerant variety were HD2851, followed by FLW11 and other remainingvarietyaremoderatesalttolerant.

Keywords: oxidative stress; conventional breeding; salinity; enzymatic activity.

1. Introduction

In terms of production and consumption, wheat (Triticum aestivum L.) is the mostsignificantcerealcropglobally.Themajorityoftheworld'spopulationdependsonwheat tomeet their nutritional needs, and wheat-based foods like chapati, bread, biscuits, pasta, andfermenteditemsareeatenbypeopleeverywhere.Ahealthydietwithadequatecalories,well-balanced proteins, and micronutrients with minimal antinutrients is necessary for a person'snormal growth and development.

Wheat is the most important staple food forhumans and is farmed on more acreage than any other crop used for commercial purposes.WithIndiacontributing96millionmetrictonnes,orthesecond-highestamountafterChina,the world's wheat production in 2017 was 754.1 million tonnes (USDA, 2017). Accordingto Curtis et al. (2002), wheat is traded more globally than all other crops combined.

With ahigher protein concentration than other main cereals like maize or rice, wheat is the bestvegetableproteinsourceforhumanmealsworldwide(ArzaniandAshraf,2017).According to Singh (2010), this crop provides over 50% of the calories needed by the people who eatit, which makes a significant contribution to the nation's food security. Much like othercrops,avarietyofbioticandabioticfactorslimittheamountofwheatthatmaybeproduced.Drought,extremeheatorcold,andsalinityareexamplesofabioticstressesthatimpactcropquality and productivity globally. This is particularly true for emerging nations, where thehighestpopulationgrowthwillplaceasignificantdemandonreliablefoodsources(Batesetal.,2008).Theissueofsoilsalinizationinagriculturehasbecomeaglobalconcern.Seawaterandirrigationwater,whichhaveverylittlesodiumchloride(NaCl)inthem,aretheprimarysourcesofsaltaccumulationinfarmedsoils(FlowersandYeo,1995;TesterandDavenport,2003).Soilsalinitylimitscropproductioninabout20%ofirrigatedland(FlowersandYeo,1995). Wheat production is also affected severely due to salt stress. In India, 6.7 Mha landunder wheat cultivation is affected by salt including 3 Mha by salinity and 3.7 Mha bysodicity/alkalinity, distributed across 15 of the 28 states. Out of these 15 states, eightcontribute~97%ofnationalwheatproductionandhave~5.6Mhaaffectedbysalt(Khokhar*et al.*, 2017; Lekshmy *et al.*, 2016). About 10% of wheat cultivated area in the world isalreadysaltaffectedandispredictedtoincreaseinthefuture(Rajendran*etal.*,2009).

Salt stress not only reduces yield but alsoimpairsanumberofphysio-chemicalprocessesinplants,including membranestability,iontoxicity, cell turgor, and the buildup of toxic metabolites (Kumar et al., 2017; Arzani andAshraf, 2016). Breeders have made progress in creating salt-tolerant lines for numerouscrops thanks to recent advances in our understanding of how plants respond to salt (Kumarand Singh, 2016; Kumar et al., 2017). In addition to identifying the genes responsible forsalttoleranceandproducingnewbreedingmaterials,understandingthebiochemical,physiological, and molecular components of salt tolerance will be useful in screeninggermplasmforbreedinginsaline circumstances(Sairametal.,2002).

Therefore, the greatest challenge for the coming decades will be increasing the wheatproduction from the salt affected lands. Understanding abiotic stress and signaling can be very helpful in improving wheat's genetic resistance to abiotic stress.

2.Materials and Methods

Ten genotypes of saline wheatviz.., FLW -11, DBW-303, DBWW-71, DBW-129,FLW-3,DBW-187,FLW-8,KHARCHIA-65,HD-2851,KRL-3-4.Kharchia-65isthecheck varietyused as the study's experimental materials, At the Acharya Narendra Deva UniversityofAgricultureandTechnology,locatedinKumarganj,Ayodhya,thesegenotypeswereproduced using a collection of genetic stock kept in the Wheat division of the Department ofPlant Molecular Biology and Genetics Engineering. This experiment is totally based on salineconditionsofwheatgenotype.

3.Results and discussions

Wheat is a staple food and a source of carbohydrate and calories for the majority ofpeople across the globe. However, wheat productivity is adversely affected by salt stresswhichis associatedwith reductioningermination,growth ,alteredreproductive behavior andenzymaticactivity,disruptedphotosynthesis,harmonalimbalance,oxidativestressandyieldreduction. Thus a better understanding of wheat (plant) behavior to salinity stress hasessentialimplicationstodevisecounterallalleviationmeasuretocopewiththesaltstress,

The production of salt-tolerant plant genotypes in salt-affected areas requires a thoroughunderstanding of how plants respond to salinity stress at different levels as well as an integratedstrategy that combines molecular tools with physiological and biochemical procedures. At themolecular, cellular, metabolic, and physiological levels, recent research has revealed avarietyofadaptiveresponsesto salinity stress.

3.1) Responseofwheatgenotypesduringgerminationunderdifferentregimeofsalinitytreatment

Tencontrastinggenotypesofwheatviz.,FLW-11,DBW-303,DBW-71,DBW-129,FLW-3,DBW-187,FLW-8,KH-65,HD-2858,KRL-3-4weresubjectedtogerminationunder fourregimes of salinity control(T_0), 25, 75 , 125 mM concentration of NaCl T_1,T_2,T_3 respectively by putting their seeds on top of the filter paper in petriplates. Thefollowingobservationwererecordedduringgerminationofdifferentparametersi.e:-

3.1) Germination Percent :-

It is expressed in percent and it was found that there was no difference ingermination among all genotypes at control treatment. A slight decrease germinationpercent in all genotypes except KH-65 ,and KRL-3-4,where germination was notsignificantlydecreasedevenat125mMNaClconcentrationofsalt.Themaximum reductionwasrecordedinFLW11,FLW8andHD2851.

Germination %						
			Treatment			
S. No.	**Genotype**	T_0(Control)	T_1(25mM)	T_2(75mM	T_3(125mM)	Mean
1	FLW11	98.00	95.00	90.00	89.25	93.06
2	DBW303	99.00	98.00	98.00	90.00	96.25
3	DBW71	98.00	98.00	95.00	95.00	96.50
4	DBW129	97.00	98.00	97.00	92.00	96.00
5	FLW3	100.00	100.00	95.00	90.00	96.25
6	DBW187	100.00	100.00	90.00	90.00	95.00

7	FLW8	97.00	96.00	92.00	90.00	93.75
8	KH 65	100.00	100.00	100.00	100.00	100.00
9	HD2851	100.00	100.00	90.00	90.00	95.00
10	KRL3-4	100.00	100.00	99.90	99.00	99.73
	Mean	98.90	98.50	94.69	92.53	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	1.01	0.714	2.014		
	Variety(V)	1.597	1.129	3.185		
	T xV	3.193	2.258	N/A		

3.2) Length of seedling:-

Seedlinglength werecalculatedbybyrootandshootoflengthofindividualseedling and summing up by selecting three random seedling from each replication.the mean value is taken from three seedling from each treatment. seedling lengthwas significantly reduced in all genotype with all sanity treatment.table no.(4.2)The maximum reduction was seen in DBW71 followed by HD2851 and least inKH65and KRL3-4.

Lengthof seedling(cm)						
		Treatment				
S. No.	**Genotype**	T_0(Control)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	7	6	6	5	6.00
2	DBW303	6	5.5	5	4	5.13
3	DBW71	6	4.5	4.5	4.15	4.79
4	DBW129	6	4	6	5	5.25
5	FLW3	6	5	4.75	4.25	5.00
6	DBW187	6.75	6	6	5	5.94
7	FLW8	6	6	5	4	5.25
8	KH 65	8	7	6.5	5.75	6.81
9	HD2851	5.75	5	5	4.25	5.00
10	KRL3-4	7	7	6.5	5	6.38
	Mean	6.25	5.60	5.53	4.64	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	0.062	0.044	0.124		
	Variety(V)	0.098	0.069	0.196		
	T xV	0.196	0.139	0.392		

Fresh wt.ofseedling (gm)						
		Treatment				
S. No.	**Genotype**	T_0(Control)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	2.55	2.71	0.98	0.92	1.79
2	DBW303	1.99	1.68	1.38	1.32	1.5925
3	DBW71	2.46	1.26	1.47	1.09	1.57
4	DBW129	2.16	2.0351	2.15	2.01	2.088775
5	FLW3	2.52	2.05	1.98	1.68	2.0575
6	DBW187	2.81	2.72	1.64	0.9	2.0175
7	FLW8	1.0921	2.55	1.38	2.7	1.93052
8	KH 65	2.85	2.71	1.9	1.3	2.19
9	HD2851	1.95	1.04	0.89	0.34	1.055
10	KRL3-4	2.68	1.95	0.95	0.91	1.6225
	Mean	2.30621	2.07051	1.472	1.317	

3.3) Fresh weight of seedling

Itwascalculatedbyaddingfreshweightofrootandshoot.Therewassignificantreduction in fresh weight of all genotypes with increase in salinity. The maximumreductionwasobservedinHD2851followedbyDBW71andleastinKH65.

	Factors	SE(d)	SE(m)	C.D.		
	TreatmentT	0.020	0.014	0.041		
	Variety(V)	0.032	0.023	0.064		
	T xV	0.064	0.046	0.128		

3.4)Dry weight of seedling:-

Seedling dry weight was calculated by adding root and shoot dry weight ofindividualseedling by selecting random seedling from treatment. Seedling dry weightis decreased significantly with increasing salinity in all genotypes. Again maximumreduction was observed in HD2851, followed by DBW71. And least in KH65 andDBW129,given belowin table

Drywt.ofseedling(g)						
		Treatment				
S. No.	**Genotype**	T_0(**Control**)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	0.261	0.155	0.146	0.144	0.1765
2	DBW303	0.257	0.171	0.15	0.121	0.17475
3	DBW71	0.214	0.152	0.132	0.125	0.15575
4	DBW129	0.242	0.155	0.129	0.107	0.15825
5	FLW3	0.17	0.144	0.134	0.139	0.14675
6	DBW187	0.181	0.171	0.153	0.139	0.161
7	FLW8	0.192	0.141	0.137	0.118	0.147
8	KH 65	0.295	0.177	0.148	0.142	0.1905
9	HD2851	0.185	0.145	0.132	0.131	0.14825
10	KRL3-4	0.275	0.152	0.122	0.125	0.1685
	Mean	0.2272	0.1563	0.1383	0.1291	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	0.002	0.001	0.003		
	Variety(V)	0.003	0.002	0.005		
	T xV	0.005	0.004	0.011		

3.5)Number of Tiller:-

Thefollowingrecordweretakenduringvegetativephaseofplant.Threeplantswereselectedrandomly fromeachtreatmentfromeachvariety.Therewerenotsomuchdifferenceobserved,butthemaximumn umberoftillersbearingplantsareobservedfromKH65andleastinHD2851

No.oftillers(Reproductive stage)						
		Treatment				
S. No.	Genotype	T_0(Control)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	6	6	6	5	5.75
2	DBW303	7	7	5	3	5.5
3	DBW71	6	5	4	4	4.75
4	DBW129	6	6	4	4	5
5	FLW3	6	4	5	4	4.75
6	DBW187	6	6	4	4	5
7	FLW8	5	5	4	4	4.5
8	KH 65	7	6	6	6	6.25
9	HD2851	5	5	4	3	4.25
10	KRL3-4	7	6	6	5	6
	Mean	6.1	5.6	4.8	4.2	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	0.055	0.039	0.109		
	Variety(V)	0.086	0.061	0.172		
	T xV	0.173	0.122	0.344		

3.6) Spikelet/panicle length:-

The spikelet length were measured, and the following observation were made.Inwhichthespikeletlengthdecreasedmostlyin HD2851followedbyFLW3.Andminimum reduction were observed in KH65, DBW187, and other remainingvarietieshaveaverageandnearly samespikeletlength.

Spikeletlength(cm)(Flowering/Reproductive)						
		Treatment				
S. No.	Genotype	T_0(Control)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	9	10	9	7	8.75
2	DBW303	9	9	7	8	8.25
3	DBW71	9	9	8	8	8.5

4	DBW129	9	9.5	9	8	8.875
5	FLW3	9	9	7.5	7	8.125
6	DBW187	10	9	8	9.5	9.125
7	FLW8	9	9.5	8	9	8.875
8	KH 65	10.25	10	9.75	8	9.1875
9	HD2851	9	8	8	7	8
10	KRL3-4	10	9	8	8	8.75
	Mean	9.3	9.1	8.225	7.95	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	0.090	0.064	0.179		
	Variety(V)	0.142	0.100	0.283		
	T xV	0.284	0.201	0.567		

3.7)Plant height:-

Height of plant is significantly changes due to change in salt concentration ofdifferent genotypes. The maximum plant height was noted in KRL 3 -4, followed byKH65. And the least plant height was observed in HD2851 and DBW 187. But theheight of plant donot effect overall yield. Some varieties with dwarf shoot characters,yieldmorethenthegenotypeshavingmoreplantheight.

Plantheight (Physical maturity)(cm)						
		Treatment				
S. No.	**Genotype**	T_0(Control)	T_1(25mM)	T_2(75mM)	T_3(125mM)	Mean
1	FLW11	81	73	70	71	75.25
2	DBW303	75	70	70	70	71.25
3	DBW71	74	74	72	70	72.5
4	DBW129	88	90	87	85	87.5
5	FLW3	88	89	84	87	87
6	DBW187	68	70	70	65	68.25

7	FLW8	91	87	88	77	85.75
8	KH65	85	91	88	81	86.25
9	HD2851	66	61	57	57	60.25
10	KRL3-4	99	90	88	85	90.5
	Mean	82.2	79.5	77.4	75.5	
	Factors	SE(d)	SE(m)	C.D.		
	Treatment(T)	0.807	0.571	1.609		
	Variety(V)	1.276	0.902	2.545		
	T xV	2.551	1.804	5.089		

Estimation of enzyme alpha amylase and isoenzyme of peroxidase:-

3.9)Alpha amylase activity:-

The estimation of enzymatic activity were done in wheat seedling (7DAS) inpetri dish (in vitro) of different salt concentration of each genotypes. The yellowcolouredcomplex wasformed.Theminimumalphaamylaseactivitywasobservedin DBW303,HD2851,DBW12andFLW11.Theminimumreductionwasobservedin KRL3-4,FLW8followedbyKH65.

α - amylase				
S. No.	Genotype	Maltose released µg/g Fresh wt. (control)	Treatment	mean
1	FLW 11	454.2	301.25	377.725
2	DBW 303	370.12	310.17	340.145
3	DBW 71	385.25	372.76	379.005
4	DBW 129	426.36	317.78	372.07
5	FLW 3	476.34	327.15	401.745
6	DBW 187	435.21	387.92	411.565
7	FLW 8	521.02	352.66	436.84
8	KH 65	456.27	395.21	425.74
9	HD 2851	436.49	300.04	368.265
10	KRL 3-4	495.75	390	442.875
	mean	445.701	345.494	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	3.27	2.32	6.65
	Variety(V)	7.32	5.18	14.88
	TxV	10.35	7.32	21.04

3.10) Isoenzymeofperoxidase

The peroxidaseactivitywas measuredinwheatseedlingfrom rootandshoot(7DAS). The peroxidase activity was found to be maximum in salt treated condition inKH65followedbyKRL3-4,DBW187,DBW129.LeastperoxidaseactivitywasfoundinHD2851 ANDFLW11.

3.11) Estimationoftotalsolublesugar

The total soluble carbohydrate was estimated in leaf and grain by phenol sulphuricacid method. The amount of total soluble was greater in grain as compare leaves.Itwasrecorded to be maximum in KH65,(195mg/ml) and KRL (187.87mg/ml) 3-4, and found tobeminimuminFLW3,DBW129,DBW303,DBW71,FollowedbyFLW11.

TSS				
S.No.	Genotype	D-glucose released(mg/ml) Freshwt, control	D-glucose released(mg/ml) Freshwt, treatment	mean
1	FLW11	180	150	165
2	DBW303	170	70	120
3	DBW71	122	207	164.5
4	DBW129	166	67	116.5
5	FLW3	165	50	107.5
6	DBW187	150	160	155
7	FLW8	180	175	177.5
8	KH 65	200	190	195
9	HD2851	195	180	187.5
10	KRL3-4	202	167	184.5
	mean	173	141.6	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	1.383	0.978	2.81
	Variety(V)	3.092	2.186	6.283
	T xV	4.372	3.092	8.885

3.12) Estimationof proteinbyfolinlowry'smethod

True protein content in wheat leaves presented in table no. (4.13) It was observedthatthehighestproteincontentwasfoundinKH65,followedbyKRL3-4.andminimuminDBW303,DBW129followed byHD2851.

S.No.	Genotyp e	Protein cont. mg/gFreshwt. control	Protein mg/g Fresh wt.treatment	mean
1	FLW11	46.78	37.21	41.995
2	DBW303	38	36.62	37.31
3	DBW71	45	39.21	42.105
4	DBW129	42	33	37.5
5	FLW3	44	32.43	38.215
6	DBW187	41	44.24	42.62
7	FLW8	40	41.73	40.865
8	KH 65	44	48.92	46.46
9	HD2851	43	32.2	37.6
10	KRL3-4	43	46.23	44.615
	Mean	42.67 8	39.17 9	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	0.286	0.202	0.581
	Variety(V)	0.639	0.452	1.299
	T xV	0.904	0.639	1.837

To estimate nitrate reductase (NR) and nitrite reductase (NiR)enzymeactivityinleavesin responseto NaClsalinity

3.13) Nitratereductase(NR)

The nitrate reductase activity was assayed from wheat leaves of ten different genotypes ,and it was observed that the nitrate was found to be maximum in KH65 in treatment of differentsaltconcentrationfollowedby KRL3-4andleastinDBW129,FLW11,HD2851andDBW303.

Nitratereductase				
S.No.	Genotype	Nitrate con. (n molesNO$_2$/gfreshwt. /hr)control	Nitrate con. (n molesNO2/gfreshwt. /hr)treatment	mean
1	FLW11	934.32	770	852.16
2	DBW303	917.02	801.28	859.15
3	DBW71	931.71	817.32	874.515
4	DBW129	926.24	772.312	849.276
5	FLW3	919.51	820.71	870.11
6	DBW187	901.72	849.29	875.505
7	FLW8	905.27	841.73	873.5
8	KH 65	912.71	872.63	892.67
9	HD2851	915.26	800.23	857.745
10	KRL3-4	907	870	888.5
	mean	917.076	821.5502	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	2.42	1.71	4.914
	Variety(V)	5.41	3.82	10.989
	T xV	7.65	5.41	15.541

3.14) Nitrite reductase activity

The estimation of nitrite reductase activity was done by wheat leaves, from tendifferent wheat genotypes.There was maximum nitrite concentration was found in KH65and KRL3-4 in treatment and least in FLW11 and HD2851, while it was also observed thatthenitritereductaseactivitywasmaximuminFLW11(596.21nmol)incontrol.

Nitritereductase				
S.No.	Genotype	Control	Treatment	mean
1	FLW11	596.21	301	448.605
2	DBW303	570.14	312	441.07
3	DBW71	507.92	365.79	436.855
4	DBW129	495.51	361.28	428.395
5	FLW3	513.24	340.85	427.045
6	DBW187	466.91	366.71	416.81
7	FLW8	502.17	345.44	423.805
8	KH 65	547.79	385.34	466.565
9	HD2851	401.37	309	355.185
10	KRL3-4	522.24	379.47	450.86

	mean	501.35	346.688	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	3.08	2.18	6.25
	Variety(V)	6.88	4.86	13.98
	T xV	9.73	6.88	19.77

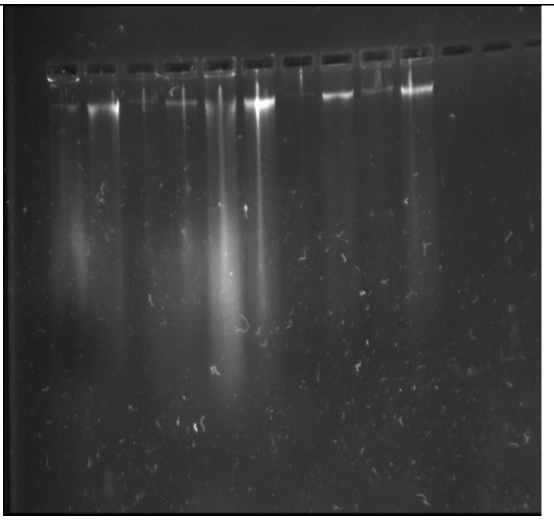
3.15) Estimation of proline

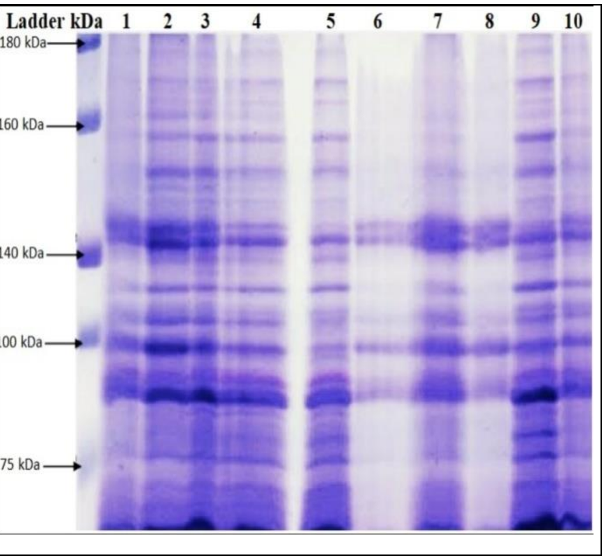
Proline was measured in both root and shoot at vegetative stage and result are presented in figure.

Initial proline content was found to be higher in leaf than in root. Salinity treatmentwas resultinincreaseinprolineconcentrationinbothrootandshoot.Howeverincreasewas more in leaf then root. The maximum accumulation of proline was recorded in KH 65and followed by KRL3-4, DBW187 in treatment. And least in FLW 11, HD2851 ,followedby DBW303.

Proline				
S.No.	Genotype	Proline releasedµg/ mlcontrol	Proline released µg/mltreatment	mean
1	FLW11	6	13	9.5
2	DBW303	5.45	13.45	9.45
3	DBW71	6	15	10.5
4	DBW129	6.12	15.75	10.935
5	FLW3	5.75	16	10.875
6	DBW187	5.9	19	12.45
7	FLW8	5.75	16	10.875
8	KH 65	7	24	15.5
9	HD2851	7	13	10
10	KRL3-4	9	20	14.5
	mean	6.39	16.52	
	Factors	SE(d)	SE(m)	C.D.
	Treatment(T)	0.079	0.056	0.161
	Variety(V)	0.177	0.125	0.360
	T xV	0.250	0.177	0.509

SDS-PAGE of Protein





DNA SDS-PAGE of Protein

Conclusion

Soil salinity has become of the limiting environmental factors for crop productivity in many parts of India. It severly hampers the response of standing crops by altering its physiological attributes. Hence, for sustaining crop production, it is imperative to understand the physiological and biochemical adaptations, imparting tolerance to crops towards abiotic stress like salt. Salt stress negatively affects seed germination, plant growth, photosynthesis, ATP production, water relationships, nutrient uptake and yield because of a salt-induced oxidative stress and ionic and hormonal imbalances. Wheat crop shows a wide range of morphological, physiological, and molecular responses under salinity stress. The physiological and molecular mechanisms are very important because they can help the breeders to develop salt tolerance in wheat. These mechanisms against salinity stress are well understood in wheat. However, a better understanding is still needed in many fields, especially in understanding the physiological basis of assimilate partitioning from plant sources to sinks. Additionally, more studies are needed to study the response of roots to salinity stress involving the root-shoot signaling and corresponding impacts on the nutrient and water uptake. Genetic manipulation of salt-tolerant traits is also an important approach to improve salinity tolerance in wheat crops.

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