EFFECT OF SALT STRESS ON GROWTH AND BIOCHEMICAL ATTRIBUTES OF SOME GRASSES FROM CHOLISTAN DESERT, PAKISTAN

Maqbool Ahmed[1]*, Nargis Naz[1], Muhammad Abdullah[2], Muhammad Shahid Hassan[3], Shazia Anjum[4], Syeda Zainab Akbar[1], Faqeer Muhammad[5], Sidra Anwar[1] and Nadia Faqir[6].

[1]Department of Botany, The Islamia University of Bahawalpur, Punjab, Pakistan.
[2]Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur, Punjab, Pakistan.
[3]Department of Botany, Government Graduate College Layyah, Punjab, Pakistan.
[4]Institute of Chemistry, The Islamia University of Bahawalpur, Punjab, Pakistan.
[5]Department of Agronomy, Faculty of agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Punjab, Pakistan.
[1]Department of Botany, Islamia College Peshawar, Khyber Pakhtunkhwa, Pakistan.

Corresponding author: maqbool.iub19@gmail.com

Submission Date: 04/04/2024 ***Acceptance: 09/04/2024*** ***Online: 14/04/2024***

***Abstract*:** Present work was conducted to evaluate the effect of NaCl stress on morpho-agronomic and biochemical responses of some desert grass species of Cholistan i.e. *Cenchrus ciliaris*, *Cynodon dactylon*, *Cymbopogon jwarancusa*, *Lasiurus scindicus* and *Panicum antidotale.* Populations of all these five grasses were taken from the RD-65 which was selected site of Cholistan desert of Pakistan. The stumps of mature plants of each species of grass were grown in the pots for the period of three months. Research work was completely in randomized design (CRD); two factors (salt levels and species) with 5 replicas of each treatment. Treatments were named as; T0 (0 mM), T1 (100 mM), T2 (200 mM) and T3 (300 mM) of NaCl levels applied were three after the intervals of seven days. Morpho-agronomic characters were noted after the completion of experiment. It was proposed that all the selected species are the halophytic grasses which were also native to the harsh climates and have some of the potential against NaCl stress. Generally, NaCl negatively affected the agro-morphic characters of *Cenchrus ciliaris*, *Cynodon dactylon*, *Lasiurus scindicus* and *Panicum antidotale* from moderate levels of salinity to higher levels of salinity 300 mM except the *Cymbopogon jwarancusa* where most of the characteristics showed positive effects from the salt levels of 0 mM to 300 mM. Some water-soluble phytochemicals like sugars, saponins and protein were mostly detected in aqueous while alcohol soluble was in ethanolic extracts. Flavonoids were not detected at all in the grasses by the selected methodology. Rest of the phytochemicals were increased up to the moderate levels of salinity 100 mM to 200 mM then decreased up to 300 mM of NaCl but in some grasses reveres of this has been analyzed. Some phyto-chemicals increased with the increase in the salinity.

***Index-terms*:** Aqueous extract; Ethanolic extracts; Cholistan Desert; *Cenchrus*; *Cynodon*; *Cymbopogon*; Morpho-agronomic responses; NaCl stress; *Lasiurus*; *Panicum*; Phytochemicals.

I. INTRODUCTION

Plants face different environmental stresses in their habitat which are classified into biotic and a biotic stress (Umar *et al*., 2021). When some of these stresses go beyond the optimum tolerance of plants, these stresses influence the biochemical, developmental, structural and physiological processes of plants (Dos *et. al.*, 2022). Among all these stresses salinity is the most detrimental and common stress which confines plant growth and productivity (Shahid *et al*., 2020).

Current global climatic changes are leading to the non-availability of water resources for lands of many countries which is causing salinity (Srivastav *et al*., 2021). Pakistan is in arid region of world where high temperature is gradually changing its climatic patterns. Salinity is the major issue of Pakistan as 3.44 million ha of land of Pakistan is saline. High salinity influences the growth and production by affecting physiological processes of plants (Ismail *et al*., 2019).

Cholistan desert is one of the hot and arid desserts of Pakistan with saline patches in it. It is in the South-West of Punjab which is a province of Pakistan. It is extended on an area of 26,000 square Kilometer. The length of Cholistan desert is about 480 km and breadth are ranging from 32 to 192 km (Akbar *et al.,* 1996, Haider *et al*., 2021). Based on topography, soil type, texture and vegetation structure Cholistan region is divided into two natural regions. Geologically these are northern region (Lesser Cholistan) and southern region (Greater Cholistan). The area of Greater Cholistan and Lesser Cholistan are 18,130 km and 7,770 km respectively (Wariss *et al*., 2021).

Vegetation of saline patches of Cholistan consist of halophytic communities which includes the tree *Tamarix dioica*, shrubs *Haloxylon stocksii*, *H. salicornicum, Salsola baryosma*, and *Suaeda fruticosa* and grasses *Aeluropus lagopoides, Cynodon dactylon*, *Cymbopogon jwarancusa, Lasiurus scindicus, Ochthochloa compressa, Sporobolus ioclados* and *Panicum antidotale* (Naz *et al.*, 2009).

There is gradually decline in yield at low salt concentration but in hot and arid Cholistan highly saline patches have naturally adapted species of plants (Ashraf, 2003, Fatima *et al*., 2021) which are salt tolerant. Presence of some species in those saline areas where no others species can grow shows the adaptive strategies of existing species. It provides excellent material for the investigation of adaptive mechanisms in relation to high salinities and growth and survival of plants (Ashraf, 2003, Buzzini *et al*., 2018).

Cenchrus ciliaris (L.) is a perennial and C_4 forage grass. Under water scare or drought conditions it can be grown on marginal soils. This is a competitive grass grows well under the conditions of elevated temperature, low moisture, solar radiation salt, drought, flooding, heat, oxidative and heavy metal stress (Agrawal, 2007, Hussain *et al*., 2020).

Cymbopogon jwarancusa (Schult.) is an aromatic grass. Due to its medicinal value it is associated with herbs. This plant is being greatly used in against various dieses like abdominal tumors, vomiting, blood impurities, Unconsciousness and skin problems (Mahmud *et al.,* 2002; Reddy *et al*., 2023).

Cynodon dactylon (L.) Pers. also known as lawn grass, is a potential fodder plant and makes excellent hay in Australia and Pakistan. This grass is extremely adapted to the variety of habitat types. *C. dactylon* is found growing on saline or sandy soils including agricultural fields, in orchids, along irrigation canals, waste places, road side and metal contaminated areas (Wu *et al.,* 2006: Kindomihou, 2020).

Panicum antidotale (Retz.) (Blue Panic grass) is distributed all over the region of Indo-Pakistan. It is a perennial and tall grass which can attain a height of 2 or more than two meters. As compare to other forage crops, this grass is more nutritional and productively suitable. Blue grass can survive with multiple stresses. fire, Drought and salinity. Its shows wide range of adaptations in to alkaline, highly saline Its suitability to highly saline, drought-hit and water logged (Ashraf, 2004; Ahmad *et al*., 2021; Irshad and Hameed, 2023).

Lasiurus scindicus (Henrard.) is one of the highly nutritious and a drought tolerant grass. It has been successfully used in the most important reseeding programs in the deserts which are facing harsh conditions in the regions of India and Pakistan. This plant can grow in the in the soils which are salt affected. Salinity tolerance is slow whiles seeds germination. At the salt levels of >200 mM of NaCl seeds germination ore totally inhibited (El-Keblawy, 2006, Mustafa *et al*., 2019).

Some of these plants produce secondary metabolites which are most abundant in the medicinal plants. These metabolites are alkaloids, flavonoids and steroids are the well-known sources of drugs. Modern scientific test of medicinal plants has been increased. Salt stress is affecting the biosynthesis of secondary metabolites in plants. There is significant fluctuation in the quantity and the quality of secondary metabolites due high salinity. There may be change in total plant content instead of some chemical fractions of plant (Muthulakshmi *et al.,* 2013).

In different species different phytochemical are present in different quantity i.e. in aqueous extract of *Cymbopogon coloratus* and *Cynodon dactylon* alkaloid contents are present (Jarald *et al.*, 2008). Flavonoids are present in the *Cynodon dactylon*, *Sacchrum spontaneum*, *Imperata cylindrical*, *Pennucetum purpureum and Cymbopogon Citrates* (Khalid and Siddiqui, 2011 and Padma *et al.*, 2013). Phenols are present in *Heteropogon contortus, Chloris barbata, Cymbopogon citrates* and *Imperata cylindrical* (Asaolu *et al.*, 2009 and Padma *et al.*, 2013). Terpenoids are present in the high quantity in the *Aristida setacea, Cymbopogon coloratus, Cynodon dactylon, Heteropogon contortus*, *Perotis indica* and *Sporobolus coromandelianus* (Babu and Savithramma, 2013).

Salt stress strongly affects the biochemical synthesis of secondary metabolites. Salinity changes the quality and quantity of these metabolites under different NaCl level. In the *Solanum nigrum* with the increase in the salt stress proline content increases due to the changes in the profile of proline metabolism (Muthulakshmi *et al.,* 2013). Phenol content also increases with the increase in the salt levels. Alkaloid content increase with the increase in the salt stress but the accumulation was reduced at the higher levels of salt stress. High salinity also increases the catalase activity and it was less at lower salt levels (Mittova *et al.*, 2002; Jaleel *et al.*, 2007; Dugasa *et al*., 2019).

Grasses that yield fodder and food are well known for their importance also yield many therapeutic products but poaceae family is least studied for this value. Under stress these grasses produce phytochemicals which are naturally occurring and biologically active chemical compounds and have protective or disease preventive properties.

This work was done to evaluate the responses of the NaCl stress on the morpho-agronomic characteristics, qualitative determination of secondary metabolites, biochemical changes, analysis of comparative responses and salinity tolerance of selected grasses; *Cenchrus cillirus*, *Cynodon dactylon*, *Cymbopogon jwarancusa, Lasiurus scindicus* and *Panicum antidotale.*

II. MATERIAL AND METHODS

2.1 Site of sample collection

Plants were sampled from saline patches RD-65 of Cholistan desert. Cholistan desert is situated in the South–West of province of Punjab Pakistan. This area is habitually dominated by the grasses and shrubs. *Cenchrus ciliaris, Cenchrus biflorus*, *Cynodon dactylon*, *Cymbopogon jwarancusa, Lasiurus scindicus, Octhocloa compressa,* and *Panicum antidotale* are native to this region. These plants are generally characterized by the arid and the semi-arid habits.

2.2 Selected plant species

Five grasses were selected; *Cenchrus ciliaris, Cyanadon dactylon*, *Cymbopogon jwarancusa*, *Lasiurus scindicus* and *Panicum antidotale.*

2.3 Establishment of plant material under control conditions

Selected grass species were identified by the local scientist and confirmed from the herbarium sheets which are present at the Department of Botany of The Islamia University of Bahawalpur. Then the stumps of mature plants of each species of grass were grown in the pots for the period of three months. Pots were placed at Modern Nursery Model Town A, Bahawalpur, Pakistan, under the sunlight and shade with daily basis irrigation.

2.4 Levels of salt stress and experimental design

One of the major components of solutes of saline soil is a Sodium Chloride (NaCl). For this reason, Sodium Chloride was chosen for experiment to evaluate the effect of Sodium Chloride on the morpho-agronomic and biochemical responses of selected grass species of Cholistan desert. There were five grass species and four salt levels for each grass. Each treatment has 5 replicas. Treatment was given in solution form and labeled with its name; T0 (control), T1 (100 mM), T2 (200 mM) and T3 (300 mM) concentration. Three treatments of mentioned concentration were given after every seven days after one month of establishment.

Experiment for this research work was completely in randomized design (CRD). In this design there were two factors (salt levels and species) with 5 replicas of each treatment. Morpho-agronomic characters were noted after the completion of experiment. When this research work was completed plants were collected carefully from the pots. Samples collected washed with tap water carefully to study various biochemical responses of all five-grass species (Figure 1).

Figure 1. Experiment plan and labeling of *Cenchrus ciliaris, Cynodon dactylon, Cymbopogon jwarancusa, Lasiurus scindicus* and *Panicum antidotale* at various levels of NaCl stress.

2.5 Morpho-agronomic Characteristics

Morpho-agronomic characteristics such as; shoot length (cm), root length (cm), number of leaves per plant, leaf area (cm^2), number of tillers, inter nodal distance, per plant fresh weight (g) and per plant dry weight (g) were recorded.

2.6 Plant material collection and identification

Fresh shoots of grasses were collected during the month of November, 2022. Shoots were washed thoroughly 2-3 times by using tap water. Plant material then dried in air under shade. Plant material was further used for phytochemical analysis after complete shade drying (Babu and Savithramma, 2013).

2.7 Plant extract preparations

To test all these biochemical's produced by plants; two extracts were prepared in laboratory.

2.7.1 Aqueous extract

Dried plant material was grinded into powder and stored at room temperature. 3 g of grinded shoot material was mixed in 25 ml of sterile water, boiled at 50-60C° for 30 minutes on water bath. After boiling it was filtered through Whatman No. 1 filter paper. In the last centrifugation of filtrate was done at 2500 rpm for 15 minutes and in the sterile bottles filtrate was stored at 5C° for biochemical test (Harborne, 1973).

2.7.2 Ethanolic extract

Dried plant material was grinded into the crude powder form. Plant material (2g) was shaken with 15 ml ethanol for several hours on a shaker. Later extract was filtered by using funnel and Whatsman No. 1 filter paper. Extract was evaporated to yield a stock solution of 15 ml for further phytochemical analysis (Khalid and Siddiqui, 2011).

2.8 Qualitative screening of phytochemical

Both plant extracts were evaluated for screening of phytochemicals such as, proteins (Tamilselvi *et al.,* 2012), lignin (Sheela, 2013) and alkaloids, carbohydrates, flavonoids, glycosides, phenols, saponins, steroids, tannins and terpenoids (Suriyavathana *et al.*, 2016) following the reported methods.

2.9 Statistical analysis

The data of morphology was subjected to the statistical analysis by using Microsoft Excel and Minitab statistical software for the analysis of the variance (ANOVA) and LSD for the comparisons of mean values.

III. RESULTS

3.1 Agro-Morphological Characteristics

3.1.1 Plant height

Plant height of all the populations generally reduced with the increase in the salt level of growth medium. Plant height of *Cyanadon dactylon* was most adversely affected with increase in salt stress (Fig. 1). In *Cymbopogon jwarancusa* plant height was promoted by higher levels of salt (300 mM NaCl). In *Lasiurus scindicus* and *Panicum antidotale* medium level of stress increased plant height but highest level of salt (300 mM NaCl) caused a slight decrease in this parameter (Figure 2).

3.1.2 Root length

Root length of selected five grasses showed quite similar response as it was observed in terms of plant height. Like *C. ciliaris, C. dactylon* and *P. antidotale* showed decrease in root length as the salt level increased. This character increased with the increase in salt level for *C. jwarancusa* and slightly affected only at higher salt level. In *L. scindicus* and root length was only increased in the medium salt level of the growth medium (Figure 2).

3.1.3 Number of tillers

The response of almost all selected grasses of selected grasses were highest in term of numbers of tillers at control level of salt (0 mM) and gradually decreased with the increase in salt level except in *C. dactylon* where number of tillers per plant were maximum only medium salt level (200 mM) (Figure 2).

3.1.4 Inter nodal length

Inter nodal length of five grasses showed variable responses. *C. ciliaris*, *C. dactylon* showed constantly decreased in inter nodal length with increasing salt levels, whereas in case of *C. jwarencusa* this characteristic was increased till 300 mM NaCl. However, *L. scindicus* and *P. antidotale* show increase in this parameter at medium level of salt (100 mM) (Figure 2).

3.1.5 Number of leaves

The very important response of plant is number of leaves per plant. Higher salt level (300 mM) reduced the number of leaves per plant of all grasses except *C. jwarencusa* where slight increase in this parameter was observed (Fig. 2). This character exhibited a slight increase in *C. ciliaris, C. dactylon, L. scindicus* and *P. antidotale* at 100 mM NaCl only (Figure 3).

3.1.6 Total leaf area per plant

By increasing the levels of salt in *C. dactylon*, *L. scindicus* and *C. jwarencusa* growth medium, total leaf area per plant was adversely affected. However, the *C. dactylon* and *P. antidotale* were less affected and showed slight increase in leaf area per plant only at 100 mM of NaCl as compared to the other grass species (Figure 3).

3.1.7 Fresh weight per plant

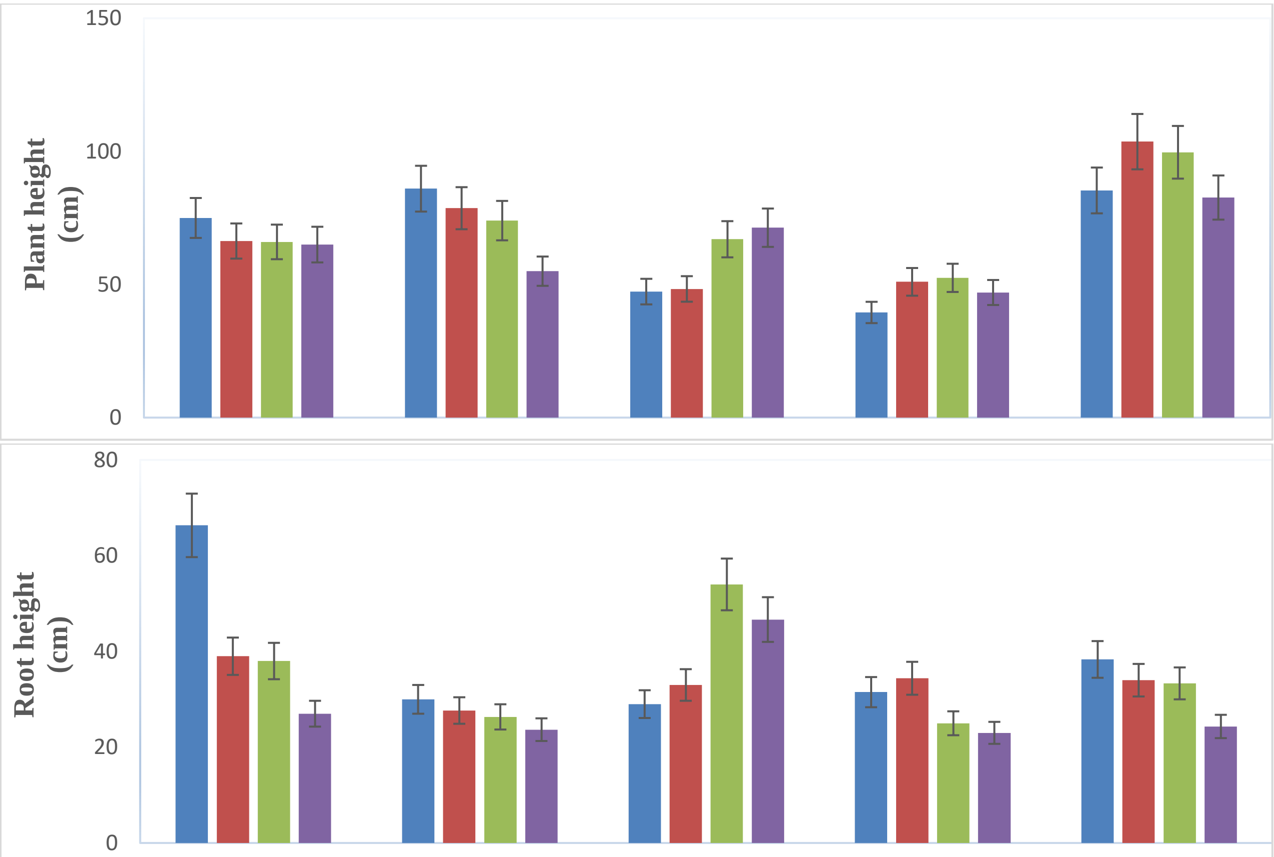
Fresh weight per plant was adversely affected characters at the higher salt level (300 mM). *C. ciliaris* showed slight decrease in the fresh weight as the salt level increased. Substantial increase in plant fresh weight was observed in *C. dactylon* and *P. antidotale* at 100 mM and in *C. jwarancusa* and *L. scindicus* up to 200 mM NaCl but thereafter it decreased gradually with further increase in the external salt level (Figure 3).

3.1.8 Dry weight per plant

The pattern of the reduction and increase in dry weight per plant of all the grasses were very much like that recorded for fresh weight per plant (Fig. 2). The *C. ciliaris*, *C. dactylon*, *L. scindicus* and *P. antidotale* were the most affected due to higher external salt stress (300 mM). Plant dry weight of *C. jwarancusa* showed increased plant dry weight with the increase in the salt levels of external growth medium (Figure 3).

3.2 The phytochemical screening and qualitative analysis

For thousands of years, nature has been the source of medicinal compounds. An impressive number of modern drugs have been isolated from the natural sources. This is because plants have ability to produce large variety of the secondary metabolites. In present qualitative analysis of five desert grasses shows presence of alkaloids, carbohydrates, glycosides, lignin, phenols proteins, saponins, steroids, tannins and terpenoids under different levels of NaCl stress by selected methodology.



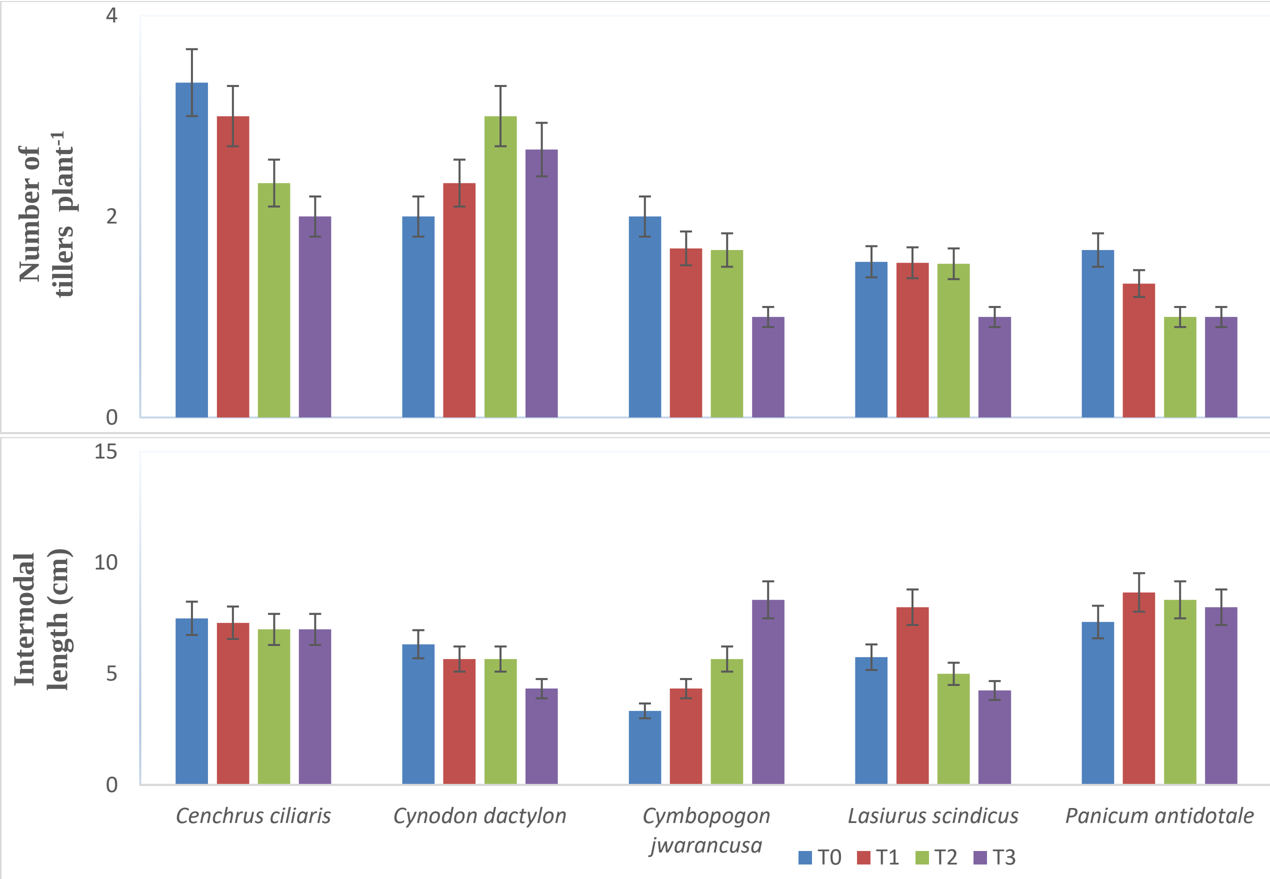
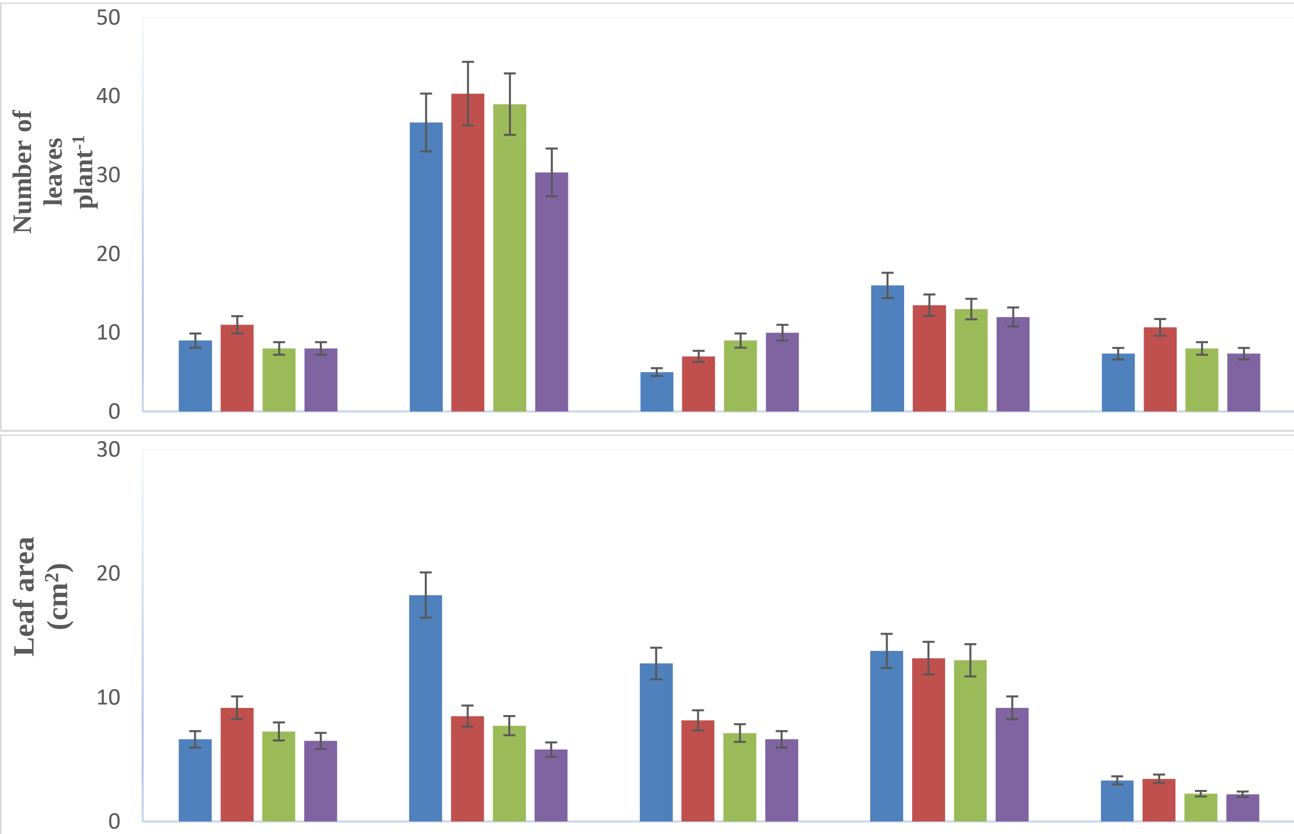


Figure 2. Plant length, root length, number of tillers and intermodal length of selected grasses under different levels of NaCl stress (T0= 0 mM; T1= 100 mM; T2= 200 m; T3= 300 mM).



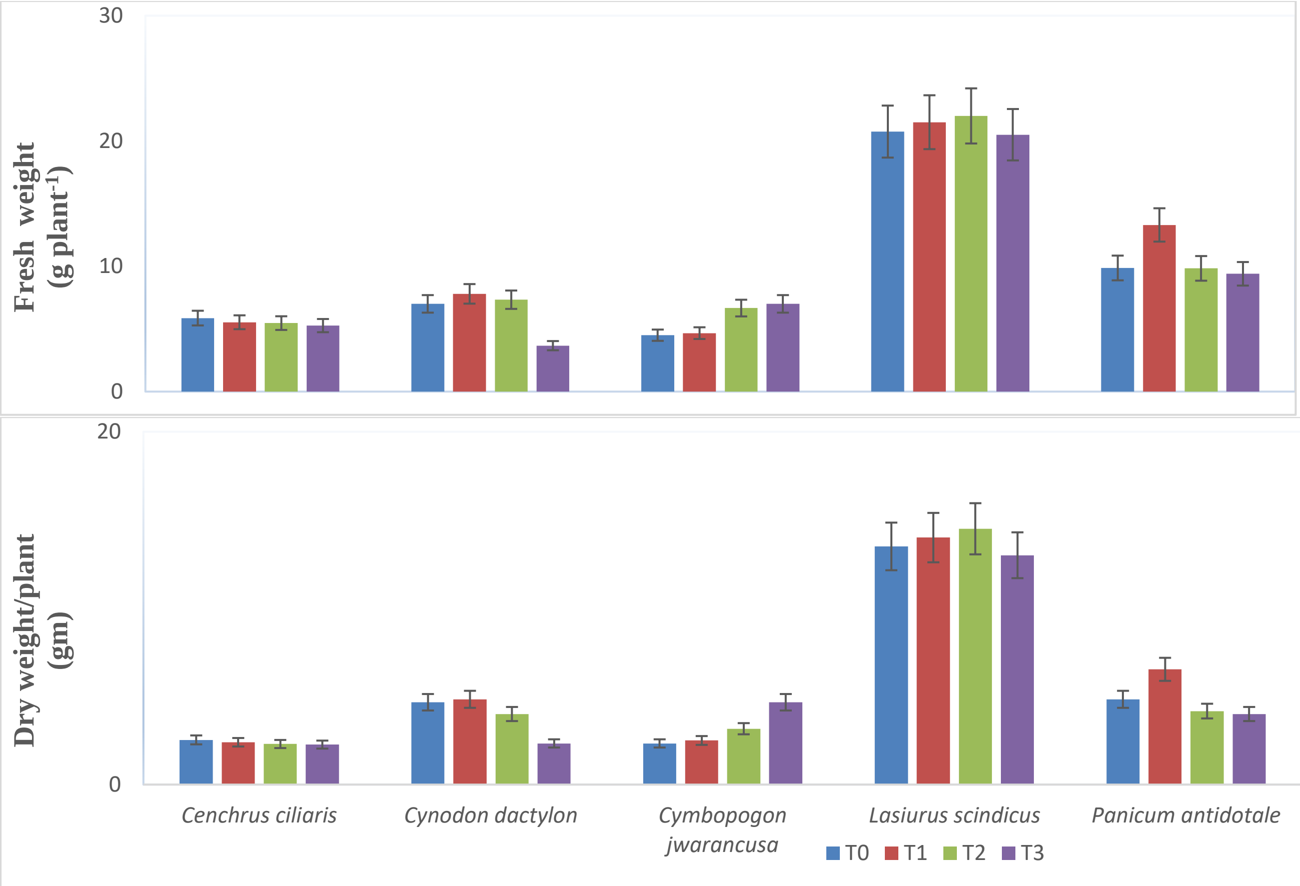


Fig. 3. Number of leaves, leaf area, fresh weight and dry weight per plant of selected grasses under different levels of NaCl stress (T0= 0 mM; T1= 100 mM; T2= 200 m; T3= 300 mM).

3.2.1 Qualitative analysis of Cenchrus ciliaris

Preliminary phytochemical screening of *Cenchrus ciliaris* aqueous shoot extract revealed the presence of alkaloids in control conditions only. Lignin, phenols and steroids were not detected in all levels of salinity. Presence of carbohydrates and proteins were not observed in control conditions but increase was analyzed with the increase in the salinity. Glycosides were detected only in the higher levels of salinity treatment of grasses. Saponins were increased only at moderate level of salinity and decreased as the salinity level increased. Tannin and terpenoids were analyzed with increased as there are increase in the level of salt.

Carbohydrates, saponins and terpenoids are not detected in ethanolic extract in all levels of NaCl treatments. Alkaloid content was not observed in control conditions and increased with the increase in the salt levels. Glycosides were only detected at control levels of salinity. Lignin content was increased with the increase in the salinity levels. Phenols and protein content were decreased with the increase in the salinity. Steroids were only analyzed in moderate to higher levels of salinity. Tannins was increased till moderate level of salinity and then decreased slightly only at higher salt levels (Table 1).

Table 1. Qualitative analysis of *Cenchrus ciliaris* in aqueous and ethanolic extract under various levels of NaCl stress.

Extract media	Aqueous extract				Ethanolic extract			
Levels	T0	T1	T2	T3	T0	T1	T2	T3
Alkaloids	+	−	−	−	−	+	++	+++
Carbohydrates	−	+	++	+++	−	−	−	−
Glycosides	−	−	−	+	+	−	−	−

Lignin	−	−	−	−	+	++	+++	++++
Phenols	−	−	−	−	+++	+++	+	−
Proteins	−	+	++	+++	++++	+++	+++	+
Saponins	+	++++	+++	++	−	−	−	−
Steroids	−	−	−	−	−	−	+	++
Tannins	+	++	+++	++++	+	++	++++	+++
Terpenoids	+	++	+++	++++	−	−	−	−

T0= 0 mM; T1= 100 mM; T2= 200 m; T3= 300 mM

3.2.2 Qualitative analysis of Cynodon dactylon

Analysis of aqueous extracts of *Cynodon dactylon* indicated that alkaloids and glycosides content increased as there is increase in salinity. Carbohydrates, lignin, proteins, saponins, tannins and terpenoids contents were in higher concentrations in control and decreased with the increase in Salinity. Phenolic compounds were detected only in the moderate levels of salinity stress and not detected in lower and higher salt levels. Steroids were only detected in the medium levels of salt concentrations.

Ethanolic extract analysis indicted that carbohydrates, phenols, steroids and terpenoids were not detected at all in all levels of NaCl salt stress. Protein was also not screened in lower levels of salinity and increased with the increase in the salinity. Alkaloids was increased with the increased with the increase in salinity but not detected in higher salt levels. Tannins were increased with the increase in the salinity. Saponins decreased gradually with the increase in the salinity. Glycosides was only detected in the control and not detected at all in all levels of salt concentrations. Lignin contents were higher in the medium levels of salt and were lowest in the lower and higher levels of salt levels (Table 2).

Table 2. Qualitative analysis of *Cynodon dactylon* in aqueous and ethanolic extract under various levels of NaCl stress.

Extract media	Aqueous extract				Ethanolic extract			
Levels	**T0**	**T1**	**T2**	**T3**	**T0**	**T1**	**T2**	**T3**
Alkaloids	+	++	+++	++++	+	++	+++	−
Carbohydrates	++++	+++	++	+	−	−	−	−
Glycosides	+	++	++++	+++	+	−	−	−
Lignin	++++	+++	++	+	++	++++	+++	+
Phenols	−	−	+	−	−	−	−	−
Proteins	++++	+++	++	++	−	−	++	+
Saponins	++++	+++	++	+	++++	+++	++	+
Steroids	−	++	+	−	−	−	−	−
Tannins	++++	+++	++	+	+	++	+++	++++
Terpenoids	++++	+++	++	+	−	−	−	−

T0= 0 mM; T1= 100 mM; T2= 200 m; T3= 300 mM

3.2.2 Qualitative analysis of Cymbopogon jwarancusa

Qualitative screening of *Cymbopogon jwarancusa* in aqueous extract showed that alkaloids was only in the higher levels of salinity. Carbohydrate, glycosides, saponins and steroids content was in higher amount in the moderate levels of salinity and lower in both higher and lower levels of salinity. Proteins, phenols and tannins decreased with the increase in the salinity. Screening of terpenoids content showed increase with the increase in the salinity while lignin content was present only the lower levels of salinity and absent in the moderate to higher levels of salinity.

In the ethanolic extracts of *Cymbopogon jwarancusa* carbohydrates, glycosides, lignin, terpenoids and phenols were detected more in the moderate levels of salinity and analyzed minimum in the lower and the higher levels of salinity. Alkaloids, protein and tannins content increased with the increase in the salinity levels. Saponins were detected only in small amount only. Steroids were only detected in medium levels of salt stress of this grass (Table 3).

Table 3. Qualitative analysis of *Cymbopogon jwarancusa* in aqueous and ethanolic extract under various levels of NaCl stress.

Extract media	Aqueous extract				Ethanolic extract			
Levels	T0	T1	T2	T3	T0	T1	T2	T3
Alkaloids	−	−	+	++	+	++	+++	++++
Carbohydrates	++	++++	+++	+	+	++++	+++	++
Glycosides	+++	++++	++	+	+++	++++	++	+
Lignin	+	++	−	−	++	+++	++++	+
Phenols	++++	+++	++	+	+	+++	++++	++
Proteins	++++	+++	++	+	+	++	+++	++++
Saponins	+	++++	+++	++	+	+	+	+
Steroids	−	++	+++	+	−	−	+	−
Tannins	++++	+++	++	+	+	++	+++	++++
Terpenoids	+	++	+++	++++	+	++++	+++	++

T0= 0 mM; T1= 100 mM; T2= 200 m; T3= 300 mM

3.2.4 Qualitative analysis of Lasiurus scindicus

In the aqueous extracts of *Lasiurus scindicus* phytochemicals like alkaloids, glycosides, lignin, phenols, proteins and steroids were not screened at all levels of salinity. Carbohydrate and tannins contents decreased with the increase in the salinity. Saponins contents increased as there is increase in the level's salinity. Terpenoids were detected in higher amount in the medium levels of salinity and decreased with the lower and highest levels of salinity.

Ethanolic extract showed that glycosides, steroids and tannins steroids not detected at all in any levels of salinity. Alkaloid content increases with the increase in the salinity. Carbohydrates contents increased as there is increase in the salt stress levels. Lignin, phenols, proteins and proteins were detected in higher amount in the medium levels of salinity and decreased with the lower and highest levels of salinity (Table 4).

Table 4. Qualitative analysis of *Lasiurus scindicus* in aqueous and ethanolic extract under various levels of NaCl stress.

Extract media	Aqueous extract				Ethanolic extract			
Levels	T0	T1	T2	T3	T0	T1	T2	T3
Alkaloids	−	−	−	−	+	++	+++	++++
Carbohydrates	++++	++	+	−	++++	+++	++	+
Glycosides	−	−	−	−	−	−	−	−
Lignin	−	−	−	−	++	++++	+++	+
Phenols	−	−	−	−	+++	+	++++	++
Proteins	−	−	−	−	++	+++	++++	+

Saponins	+	++	+++	++++	+	+	+	+
Steroids	−	−	−	−	−	−	−	−
Tannins	++++	+++	++	+	−	−	−	−
Terpenoids	++	++++	+++	+	++	+++	++++	+

T0= 0 mM; T1= 100 mM; T2= 200 mM; T3= 300 mM

3.2.5 Qualitative analysis of Panicum antidotale

In the aqueous extract of *Panicum antidotale* carbohydrates and proteins content of was not detected in control and increased with the increase in the salinity. Alkaloids detected only in lower levels of salinity and not detected in the moderate levels of salinity. Lignin, phenols and steroids were not detected at all in levels of salt stress. Tannins increased with increase in the salinity. Saponins and terpenoids seem to be increase with the increase in the salinity. Glycosides were detected in small amount only in the higher levels of salinity and not detected in lower and moderate levels of salinity.

Carbohydrates, glycosides, lignin, phenols, saponins and steroids were not detected in the ethanolic extracts of *Panicum antidotale.* Proteins and alkaloids were detected in higher amount in the medium levels of salinity and decreased in the lower and highest levels of salinity. Terpenoids increased with the increase in the salinity (Table 5).

Table 5. Qualitative analysis of *Panicum antidotale* in aqueous and ethanolic extract under various levels of NaCl stress.

Extract media	Aqueous extract				Ethanolic extract			
Levels	**T0**	**T1**	**T2**	**T3**	**T0**	**T1**	**T2**	**T3**
Alkaloids	+	−	−	−	+	++++	+++	++
Carbohydrates	−	+	++	+++	−	−	−	−
Glycosides	−	−	−	+	−	−	−	−
Lignin	−	−	−	−	−	−	−	−
Phenols	−	−	−	−	−	−	−	−
Proteins	−	+	++	+++	+	++++	+++	++
Saponins	+	++++	+++	++	−	−	−	−
Steroids	−	−	−	−	−	−	−	−
Tannins	+	++	+++	++++	+	−	−	−
Terpenoids	+	++	+++	++++	+	++	+++	++++

T0= 0 mM; T1= 100 mM; T2= 200 mM; T3= 300 mM

IV. DISCUSSION

4.1 Morpho-agronomic characteristics

It is well known fact that mostly plants growing under saline condition remain stunted due to reduction in cell elongation and cell division, which are under the control of different auxins, whose synthesis is retarded by the salinity (Balal *et al.,* 2011). One of the most important parameters in the plant growth is plant height which is an important factor that contributes more in the biomass of plant. In the current study high salinity levels significantly, reduced plant height in *C. ciliaris* and *C. dactylon.* Previous studies carried out with *Zea mays* L. (Hamada, 1995), *Distichlis spicata* (Pessarakli *et al.*, 2001) as well as in *Oryza sativa* L.seedlings vr. Damodar also showed that shoot growth was inhibited by NaCl. Hence salinity has a great impact on plant height because of growth of leaf and its development, due to effects on photosynthesis (Nadeem *et al.*, 2012). The reduction in plant length is caused by the toxic effects by the higher levels of salt NaCl and unbalanced uptake of nutrient by the plants. Higher salinity levels may also reduce the shoot elongation due to the slow uptake of water for overall of the osmotic adjustments in the body of plants (Datta *et al.,* 2009). From all the data discussed it conforms that *C. ciliaris* and *C. dactylon* are salt sensitive plants. *L. scindicus* and *P. antidotale* were stimulated the plant height at 100 to 200 mM NaCl as results were shown in Manila grass and Bermuda grass (Marcum and Murdoch, 1994) where shoot length increased till moderate level of salinity. Increase in plant height of *C. jwarancusa* appears to be adaptation to salinity. Similar results have been reported in Augustine grass and seashore Paspalum where shoot growth rates due to maintained shoot tissue succulence, $Ca^{2+,}$ K^{+}, Ca^{2+} and Mg^{2+} concentrations and salt secretive character (Marcum and Murdoch, 1994).

Results for the root length were also negative because by increase in the salinity over all reduced the root length in all grass species. Root length of *C. ciliaris, C. dactylon* and *Panicum antidotale* was decreased with the increase in the NaCl gradually from 0 mM to the 300 mM of salt levels. In all varieties of wheat cultivar except HD-6859 (Pessarakli *et al.,* 2001, Datta *et al.,* 2009) increase in the salt levels from 0 to 25mM of NaCl showed no effect on the root length of plant. By further increase in salt levels from 50mM to beyond significantly reduced the length of root. The reduction in root length may be caused by the toxic effects by the higher levels of salt NaCl and unbalanced uptake of nutrient by the plants. Higher salinity levels may also reduce the root elongation due to the slow uptake of water for overall of the osmotic adjustments in the body of plants (Datta *et al.,* 2009). *C. jwarancusa* and *L. scindicus* showed more length for root till 200 mM and 100 mM of salt levels respectively. In other studies root growth was also less affected by the salinity levels as in Glycine max L. Merrill (Essa, 2002). Inorganic ions accumulation for the osmotic adjustments is energy-effective way for the increased root length in the plants to combine productivity with the salt tolerance (Essa, 2002). Roots seemed to be more resistant which shows that *C. jwarancusa* is more salt tolerant than other selected grasses.

Number of tillers decrease slightly with the increase in the NaCl level in *C. ciliaris, C. jwarancusa. L. scindicus* and *P. antidotale.* Studies related to this shows that number of tillers of *Oryza sativa* L. genotype IR 29, IR 59418, IR 72593, IR 73055 and NERICA 4 at 12 dS m^{-1}were highly affected by increase in salinity (Girma *et al.,* 2017). Results also showed that Na+ ion content in the leaves increases with the increase in salinity levels while trend was reverse observed in the case of K+ and Ca++ uptake. Toxic effect was created due to excess amount of Na on plant metabolic processes (Karim *et al.,* 1992 and Mondal *et al*., 2103). Number of tillers increase from control to 200 mM of MaCl level in *C. dactylon* then decrease at 300 mM of salinity levels. The results agreed with many researchers as in rice variety BR11 where an only higher salinity level reduces the number of tillers (Gain *et al.,* 2004). In other results, it was reported that salinity have fewer negative effects on salinity (Mondal *et al*. 2013) due to low amount of Na+ with high amount of K+ and Ca++ (Mondal *et al*., 2013).

With the increase in salinity inter nodal length decreased in *C. ciliaris* and *C. dactylon*. Similar results were reported in rice where decrease in internode length was observed with increasing salinity stress (Alizadeh *et al.,* 2011). Such decrease was due to typical effects of accumulation of the toxic ions in the cells, which adversely affected the cell division and expansion (Munns, 1993; Alizadeh *et al.,* 2011). Inter nodal length of *P. antidotale* and *L. scindicus* increased up to 100 mM of salinity then decreased with the increase in salinity where as in *C. jwarancusa* this parameter increased with the increase in salinity. Similar trend was observed in in this parameter in the standard and the tolerant genotypes of sugar cane as compared to the sensitive one (Akhtar *et al.,* 2003).

Number of leaves of *C. ciliaris, C. dactylon* and *P. antidotale* was increased up to 100 mM of NaCl stress and then decreased with the increase in the salinity. These results corroborate with those reported by (Aggrwal *et al*. 2013) in fenugreek. High NaCl levels decrease the number of leaves throughout their experiment while working on *Vicia faba* L. (Qados, 2011). *L. scindicus* showed continues decrease in the number of leaves at all salinity levels. Similar results was the outcome of (Munns, 2002) while studying the leaves of *Phaseolus acutifolius* L., *Vigna unguiculata* L., and *Phaseolus filiformis* L. Decrease in the number of numbers occur due to accumulation of the sodium chloride in cell walls and the cytoplasm of older leaves and their vacuole sap. Meanwhile the sap of vacuole cannot accumulate further salt and it decreases the salt concentration inside the cells. It eventually leads to rapid death and decline in the numbers of leaves and vice versa (Munns and Tester, 2008). Number of leaves of

C. jwarancusa increased with the increase in the salinity. Studies on common purslane Ac13 as well as in Ac5 and Ac9 accessions revealed the largest number of leaves as there is increase in salinity (Alam *et al.,* 2016).

Agro-morphological results showed that the leaf area of *C. ciliaris* increased upto 100mM of NaCl then decreased with the increased in the salinity. Similar trend is seen in some ecotypes of cheat grass (Rasmuson and Jay, 2002). Leaf area of *C. dactylon* and *C. jwarancusa L. scindicus P. antidotale* and greatly decreased with the increase in the salinity. Same results are observed in *Vigna aconitifolia* L. (Jamil *et al.,* 2007) and are also supported by Zhao *et al*. (2007). Both developmental and physiological mechanisms are behind the reduction in the leaf area to salt treatments. Inhibition of leaf expansion was observed in the NaCl treated plant was partially related to the low photosynthetic rates. On the other hand, lower water potentials of the plants in high-salt treatment have affected the cellular expansion through effects on the cell turgor (Netondo *et al.*, 2004, Qados, 2011).

Negative and toxic effect of NaCl was prominent in all grass species of this research except *C. jwarancusa* where fresh and dry weight of grass increased with the increase in salinity. *C. dactylon*, and *P. antidotale* show increase in biomass upto 100 mM of NaCl while in *L. scindicus* biomass increased upto 200 mM of NaCl then decreased with the increased in the salinity up to 300 mM level of NaCl. Increase in bio mass was reported in *Pennisetum alopecuroides* at 100 mM salinity (Mane *et al.*, 2011). Other study shows that in the *Portulaca oleracea* L. accessions (Ac1 at 8 dS m^{-1} salinity, Ac9 at 16, 24, and 32 dS m^{-1}salinity, and Ac13 at 8 and 16 dS m^{-1} salinity levels) there is increase in fresh weight and dry weight with the increasing of salinity levels (Alam *et al.,* 2015). Such stimulation in fresh and dry biomass production might be due to accumulation of inorganic ions and the organic solutes for the osmotic adaptation (Xu *et al.,* 2008). Elevated salinity caused very high reduction in fresh and dry weight of *C. ciliaris* consecutively with the increasing of salinity augmentation. Other study on purslane showed similar trend (Alam *et al.,* 2015). These decreases in the plant fresh and dry weights may be due to the shrinkage of the contents of cells, reduced ion in growth, less development, reduction in number of leaves, less leaf area and low differentiation level of tissues. It could be due to the disturbed mechanisms, avoidance in the different species of plants under higher levels of salt stress (Munns and Tester, 2008, Nadeem *et al.,* 2012).

4.2 Bio-chemical parameters

In the selected grass *C. ciliaris* phenols, steroids and lignin were not detected in aqueous while carbohydrates, saponins, glycosides and terpenoids not detected in the ethanolic extracts in all levels of salinity. Carbohydrates, proteins, tannins and terpenoids increases with increases in salinity from 0 mM to 300 mM in aqueous extracts. In ethanolic extracts alkaloids, and lignin increases while phenolic and protein contents decrease with increases in the salinity. In the grass *C. dactylon* carbohydrates, phenols, steroids and terpenoids were not detected in ethanolic solution. Carbohydrates. proteins, tannins, liginins and terpenoids decreases while alkaloids and glycosides increase with the increase in the salinity in aqueous solution. Saponin decreased while Alkaloids, tannins increased with the increase in the salinity in the ethanolic extracts. Biochemical responses of the grass *C. jwarancusa* showed carbohydrates, proteins, tannins, phenols, saponins, glycosides, steroids and lignin decreased at salt higher salt level while the with the increases in the terpenoids increased at medium salt levels in aqueous solution. Carbohydrates, glycosides, terpenoids, and lignin decreased at higher while the proteins, alkaloids, tannins and phenols increases at 100 mM of salt levels in ethanolic extracts. In the qualitative analysis of *L. scindicus* proteins, alkaloids, phenols, glycosides, steroids and lignin were not detected in aqueous and tannins, glycosides and steroids were not detected in ethanolic extracts in all salinity levels. In the aqueous extract's carbohydrates, tannins, terpenoids decreased while only saponins increased with the increase in salinity. In the ethanolic extracts carbohydrates decreases, while alkaloids increased in all salinity levels but proteins, phenols, terpenoids and lignin content increased up to the 200 mM of salinity then sudden decline seen in 300 mM of salt levels. In the *p. antidotale* phenols, glycosides, steroids and lignin not detected in aqueous while carbohydrates, tannins, phenols, saponins, glycosides, steroids and lignin not detected in the ethanolic extracts. In the aqueous extract's carbohydrates, proteins, tannins and terpenoids increase while saponins decreased with the increased salt levels. In the ethanolic extracts terpenoids increased with the increase in the salt levels up to 300 mM while proteins and alkaloids showed increase only at medium salt levels.

Sugar content of salt tolerant cultivar can assist in osmotic adjustment in plants (Ghoulam *et al*., 2002). These results also suggested that increase in carbohydrates increases the plant tolerance to the salinity stress. Results were further supported by the in conformity in *satureja hortensis* (Najafi *et al.*,2010; Muthulakshmi *et al.*, 2013).

Several researchers showed that protein contents of the leaves decreased in response to salinity (Agastian *et al.,* 2000; Muthukumarasamy *et al.,* 2000; Parida *et al.,* 2002). Soluble proteins may increase at low up to the moderate stress NaCl (Agastian *et al.,* 2000). By increasing salt levels, the proteins may be serving as reservoirs of energy or adjuster of the osmotic potentials in the plants which are subjected to salinity (Pessarakli and Tucker, 1985; Torabi *et al.,* 2014). There is also seen increase in protein content with the increase in salt levels because of *de novo synthesis of proteins* in response to the salt stress (Parvaiz and Satyawati, 2008). It is reported that that the number of proteins which are induced by the salinity are mostly cytoplasmic which may cause alterations in the cytoplasm viscosity in the cells of that plants (Pessarakli and Tucker, 1985; Hasegawa *et al.*, 2000; Torabi *et al.*, 2014).

Results for alkaloids was also shown by other researchers that the salt stress enhanced the accumulation of alkaloids. on the other hand, positive correlations have been observed up to the 80 mM of salt levels while further increase in NaCl levels from the 80mM to the 100mM has shown negative effects in the production of alkaloids. However higher NaCl levels 100mM may cause decrease in accumulation of alkaloids. Our results were further supported by the earlier reports of (Jaleel *et al.,* 2007) with more alkaloid was analyzed with increased salt levels (Muthulakshmi *et al.,* 2013).

Current study results are supported by the earlier study which showed that Phenol increases as there is increase in salt levels from 0 mM to 300 mM of NaCl. Phenols are produced in leaves and then transported to the other tissues of plants (Muthulakshmi *et al.,* 2013). Studies showed that the saponin increased gradually by the increase in NaCl levels. Maximum saponins were greater by the 25% in highest NaCl levels (150mM) as compare to the control (0 mM) (Elhaak *et al.,* 2014). With the increase in the salinity steroids increased but at higher levels steroidal production becomes less. Our results confirmed by the earlier reports (Šutković *et al*, 2011).

V. CONCLUSION

The current work was conducted to evaluate the effect of NaCl stress on morpho-agronomic and biochemical responses of some Cholistan desert grass species i.e. *Cenchrus ciliaris, Cynodon dactylon, Cymbopogon jwarancusa, Lasiurus scindicus* and *Panicum antidotale.* NaCl negatively affected the morpho-agronomic characters of all selected grasses from moderate levels of salinity to higher levels of salinity (300 mM) except the *Cymbopogon jwarancusa.* Some phytochemicals like sugars, saponins and protein were mostly detected in aqueous while alcohol soluble was in ethanolic extracts. Other phytochemicals were increased up to the moderate levels of salinity 100 mM to 200 mM then decreased at 300 mM of NaCl while few phyto-chemicals increased with the increase in the salinity. Our results supported by different studies showed that these grasses have some mechanism of adaptations which help them to grow and showed increased growth up to 100 mM to 200 mM of NaCL levels.

***Acknowledgments*:**

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Agarwal, P., Dabi, M., Kinhekar, K., Gangapur, D. R., and Agarwal, P. K. 2020. Special adaptive features of plant species in response to salinity. Salt and Drought Stress Tolerance in Plants: Signaling Networks and Adaptive Mechanisms. 53-76.

Agrawal, P. 2007. Ecophysiological and Biochemical studies Related to drought adaptation in grasses of Indian Desert. (Doctoral dissertation, Ph. D. Thesis, JN Vyas University).

Agastian, P., Kingsley, S. J., and Vivekanandan, M. 2000. Effect of salinity on photosynthesis and biochemical characteristics in mulberry genotypes. Photosynthetica. 38(2): 287-290.

Ahmad, F., Hameed, M., Ahmad, M. S. A., and Ashraf, M. 2021. Ensuring food security of arid regions through sustainable cultivation of halophytes. Handbook of Halophytes: From Molecules to Ecosystems towards Biosaline Agriculture. 2191-2210

Akbar, G., Khan, T. N., and Arshad, M. 1996. Cholistan desert, Pakistan. Rangelands. 124-128.

Akhtar, S., Wahid, A., and Rasul, E. 2003. Emergence, growth and nutrient composition of sugarcane sprouts under NaCl salinity. Biologia Plantarum. 46(1): 113-116.

Alam, M. A., Juraimi, A. S., Rafii, M. Y., Hamid, A. A., Aslani, F., and Alam, M. Z. 2015. Effects of salinity and salinity-induced augmented bioactive compounds in purslane (*Portulaca oleracea* L.) for possible economical use. Food Chemistry. 169: 439-447.

Alizadeh, M. R., Rahimi-Ajdadi, F., and Dabbaghi, A. 2011. Cutting energy of rice stem as influenced by internode position and dimensional characteristics of different varieties. Australian journal of crop science. *5*(6): 681.

Asaolu, M. F., Oyeyemi, O. A., and Olanlokun, J. O. 2009. Chemical compositions, phytochemical constituents and in vitro biological activity of various extracts of *Cymbopogon citratus*. Pakistan Journal of Nutrition. 8(12): 1920-1922.

Ashraf, M. 2003. Relationships between leaf gas exchange characteristics and growth of differently adapted populations of Blue panicgrass (*Panicum antidotale* Retz.) under salinity or waterlogging. Plant science. 165(1): 69-75.

Ashraf, M. 2004. Some important physiological selection criteria for salt tolerance in plants. Flora-Morphology, Distribution, Functional Ecology of Plants. 199(5): 361-376.

Babu, R. H., and Savithramma, N. 2013. Phytochemical screening of underutilized species of Poaceae. Journal of Pharmacy Research. 1: 947-951.

Balal, R. M., Ashraf, M. Y., Khan, M. M., Jaskani, M. J., and Ashfaq, M. 2011. Influence of salt stress on growth and biochemical parameters of citrus rootstocks. Pakistan Journal of Botany. 43(4): 2135-2141.

Buzzini, P., Turchetti, B., and Yurkov, A. 2018. Extremophilic yeasts: the toughest yeasts around?. *Yeast*. *35*(8): 487-497.

Datta, A., Bansal, V., Diaz, J., Patel, J., Reato, D., and Bikson, M. 2009. Gyri-precise head model of transcranial direct current stimulation: improved spatial focality using a ring electrode versus conventional rectangular pad. Brain stimulation. 2(4): 201-207.

Dos S, T. B., Ribas, A. F., de Souza, S. G. H., Budzinski, I. G. F., and Domingues, D. S. 2022. Physiological responses to drought, salinity, and heat stress in plants: a review. *Stresses*. 2(1): 113-135.

Dugasa, M. T., Cao, F., Ibrahim, W., and Wu, F. 2019. Differences in physiological and biochemical characteristics in response to single and combined drought and salinity stresses between wheat genotypes differing in salt tolerance. Physiologia Plantarum. 165(2): 134-143.

Elhaak, M. A., Abo-Kassem, E. M., and Saad-Allah, K. M. 2014. Effect of the combined treatment with sodium and calcium chlorides on the growth and medicinal compounds of *Cichorium intybus*. International Journal of Current Microbiology and Applied Sciences. 3(7): 613-630.

El-Keblawy, A., and Al-Rawai, A. 2006. Effects of seed maturation time and dry storage on light and temperature requirements during germination in invasive *Prosopis juliflora*. Flora-Morphology, Distribution, Functional Ecology of Plants. 201(2): 135-143.

Essa, T. A. 2002. Effect of salinity stress on growth and nutrient composition of three soybean (*Glycine max* L. Merrill) cultivars. Journal of Agronomy and Crop Science. 188(2): 86-93.

Fatima, S., Hameed, M., Naz, N., Shah, S. M. R., Naseer, M., Ahmad, M. S. A., ... and Ahmad, I. 2021. Survival strategies in khavi grass [Cymbopogon jwarancusa (Jones) Schult.] colonizing hot hypersaline and arid environments. Water, Air, and Soil Pollution. 232, 1-17.

Gain, P., Mannan, M. A., Pal, P. S., Hossain, M. M., and Parvin, S. 2004. Effect of salinity on some yield attributes of rice. Pak. J. Biol. Sci. 7(5): 760-762.

Ghoulam, C., Foursy, A., and Fares, K. 2002. Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. Environmental and experimental Botany. 47(1): 39-50.

Girma, B. T., Ali, H. M., and Gebeyaneh, A. A. 2017. Effect of salinity on final growth stage of different rice (*Oryza sativa* L.) genotypes. Asian J Agric Res. 11, 1-9.

Haider, S., Malik, S. M., Nadeem, B., Sadiq, N., and Ghaffari, A. S. 2021. Impact of Population Growth on The Natural Resources of Cholistan Desert. PalArch's Journal of Archaeology of Egypt/Egyptology. 18(10): 1778-1790.

Hamada, A.M., 1995. Alleviation of the adverse effects of NaCl on germination, seedling, growth and metabolic activities of maize plants by calcium salts. Bull. Fac. Sci. Assiut Univ. 24: 211–220.

Harborne, J. B. 1975. The biochemical systematics of flavonoids. In *The flavonoids* . Boston, MA: Springer US. 1056-1095,

Hasegawa, P. M., Bressan, R. A., Zhu, J. K., and Bohnert, H. J. 2000. Plant cellular and molecular responses to high salinity. Annual review of plant biology. 51(1): 463-499.

Hussain, M. I., Farooq, M., Muscolo, A., and Rehman, A. 2020. Crop diversification and saline water irrigation as potential strategies to save freshwater resources and reclamation of marginal soils—A review. Environmental Science and Pollution Research. 27(23): 28695-28729.

Irshad, M., and Hameed, M. 2023. Influence of environmental heterogeneity on distributional pattern of blue panic grass (*Panicum antidotale* Retz.) in the Punjab, Pakistan. Pak. J. Bot. 55(3): 1145-1155.

Ismail, S., Rao, N. K., and Dagar, J. C. 2019. Identification, evaluation, and domestication of alternative crops for saline environments. Research developments in saline agriculture. 505-536.

Jaleel, C. A., Manivannan, P., Sankar, B., Kishorekumar, A., and Panneerselvam, R. 2007. Calcium chloride effects on salinity-induced oxidative stress, proline metabolism and indole alkaloid accumulation in *Catharanthus roseus*. Comptes Rendus Biologies. 330(9): 674-683.

Jaleel, C. A., Manivannan, P., Sankar, B., Kishorekumar, A., Gopi, R., Somasundaram, R., and Panneerselvam, R. 2007. Pseudomonas fluorescens enhances biomass yield and ajmalicine production in *Catharanthus roseus* under water deficit stress. Colloids and Surfaces B: Biointerfaces. 60(1): 7-11.

Jamil, M., Lee, K. J., Kim, J. M., Kim, H. S., and Rha, E. S. 2007. Salinity reduced growth PS2 photochemistry and chlorophyll content in radish. Scientia Agricola. 64(2): 111-118.

Jarald, E. E., Joshi, S. B., and Jain, D. C. 2008. Antidiabetic activity of aqueous extract and non-polysaccharide fraction of *Cynodon dactylon* Pers.

Khalid, M., and Siddiqui, H. H. 2011. Pharmacognostical evaluation and qualitative analysis of *Saccharum spontaneum* (L.) root. International journal of pharmaceutical sciences and drug research. 3(4): 338-341.

Kindomihou, V. M. 2020. Introductory Chapter: Milestones in Grasses and Grassland Research. Grasses and Grassland Aspects. 1-30.

Mahmud, A., and Feely, J. 2002. Reduction in arterial stiffness with angiotensin II antagonist is comparable with and additive to ACE inhibition. American journal of hypertension. 15(4): 321-325.

Mane, A. V., Karadge, B. A., and Samant, J. S. 2011. Salt stress induced alteration in growth characteristics of a grass *Pennisetum alopecuroides*. Journal of Environmental Biology. 32(6): 753.

Marcum, K. B., and Murdoch, C. L. 1994. Salinity tolerance mechanisms of six C4 turfgrasses. Journal of the American Society for Horticultural Science, 119(4): 779-784.

Mittova, V., Tal, M., Volokita, M., and Guy, M. 2002. Salt stress induces up-regulation of an efficient chloroplast antioxidant system in the salt-tolerant wild tomato species *Lycopersicon pennellii* but not in the cultivated species. Physiologia Plantarum, 115(3): 393-400.

Mondal, M. M. A., Puteh, A. B., Malek, M. A., and Rafii, M. Y. 2013. Salinity induced morpho-physiological characters and yield attributes in rice genotypes. Journal of Food, Agriculture and Environment. 11(2): 610-614.

Mondal, T. K., and Ganie, S. A. 2014. Identification and characterization of salt responsive miRNA-SSR markers in rice (Oryza sativa). Gene. 535(2): 204-209.

Munns, R. 1993. Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. Plant, Cell and Environment. 16(1): 15-24.

Munns, R. 2002. Comparative physiology of salt and water stress. Plant, cell and environment. 25(2): 239-250.

Munns, R., and Tester, M. 2008. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 59: 651-681.

Mustafa, F. 2019. Adaptive Components of Drought Tolerance in Different Populations of *Cymbopogon Jwarancusa* (Jones) and *Lasiurus Scindicus Henrard* (Doctoral dissertation, University of Agriculture, Faisalabad.).

Mustafa, F., Ahmad, F., Hameed, M., and Sadia, B. 2019. Anatomical adaptations for drought tolerance in Lasiurus scindicus from Punjab, Pakistan.

Muthukumarasamy, M., Gupta, S. D., and Panneerselvam, R. 2000. Enhancement of peroxidase, polyphenol oxidase and superoxide dismutase activities by triadimefon in NaCl stressed *Raphanus sativus* L. Biologia Plantarum. 43(2): 317-320.

Muthulakshmi, S. Gurulakshmi G., Rajathi S. 2013. Effect of Salt Stress on Physiological and Biochemical Characteristics in Solanum nigrum L. International Journal of Science and Research. 2319-7064.

Nadeem, M., Younis, A., Riaz, A.. Hameed, M., Nawaz, T., and Qasim, M. 2012. Growth response of some cultivars of bermuda grass (*Cyanodon dactylon* L.) to salt stress. Pak J Bot. 44: 1347-1350.

Najafi, F., and Khavari-Nejad, R. A. 2010. The effects of salt stress on certain physiological parameters in summer savory (*Satureja hortensis* L.) plants. Journal of Stress Physiology and Biochemistry. 6(1).

Naz, N., Hameed, M., Wahid, A., Arshad, M., Ahmad, A., and Sajid, M. 2009. Patterns of ion excretion and survival in two stoloniferous arid zone grasses. Physiologia plantarum. 135(2): 185-195.

Netondo, G. W., Onyango, J. C., and Beck, E. 2004. Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress. Crop Science. 44(3): 806.

Padma, R., Parvathy, N. G., Renjith, V., Kalpana, P. R., and Rahate, P. 2013. Quantitative estimation of tannins, phenols, and antioxidant activity of methanolic extract of *Imperata cylindrica.* Int J Res Pharm Sci. 4(1): 73-7.

Parida, A., Das, A. B., and Das, P. 2002. NaCl stress causes changes in photosynthetic pigments, proteins, and other metabolic components in the leaves of a true mangrove, *Bruguiera parviflora*, in hydroponic cultures. Journal of Plant Biology. 45(1): 28-36.

Parvaiz, A., and Satyawati, S. 2008. Salt stress and phyto-biochemical responses of plants-a review. Plant Soil and Environment. 54(3): 89.

Pessarakli, M. 2001. Physiological responses of Cotton (*Gossypium hirsutum* L.) to salt stress. Handbook of plant and crop physiology. 681-696.

Pessarakli, M., and Tucker, T. C. 1985. Uptake of nitrogen-15 by cotton under salt stress. *Soil Science* Society of America Journal. 49(1): 149-152.

Puteh, A. B., Mondal, M., Ismail, M., and Latif, M. A. 2014. Grain sterility in relation to dry mass production and distribution in rice *Oryza sativa* L.. BioMed research international.

Qados, A. M. A. 2011. Effect of salt stress on plant growth and metabolism of bean plant *Vicia faba* (L.). Journal of the Saudi Society of Agricultural Sciences. 10(1): 7-15.

Rasmuson, K. E., and Anderson, J. E. 2002. Salinity affects development, growth, and photosynthesis in cheatgrass. Journal of Range Management. 80-87.

Reddy, C. S., and Bose, N. S. C. 2023. Biochemicals and Biological activities of Cymbopogon jwarancusa (Jones) Schult. Phytochemical Composition and Pharmacy of Medicinal Plants: 2-volume set. 259.

Shahid, M. A., Sarkhosh, A., Khan, N., Balal, R. M., Ali, S., Rossi, L., ... and Garcia-Sanchez, F. 2020. Insights into the physiological and biochemical impacts of salt stress on plant growth and development. Agronomy. 10(7): 938.

Sheela, J. A. H. 2013. Qualitative analysis of secondary metabolites of the plant Clematis gouriana. Int J Innov Res Sci Eng Technol. 2(6): 2356-2358.

Srivastav, A. L., Dhyani, R., Ranjan, M., Madhav, S., and Sillanpää, M. 2021. Climate-resilient strategies for sustainable management of water resources and agriculture. Environmental Science and Pollution Research. 28(31): 41576-41595.

Suriyavathana, M., and Roopavathi, I. 2016. Phytochemical Characterization of *Triticum Aestivum* (Wheat Grass). Journal of Pharmacognosy and Phytochemistry. 5(1): 283.

Šutković, J., Ler, D., and Gawwad, M. R. A. (2011). vitro Production of Solasodine Alkaloid in *Solanum nigrum* under Salinity Stress. Journal of Phytology. 3(1).

Tamilselvi, N., Krishnamoorthy, P., Dhamotharan, R., Arumugam, P., and Sagadevan, E. 2012. Analysis of total phenols, total tannins and screening of phytocomponents in Indigofera aspalathoides (Shivanar Vembu) Vahl EX DC. Journal of Chemical and Pharmaceutical Research. 4(6): 3259-3262.

Torabi, M. 2014. Physiological and biochemical responses of plants to salt stress. International Conference on New Ideas in Agriculture. 26-27.

Torabi, S. A., Soufi, H. R., and Sahebjamnia, N. 2014. A new framework for business impact analysis in business continuity management (with a case study). Safety Science. 68: 309-323.

Umar, O. B., Ranti, L. A., Abdulbaki, A. S., Bola, A. L., Abdulhamid, A. K., Biola, M. R., and Victor, K. O. 2021. Stresses in plants: Biotic and abiotic. Current Trends in Wheat Research. 1-8.

Wariss, H. M., Salim, M. A., Ahmad, S., Alam, K., Qazi, M. A., Anjum, S., and Akram, M. 2021. Plant Diversity of the Cholistan Desert in Pakistan: Anthropogenic Factors and Conservation. In Sustainable Soil and Land Management and Climate Change. CRC Press. 147-164.

Wu, Y. Q., Taliaferro, C. M., Martin, D. L., Goad, C. L., and Anderson, J. A. 2006. Genetic variability and relationships for seed yield and its components in Chinese *Cynodon* accessions. Field crops research. 98(2): 245-252.