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Genotypic Difference in Growth and Physiological Indices of Grain Amaranth Species under Salinity Stress

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ABSTRACT

The present experiment was conducted during October to February of year 2019–20, to investigate the effect of salinity on morpho-physiological traits and identify the genotype have higher salt tolerance among ten genotypes belongs to three grain Amaranth species. Plant growth traits viz., plant height, shoot and root dry weight decreases with increase in the salinity stress level (EC of 5 and 10 dS m^{-1}) in all the genotypes, however significant (p<0.01) genotypic difference were present among genotypes and GA-5 maintained the maximum growth under salinity. Percent decrease in SDW and RDW was lowest (10.61–23.86 and 10.37 and 26.59) in *A. hypochondriachus* while in *A. cruentus* (15.10-29.55 and 12.78-33.09) and *A. caudatus* (15.15–28.84 and 16.62-34.90). Salinity significantly (p<0.01) decreases the membrane stability, relative water content and leaf potassium content while, leave sodium content increases. As compared to other genotype GA-5 have maximum membrane stability (53.30), relative water content (85.40%), K^+ accumulation and minimum Na^+ accumulation in leaves. Morpho-physiological traits of grain Amaranthus species are significantly positively correlated with dry shoot biomass (0.649), MSI (0.770), RWC (0.768), chlorophyll (0.908), carotenoid (0.883) and leaf potassium (0.883). It might be concluded that among studied genotypes GA-5 maintained the growth and have higher physiological efficiency results into maximum salt tolerance index also morpho-physiological traits like dry weight, RWC, MSI, Chlorophyll, Carotenoid and leaf potassium content might be utilised for selection of salt tolerant Amaranth genotypes.

KEYWORDS: Amaranthus, growth, physiological indices, salt tolerance index

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1. INTRODUCTION

Amaranthus species are consumed both as leafy vegetables and grain, among them the species viz., *Amaranthus cruentus*, *Amaranthus caudatus*, and *Amaranthus hypochondriacus* produces grain. Amaranths seed are rich in higher level of protein 13–19% range containing good amount of essential amino acids (Venskutonis and Kraujalis, 2013), seeds also contain higher quality oil rich in unsaturated fatty acid (Nasirpour-Tabrizi et al., 2020). Amaranthus are C4 crops having mechanism to survive under low water and nutrient. They also have better adaptability for growth under abiotic stress conditions, and particularly under saline conditions (Shimose et al., 1991 Huerta-Ocampo et al., 2014, Pulvento et al., 2015). Because of its higher nutritive value and better adaptability to stress it became an alternative for sustainable food production under era of climate change. Salinity is the major problem all over the world which leads to the yield loss in crop plants (Rasel et al., 2020). Most crops are glycophytes and therefore have limited production under saline condition. Soil salinity leads to early osmotic stress effect, which will disturb the water balance of soil and plants, during later stage plants accumulate to toxic ions (Munns et al., 2006, Munns and Tester, 2008). Salt stress in soil decrease the plant population through reducing germination, toxic ion damages the membrane integrity of plant cell also cause oxidative stress, decreases the chlorophyll content, photosynthesis, causes imbalance in nutrient and water content, and reduce the potential capacity of yield (Parihar et al. 2015, Basu et al. 2017). During evolution plants adapt to salinity stress by different mechanism such as osmotic adjustment, antioxidants response, (Tang et al. 2015, Munns et al. 2020) compartmentalize ions, exclude Na^+/or tolerate high tissue Na^+ as in halophytes (Zhu, 2003, Flowers et al. 2010, Shabala et al. 2013), unravelling the salt tolerance mechnism in crop species is a tool toward development of salt tolerant genotypes (Isayenkov, 2019). Identification tolerant genotype under salinity is economically effective strategy among several strategy for cultivation under saline soil and irrigation water. Being a C4 species Amaranthaceae family require require sodium to complete its life cycle but continues exposure to Na^+ along with Cl^- ion decrease the growth (Murata et al. 1992, Kashem et al. 2000). Amaranths species have been considered as salt-tolerant, however genetically diiference in tolerance against salinity have been recorded (Kiani et al. 2019). Omamt et al. (2006) investigated the response of four amaranths species and cultivar *(A. tricolor, A. cruentus*, *A. hypochondriacus,* and Accession '83*)* to saline water they recorded a decrease in the growth of Amaranth species under salinity, they also recorded that *A. Hypochondriacus* is most saline tolerant. Plant biomass also decreases under salinity in *A. cruentus* (Lavini et al., 2016, Gandonou et al., 2018) and in *A. caudatus* (Estrada et al., 2021). However, comparative study regarding the genotypic differences in salinity tolerance of grain amaranths species are not explored much. The present investigation was done with following aims (a) Effect of saline irrigation of (0 to 10 dS m^{-1}) on morphological and physiological traits of grain amaranths (b) Identify the most salt tolerant grain amaranth species and genotypes (c) Correlation of growth and physiological traits with salinity tolerance in grain amaranths.

2. MATERIALS AND METHODS

2.1. Detail of pot experiment

The pot experiment was conducted during October to February of the year 2019–20, at S. D. Agricultural University, Sardarkrushinagar, the region falls under North Gujarat Agro-climatic Zone (AES-IV), Gujarat, India characterized by semi-arid climate with extreme cold winter and hot and dry windy summer. Which, is situated at 24° 19' 22" north latitude and 72° 19' 0" east longitude with altitude of 175 m above mean sea level. In the experiment ten genotypes of *A. hypochondriacus* viz. GA 1, GA 2, GA 3, GA 4, GA 5, SUVARNA, *A. cruentus* viz. EC 198122, EC 198127 and *A. caudatus* viz. NIC 22553, IC 294449 were obtained from Centre for Crop Improvement S.D.A.U., Sardarkrushinagar.

Ten genotypes were sown as per factorial completely randomized design (FCRD) with three replications. Pot was filled with soil and vermicompost mix in the ratio of 1:1. Three seed of each genotypes were sown in pot (26.00×30.50 cm^2) spacing was 10 cm between plants and after 60 days of sowing single plant was maintained up to the harvest. The following treatment was given viz. T_1: distilled water Control, T_2: 5 dS m^{-1} and T_3: 10 dS m^{-1} in 3 replications for each genotype as per the Table 1. The pots were irrigated with salt solution of different concentration at regular interval after germination.

2.2. Growth traits

2.2.1. Plant height (cm)

The height of the selected plants was measured at 60 days after sowing when maximum height was achieved, from the base of the plant to the shoot tip of the main stem and

Table 1: Chemical added l^{-1} of distilled water to create required electrical conductivity

Chemical name	Amount of chemical dissolved l^{-1} (g l^{-1})	
	5 dS m^{-1}	10 dS m^{-1}
NaCl	0.761	1.156
Na_2SO_4	0.462	0.702
$CaCl2•2H_2O$	1.490	3.400
$MgSO_4•7H_2O$	1.252	2.2889

Source: Arora et al. (2018)

expressed in cm.

2.2.2. Dry shoot biomass (g plant^{-1})

Single plants from each replication were harvested at 60 days after sowing and shoot were excised from base of shoot and oven dried at 65°C till the plant attain the constant weight.

2.2.3. Dry root biomass (g plant^{-1})

Single plants from each replication were harvested at 60 DAS and roots were excised from base of shoot and oven dried at 65°C till it attains the constant weight.

2.3. Physiological traits

2.3.1. Membrane stability index (MSI)

The leaves were excised during 8:00 to 10:00 a.m. placed in polythene bag and brought to the lab. The leave section of 100 mg was placed in test tubes containing 10 ml of chilled distilled water. The test tube was kept for 30 m in preset water bath have temperature of 40°C and then initial electrical conductivity EC1 (dS m^{-1}) was recorded. After initial recording of EC the same leave samples were autoclaved at 100°C for 15 m to record EC2 (dS m^{-1}) and MSI were calculated denoted in % (Sairam et al., 2002).

MSI=[1-(EC1/EC2)]×100 .....(1)

2.3.2. Relative water content (RWC percentage)

The top fully expanded leaves were excised during 9:00 to 10:00 a.m. placed in ice bucket and brought to the lab. After surface cleaning 300 mg of leaf were submerged in distilled water for 7 h, at room temperature, under low light to attain full turgidity. After measuring the turgid weight, leaves were oven-dried at 65°C, till it attains the constant dry weight (Barrs and Weatherly, 1962). RWC was calculated by using the below formulae.

RWC=[(Fresh weight-Dry weight)/(Turgid weight-Dry weight)]×100 .....(2)

2.3.3. Total chlorophyll content (mg g^{-1} FW) and carotenoid contents (mg g^{-1} FW)

Total chlorophyll and carotenoid content were determined at 60 DAS. Extraction of pigments was done in dimethyl sulfoxide (DMSO) according to the method described by Hiscox and Israelstam (1979). 25 mg of fresh leaf samples were kept in test tubes containing 5 ml DMSO. Test tubes were kept in hot air oven at 70°C for 2 h or more depend on the pale colour appearance of leaf. After that volume make with DMSO was made up to 10 ml. The absorbance was observed at 470, 645 and 663 nm using DMSO as blank. The total chlorophyll and carotenoid content was calculated as formula given by Arnon (1949) and Lichtenthaler (1987), respectively.

2.3.4. Potassium and sodium content in leave (mg g^{-1} dry weight)

K^+ and Na^+ content in leave were determined at 60 days after sowing. Harvested leave samples were oven dried till it loses all the moisture. Digestion of sample for estimation of potassium and sodium was done according to (Zarcinas et al., 1987). The 100 mg leave of sample were kept overnight in concentrated HNO_3, during next samples were heated for 30 m on the heater till it became colourless. The volume make of 100 ml with double distilled water was done after cooling the digested sample. A blank was prepared by taking same amount of HNO_3 and following above same procedure. Potassium and sodium contents were determined by flame photometer (Model no. CL-378).

2.3.5. Stress tolerance index (STI)

It was calculated ratio of biomass plant^{-1} under saline condition with respect to biomass under control condition.

2.4. Statistical analysis

The two way analysis of variance and correlation analysis was performed using OPSTAT software (Sheoran et al., 1998).

3. RESULTS AND DISCUSSION

3.1. Growth traits of grain amaranths genotypes under salinity

Salinity negatively impact the plant growth by water imbalance and ionic toxicity. Osmotic stress leads to the reduced water uptake, decrease in turgor and reduced growth thus, higher biomass production under salinity indicates salinity tolerance (Munns and Tester, 2008). In the present investigation the effects of salt stress imposed by utilizing irrigation water of electrical conductivity (EC) of 5 dS m^{-1} and 10 dS m^{-1}, on growth of 10 amaranth genotypes belongs to 3 grain amaranths species were studied. Results showed that the plant growth (total height, shoot and root dry weight) was significantly (p<0.05) reduced with the increasing EC of 5 and 10 dS m^{-1} in all 10 genotypes. Results of plant height in Figure 1 indicates that at moderate level of salinity T_2 (5 dS m^{-1}) the highest value was recorded in genotype SUVARNA and the lowest value was recorded in genotype EC-198127 while, at 10 dS m^{-1} the maximum height was maintained by GA-5 which is at par with SUVARNA belong *A. hypochondriachus* species.

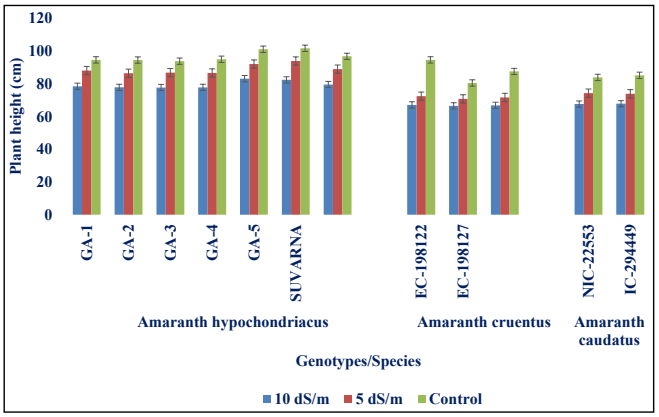

Figure 1: Height of the grain amaranth genotypes at different level of salinity

Investigation related to dry shoot and root biomass of grain amaranth genotypes was also performed (Table 2 and 3). The difference with respect to genotypes, treatments and interaction of G×T differed significantly (p<0.05). GA-5 genotypes maintained its maximum dry root and shoot biomass at all the salinity level. On an average the percentage decrease of shoot dry weight at T_2 and T_3 with respect to control, of species *A. hypochondriachus* (10.64 and 23.86) is lower than *A. cruentus* (15.10 and 29.55) and *A. caudatus* (15.15 and 28.84) genotypes. Similary, the root biomass *A. hypochondriachus* also decreases less with respect to control (Table 3). Similarly, reduction in plant growth under salinity also recorded in several studies (Omamt et al. 2006, Fageria et al., 2012, Rahneshan et al., 2018; Sahin et al., 2018). Decrease in biomass under salinity is due to osmotic stress and ion toxicity **(**Munns and Tester, 2008, Petretto et al., 2019), osmotic stress under salinity reduce the biomass due to decline in stomatal conductance and photosynthesis (Odjegba and Chukwunwike, 2012, Menezes et al., 2017, Sarker and Oba, 2020). Plant also expend most energy in maintenance of disturbed cell homeostasis under salinity which leads to decreased biomass (Atkin and Macherel, 2009, Sarker and Oba, 2020).Overall on the basis of genotype mean salt stress cause the inhibition of growth of grain amaranths species however, decreasing percent was pronounced in *A. cruentus* and *A. caudatus* than *A. hypochondriachus* genotypes. Also genotype GA-5 maintained the maximum plant height, root and shoots dry weight at all the salinity level. Therefore on the basis of minimum biomass reduction of *A. hypochondriachus and* maintenance of higher biomass at all salinity level in genotype of GA-5 belong to *A. hypochondriachus* we might consider that it have better salt tolerance capacity.

3.2. Influence of salt stress on photosynthetic pigments in grain amaranths

Chlorophylls and carotenoids are important photosynthetic pigments involve in light harvesting for photosynthesis process. Carotenoids have also act as accessory pigment and provide photoprotection to photosystem. Higher sodium content in plant tissues is the effective factor cause the reduction of chlorophyll and carotenoid contents and photosynthesis under salinity (Sairam et al., 2002, Ghogdi et al., 2012). In the literature we found that chlorophyll and carotenoid content increase as well decreases under saline condition. Chlorophyll level was reported to be decreased in several crops (Celik and Atak, 2012, Meriem et al., 2014, Sharif et al., 2017) as well as increase in some crops

Table 2: Dry shoot biomass of grain Amaranth genotypes under different level of salinity stress at 60 days after sowing

Genotypes	Dry shoot biomass (g plant^{-1})			Mean
	Treatments			
	T_1	T_2	T_3	
GA-1	25.47	22.63	18.97	22.36
GA-2	23.07	20.03	17.67	20.26
GA-3	23.43	20.70	17.53	20.56
GA-4	25.37	22.83	19.57	22.59
GA-5	30.47	27.60	23.33	27.13
SUVARNA	28.27	25.73	21.77	25.26
Amaranth hypochondriacus	26.01	23.25 (10.61)	19.81 (23.86)	
EC-198122	22.13	18.63	15.67	18.81
EC-198127	17.33	14.87	12.13	14.78
Amaranth cruentus	19.73	16.75 (15.10)	13.90 (29.55)	
NIC-22553	18.13	15.33	13.27	15.58
IC-294449	19.77	16.83	13.70	16.77
Amaranth caudatus	18.95	16.08 (15.15)	13.49 (28.84)	
Mean	23.34	20.52	17.36	
ANOVA	Genotype (G)	Treatment (T)	G×T	
SEm±	0.14	0.08	0.25	
CD (p<0.05)	0.41	0.22	0.71	

*value in bracket indicate percent decrease

Table 3: Dry root biomass of grain Amaranth genotypes under different level of salinity stress at 60 days after sowing

Genotypes	Dry root biomass (g plant^{-1})			Mean
	Treatments			
	T_1	T_2	T_3	
GA-1	34.10	29.80	24.60	29.50
GA-2	32.60	28.43	22.67	27.90
GA-3	32.90	28.27	22.47	27.88
GA-4	34.10	30.17	24.93	29.73
GA-5	39.87	36.50	30.90	35.76
SUVARNA	37.00	35.57	29.00	33.86
Amaranth hypochondriacus	35.10	31.46 (10.37)	25.76 (26.59)	
EC-198122	31.43	27.70	21.47	26.87
EC-198127	28.80	24.83	18.83	24.16
Amaranth cruentus	30.12	26.27 (12.78)	20.15 (33.09)	
NIC-22553	29.87	25.10	19.17	24.71
IC-294449	31.33	25.93	20.67	25.98
Amaranth caudatus	30.60	25.52 (16.62)	19.92 (34.90)	
Mean	33.20	29.23	23.47	
ANOVA	Genotype (G)	Treatment (T)	G×T	
SEm±	0.14	0.08	0.24	
CD (p<0.05)	0.39	0.22	0.68	

*value in bracket indicate percent decrease

like amaranth (*Amaranthus tricolor*), sugar beet, and cabbage (Wang and Nii, 2000, Jamil et al. 2007) under salinity stress. Similarly, mixed response regarding the increase in carotenoid content (Celik and Atak, 2012) decreased content (Hajar et al. 1996) in black cumin under salinity. However, in the present study we found that increase in salinity level decreases the chlorophyll and carotenoid concentration. The decrease in total chlorophyll under increased salinity level might be due to the increase of salt concentration in the treatments. Na^+ and Cl^- toxicity damage the membrane of chloroplast (Munns and Tester, 2008). The highest chlorophyll content was recorded in genotype SUVARNA and the lowest was recorded in genotype EC-198127 at 5 and 10 dS m^{-1} (Figure 2). Regarding total carotenoid content in moderate level of salinity T_2 (5 dS/m) the maximum value was recorded in genotype EC-198122 which is at par with GA-4, SUVARNA and the minimum value was recorded in genotype IC-294449. The maximum carotenoid content was recorded in SUVARNA at 10 dS/m (T_3) salinity level (Figure 3). We have recorded that on an average *A. hypochondriachus* species have higher chlorophyll content while total carotenoid content was maximum in *A. cruentus*. The chlorophyll content (0.908) and carotenoid

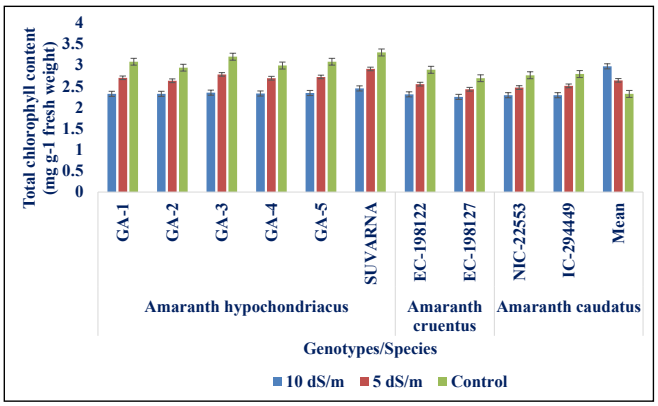

Figure 2: Total chlorophyll content in leaves of the grain amaranth genotypes at different level of salinity

content (0.812) is significantly positively correlated (Table 6) with salt tolerance index based on biomass. Thus, photosynthetic pigment might be a important traits for selection of salinity tolerant grain amaranth.

3.3. Membrane stability of grain amaranths under salinity

In the present investigation membrane stability index differed significantly with respect to genotypes, treatments and interaction of G×T (Table 4). MSI decreases with increase in the salinity level, however genotypic differences

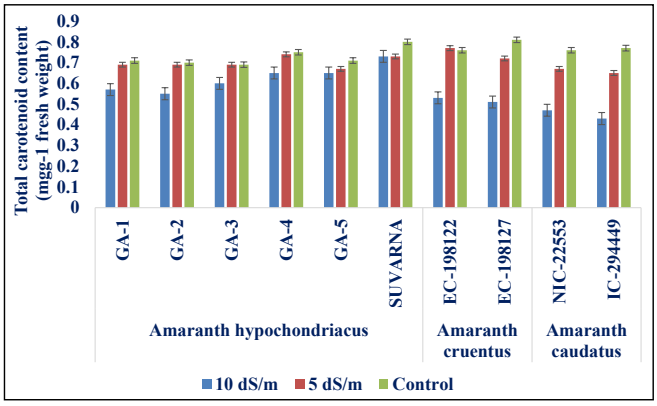

Figure 3: Total carotenoid content in leaves of the grain amaranth genotypes at different level of salinity

are significant (p<0.01). The genotype GA-5 maintained significantly higher stability of membrane at 5 dSm^{-1} while at 10 dS m^{-1} GA-3 have maximum stability however, GA-5 differed not significantly with GA-3. When we observed percent decrease in membrane stability of the species we found that *A. hypochondriachus* (3.87 and 10.86) have lower decreses than *A. cruentus* (6.93 and 16.04) and *A. caudatus* (7.54 and 17.30) genotypes. Osmotic stress under salinity have been an important reason for membrane damage in crop plants (Tabaei et al., 2000). Ion toxicity particularly Na^+ also become prominent reason for the membrane damage (Tester and Davenport, 2003) during later stage of salinity stress. In the present investigation we also recorded that membrane stability is positively correlated (0.770) with salt tolerance index based on the biomass.

3.4. Salinity stress effect on leave relative water content

RWC is an important traits indicates the water status of plant tissue under salinity (Sarker and Oba, 2020; Sharif et al., 2017). In the present investigation data pertaining to relative water content of grain amaranth genotypes was recorded under various treatments and data was presented in Table 5. The difference with respect to genotypes, treatments and interaction of G×T was differed significantly (p<0.01). At 5 dS m^{-1} the maximum value was recorded in genotype GA-5 minimum value was recorded in genotype EC-198127. Similarly, GA-5 at 10 dS m^{-1} maintained the higher water status than other genotypes. In general, with increase in salinity level the RWC of all the genotypes was decreased. Osmotic stress cause by salinity may be the reason

Table 4: Leaf Membrane Stability index of grain Amaranth genotypes under different level of salinity stress at 60 days after sowing

Genotypes	Membrane stability index			Mean
	Treatments			
	T_1	T_2	T_3	
GA-1	54.00	52.75	48.82	51.86
GA-2	52.42	49.27	47.77	49.82
GA-3	54.88	52.67	49.36	52.31
GA-4	54.23	52.56	48.73	51.84
GA-5	56.87	53.97	49.05	53.30
SUVARNA	54.67	53.18	47.83	51.89
Amaranth hypochondriacus	54.51	52.40 (3.87)	48.59 (10.86)	
EC-198122	52.98	48.97	45.75	49.23
EC-198127	48.96	45.91	39.84	44.90
Amaranth cruentus	50.97	47.44 (6.93)	42.80 (16.04)	
NIC-22553	50.06	46.18	41.40	45.88
IC-294449	51.50	47.72	42.59	47.27
Amaranth caudatus	50.78	46.95 (7.54)	42.00 (17.30)	
Mean	53.06	50.32	46.12	
ANOVA	Genotype (G)	Treatment (T)	G×T	
SEm±	0.12	0.07	0.21	
CD (p<0.05)	0.34	0.19	0.59	

*value in bracket indicate percent decrease

Table 5: Relative water content in leaves of grain Amaranth genotypes under different level of salinity stress at 60 days after sowing

Genotypes	Relative water content (%)			Mean
	Treatments			
	T_1	T_2	T_3	
GA-1	86.35	84.11	77.68	82.71
GA-2	85.20	83.84	76.86	81.97
GA-3	86.57	84.33	79.16	83.35
GA-4	85.94	83.46	77.94	82.45
GA-5	89.10	85.73	81.38	85.40
SUVARNA	85.66	82.61	79.89	82.72
Amaranth hypochondriacus	86.47	84.01 (2.84)	78.82 (8.85)	
EC-198122	83.83	81.33	77.59	80.92
EC-198127	79.16	76.40	73.26	76.27
Amaranth cruentus	81.50	78.87 (3.23)	75.43 (7.45)	
NIC-22553	79.73	77.25	74.72	77.23
IC-294449	80.86	77.78	75.75	78.13
Amaranth caudatus	80.30	77.52 (3.46)	75.24 (6.30)	
Mean	84.24	81.68	77.42	
ANOVA	Genotype (G)	Treatment (T)	G×T	
SEm±	0.01	0.00	0.01	
CD (p<0.05)	0.02	0.01	0.03	

*value in bracket indicate percent decrease

for reduced relative water content in leaves of amaranth. Osmotic stress under salinity leads to a series of events such as stomatal closure, lower transpiration pull, lower water uptake which ultimately reduce the RWC of cell (Blatt and Armstrong, 1993). The maintenance of higher relative water content of GA-5 leads to higher salinity tolerance indicated by positive correlation of (0.768).

3.5. Salinity stress effect on leave potassium and sodium content

Salinity stress increases the content of Na^+ ions in the cell, to make electrostatic balance K^+ ion efflux occurs and concentration of K^+ ions in the cell decreases, furthermore decrease in K^+ uptake under salinity also reported due to competition for same transporter (Sarker and Oba, 2020). The genotypes have potential to lower leave Na^+ content and higher K^+ content are considered to be tolerant to salinity (Yassin et al. 2019, Hussain and Munns, 2005). Similarly, a significantly higher (p<0.01) leaf potassium content was recorded *A. hypochondriachus* genotypes GA 1, GA 2, GA 3, GA 4, GA 5 and SUVARNA than genotypes of *A. cruentus* and *A. caudatus*. In present study the decrease in leaf K^+ uptake and increase in Na^+ uptake was observed at 5 and 10 dS m^{-1} of salinity with respect to control (Table 6), however, significant genotypic differences were recorded in grain amaranths regarding lower leaf Na^+ and higher leaf K^+ under salinity. The genotype GA-5 maintained the maximum leaf potassium (32.44 and 21.61 mg g^{-1} dry weight) and minimum leaf sodium (3.25 and 4.18 mgg^{-1} dry weight) at 5 and 10 dS m^{-1} with respect to other genotypes. Thus, we can conclude that GA-5 are relatively tolerant to salinity than other studied genotypes. Higher accumulation of inorganic ions to osmotically adjust under saline condition is a energy efficient strategy must prevails in salt tolerant genotypes (Munns et al., 2020), similarly we can observe that GA-5 have capacity to accumulate higher inorganic solute like potassium under salinity thus it is more tolerant to salinity.

3.6. Salt tolerance index (STI) and its correlation with phenotypic traits

Sustain biomass production under salinity is an important traits for selection (Ashraf and McNeilly, 1987, Shannon, 1984) of tolerant line. In present study salt tolerance index based on biomass was maximum in genotype GA-4, GA-5 and SUVARNA was 0.84 followed by GA-1, GA-2 and

Table 6: K+ and Na+ content in leaves of grain amaranth genotypes under different level of salinity stress at 60 days after sowing

Genotypes	K+ content in leaves (mg g^{-1} dry weight)				Na+ content in leaves (mg g^{-1} dry weight)			
	Treatments				Treatments			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
GA-1	45.13	31.87	21.47	32.82	2.62	3.50	4.34	3.49
GA-2	42.10	29.78	19.77	30.55	3.12	3.91	4.68	3.90
GA-3	43.79	30.58	20.01	31.46	2.69	3.62	4.48	3.60
GA-4	40.15	26.84	16.47	27.82	3.10	3.90	4.90	3.97
GA-5	46.56	32.44	21.61	33.54	2.49	3.25	4.18	3.31
SUVARNA	39.99	24.84	15.82	26.89	3.34	4.20	5.19	4.25
EC-198122	38.69	24.05	13.15	25.30	3.36	4.32	5.22	4.30
EC-198127	30.66	20.45	10.31	20.47	3.67	4.56	5.60	4.61
NIC-22553	38.21	22.50	12.73	24.48	3.38	4.33	5.30	4.34
IC-294449	38.64	22.93	13.23	24.93	3.35	4.38	5.26	4.33
Mean	40.39	26.63	16.46		3.11	4.00	4.92	
ANOVA	Genotype (G)	Treatment (T)	G×T		Genotype (G)	Treatment (T)	G×T	
SEm±	1.42	0.78	2.46		0.19	0.11	0.34	
CD (p=0.01)	4.03	2.21	6.99		0.55	0.30	0.95	

GA-3 the value is 0.82, all the genotypes having higher salt tolerance index was belongs to *A. hypochondriachus* species, the genotypes EC-198122, EC-198127, NIC-22553 and IC-294449 belong to *A. cruentus* and *A. caudatus* have lower salt tolerance index (Figure 4). In the present investigation the plant height (0.730), shoot weight (0.649), root weight (0.796), RWC (0.768), MSI (0.770) total chlorophyll content (0.908), total carotenoid content (0.812) and leaf postassium contents (0.883) are significantly positively associated with salt tolerance index (Table 7). Therefore, salt tolerant genotypes of grain amaranths might be selected on the basis of above parameters.

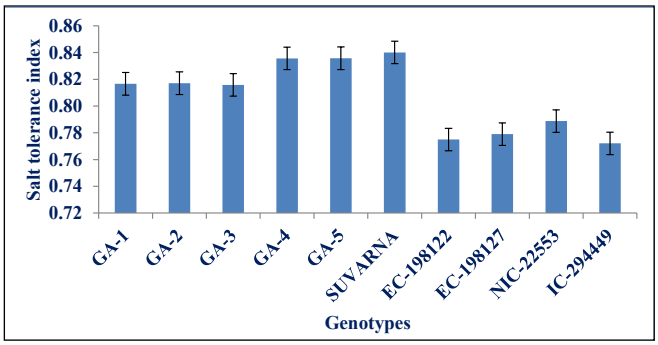

Figure 4: Salt tolerance index of the grain amaranth genotypes at different level of salinity

Table 7: Correlation of growth traits and physiological indices with salt tolerance index in grain amaranths.

	DSB	DRB	MSI	RWC	Chl	Car	K	Na	STI
PH	0.936**	0.893**	0.899**	0.884**	0.808**	0.622**	0.803**	-0.795**	0.730**
DSB		0.945**	0.899**	0.879**	0.723**	0.635**	0.719**	-0.740**	0.649**
DRB			0.857**	0.870**	0.823**	0.752**	0.774**	-0.776**	0.796**
MSI				0.909**	0.798**	0.711**	0.861**	-0.872**	0.770**
RWC					0.838**	0.687**	0.887**	-0.874**	0.768**
Chl						0.708**	0.829**	-0.775**	0.908**
Car							0.671**	-0.625**	0.812**
K								-0.984**	0.883**
Na									-0.841**

*PH: plant height, DSB: dry shoot biomass, DRB: dry root biomass, MSI: membrane stability index, RWC: relative water content, Chl: chlorophyll content, Car: carotenoid content, K: potassium content, Na: Sodium content, STI: salt tolerance index

4. CONCLUSION

Genotype GA-5 had minimum membrane damage, higher chlorophyll content, higher relative water content and higher potassium Accumulation leads to maximum plant biomass under salinity stress. Morpho-physiological indices and salt tolerance index indicated that *A. hypochondriachus* species have higher salt tolerance index than *A. cruentus* and *A. caudatus*. Physiological traits like chlorophyll content, membrane stability, relative water content and leave potassium content was significantly positively correlated with STI might be utilised for selection of salt tolerant grain amaranth genotypes.

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