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CHANGES IN INORGANIC CONSTITUENTS IN THE LEAVES OF *VETIVERIA ZIZANIOIDES* (L.) NASH UNDER THE INFLUENCE OF NACL SALINITY

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Abstract: Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality. Plants need different essential minerals to grow and survive but excessive soluble salts in the soil are harmful to most of the plants. There is often an interaction between macronutrients and micronutrients in the root medium and in plants. In the present investigation effect of various levels of salinity on the mineral content of the leaves of *Vetiveria zizanioides* was studied. The experimental species was treated with increasing concentrations of Sodium chloride (25, 50,100, 200 and 300 mM). The concentration of sodium showed a perfect positive correlation with the increasing concentration of NaCl salinity. There was 43.18% increase in the sodium content at 300 mM NaCl over the control. Similar result was recorded in case of chloride which was increased in the leaves at all levels of salinity and also showed a perfect positive correlation. It was increased by 127.99% at 300 mM NaCl. The concentration of potassium was also increased in the leaves of *Vetiveria* at all salt concentrations. The concentration of Mg was slightly increased in the leaves of this grass at the lower levels of salinity. The level of 300 mM NaCl appears to be inhibitory in the uptake of magnesium. Fe content was decreased drastically at 300 mM concentration of NaCl in the rooting medium. The highest increase in the concentration of Fe for the *Vetiveria* was 16.21% at 200 mM NaCl. The details of other minerals studied in relation with salinity are discussed in the present paper.
Keywords: Abiotic stress; Minerals; Salinity; *Vetiveria zizanioides.*
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INTRODUCTION

Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality (Shani and Dudley, 2001; Ouda, 2008) with increasing impact on the socio-economic fabric and health, especially of the farming communities. Sehgal and Abrol, (1994) report that 187.2 mha areas in India is degraded, of which 162.4 mha is degraded by water and wind erosion and 21.7 mha by salinity and water logging. The remaining 4 mha area is affected by the depletion of nutrients. According to Fitter and Hay (1987), plants resist salinity by four different ways 1) Phenological Escape (seasonal adaptation) 2) Exclusion (selective absorption) often seen in halophytes (Epstein, 1969) 3) Amelioration (selective localisation) and 4) Tolerance (stress acceptance). Plants need different essential minerals to grow and survive but excessive soluble salts in the soil are harmful to most of the plants. There is often an interaction between macronutrients and micronutrients in the root medium and in plants (Marschner, 1995). It is confirmed that the micronutrients are generally less affected by salt stress than macronutrients (El-Fouly and Salama, 1999). The changes in the micronutrient concentrations in plants depend upon the type of crop species (Sharpley, 1992); Mn, Zn, Fe, and B concentrations under saline conditions, the levels of macronutrients, the levels of salinity and the organs of plants (Hu and Schmidhalter, 2001).

Salinity increases the Fe concentration in the shoots of pea (Dahiya and Sing, 1976), tomato (Maas *et al*., 1972), and rice (Verma and Neue, 1984), but decreases its concentration in the shoots of barley and corn (Hassan *et al*, 1970). Decrease in Mg and Mn in barley under salinity stress is reported by Cramer *et al*. (1991). Decrease in concentrations of B in the shoots at anthesis and in the grains of wheat by increasing salinity was observed by Holloway and Alston (1992). Na^+ and Cl^- accumulate in the shoots under increased levels of NaCl salinity (Jarunee *et al*., 2003, Mathangi *et al*., 2006, Lycoskoufis *et al*., 2005, Nathalie and Ernesto, 2008; Marosz and Nowark, 2008) and among that the increased levels of Cl^- ions decreases the B content under salinity stress (Yermiyahu *et al*., 2008). Huang and Stevninck (1990) suggested that vacuolation might provide a means for accumulation of excess ions in plants. Thus, the composition of macroelements and microelements alters greatly under varying levels of salinity and depends on plant species. *Vetiveria zizanioides* (L.) Nash (syn. *Chrysopogon zizanioides*) is a perennial grass of the Poaceae family, native to India and belongs to the grass family Graminae (Poaceae). The name comes from Tamil. In western and northern India, it is popularly known as Khus. Some common names of it are Vetiver, Khas-Khas, Khus-Khus (English); Ushira, Reshira, Sugandhimula (Sanskrit). Vetiver can grow up to 1.5 m high and form clumps as wide. The stems are tall and the leaves are long, thin, and rather rigid; the flowers are brownish purple. Unlike most grasses, which form horizontally spreading mat-like root systems, Vetiver's roots grow downward, 2-4 meters in depth. Though it originates in India, Vetiver is widely cultivated in the tropical regions of the world. The world's major producers include Haiti, India, Java, and Reunion. Several aspects of Vetiver make it an excellent erosion control plant in warmer climates. This makes Vetiver an excellent stabilizing hedge for stream banks, terraces and rice paddies. The close growing culms also help to block the runoff of surface water. Because Vetiver propagates itself by small offsets instead of underground stolons, it is non-invasive and can easily be controlled by cultivation of the soil at the boundary of the hedge. It is mainly cultivated for the fragrant essential oil distilled from its roots which is amber brown and rather thick. The odour of Vetiver oil is described as deep, sweet, woody, smoky, earthy, amber, balsam. Vetiver oil or Khus oil is complex oil containing over 100 identified components. Due to its excellent fixative properties, Vetiver is used widely in high-end perfumes. Vetiver has been used in traditional medicine in South Asia, Southeast Asia and West Africa. The present investigation was carried out to determine the effect of the Sodium chloride on the levels of various minerals namely sodium, chloride, calcium, potassium, magnesium, iron, zinc, copper, manganese, nickel and lead.

EXPERIMENTAL

The seedlings of *Vetiveria zizanioides* (L.) Nash (Figure 1) was collected from government nursery, Kagal (Kolhpaur). The seedlings were uniformly cut to a minimum height required for their growth and were transplanted into the earthen pots (30 cm height with a narrow base) to grow and establish under normal conditions with proper irrigation. After four weeks of their normal growth and stabilization salinity treatments were commenced. The plants were treated with increasing concentrations of Sodium chloride (25, 50, 100, 200 and 300 mM). Every alternate day, they were watered with a double amount of water to maintain the uniform salt concentration in the pots and to cope up with the loss of water by evaporation from the soil surface and by transpiration from the plant surface. Inorganic constituents like Na+, Ca+, K+ Mg++, Fe+++, Zn++ , Cu++, Mn++, Ni++ and Pb++ were estimated from oven dried leaves of the species. 0.5 g oven dried plant material was acid digested following the standard method by Toth *et al*. (1948) and were estimated using Atomic Absorption Spectrophotometer (Perkin-Elmer, 3030 A). Chlorides were extracted according to the method described by Imamul Huq and Larher (1983) with slight modification and estimated according to the method of Chapman and Pratt (1961). Statistical analysis of the data was carried out by using GraphPad software.

RESULTS AND DISCUSSION

Under saline conditions mutual effects of ions on their absorption are of particular interest. It is no wonder that reports on the micronutrients in different species are so variable (Hu and Schmidhalter, 2001). It is well known that the micronutrients are generally less affected by salt stress than macronutrients (El-Fouly and Salama, 1999). Deficiency of other nutrients in the soil is due to the high concentration of Na^+ that interacts with other environmental factors, such as drought, which exacerbate the problem to the plants (Silberbush and Ben-Asher, 2001). Problems arise in saline soils, since high concentrations of sodium disrupt potassium, iron and other mineral nutrients create hyper osmotic stress and cause secondary problems such as oxidative stress (Zhu, 2001). There is often an interaction between macronutrients and micronutrients in the root medium and in plants (Marschner, 1995). Therefore, it is necessary to investigate the interaction of salinity and macronutrients on the micronutrient composition in plants. Hu and Schmidhalter (2001) observed that the changes in the Mn, Zn, Fe and B concentrations in wheat under saline conditions depend upon the levels of macronutrients, salinity and on the organs of plants.

The influence of NaCl salinity on the concentration of various inorganic nutrients in the leaves of *Vetiveria zizanioides* is shown in Table1. It is very clear from the results that the concentration of sodium showed a perfect positive correlation with the increasing concentration of NaCl salinity. There was 43.18% increase in the sodium content at 300 mM NaCl over the control. Leaves are more vulnerable than roots to Na^+ simply because Na^+ and Cl^- accumulate to higher levels in shoots than in roots (Tester and Davenport, 2003). It has been suggested that a restriction of Na^+ transport from roots to shoots take place, minimizing Na^+ accumulation in the leaves (Sagi *et al*., 1997). Cuartero *et al*. (2002) also observed the increase in Na^+ concentration in mature tomato leaves and such accumulation can be considered as an important indicator for salt tolerance (Yasar, 2007; Yildiz *et al*., 2008). Khan *et al*. (2009) observed an increase in leaf Na^+ content in six different genotypes of wheat under excess of NaCl. Similar results were reported in sugar beet cultivars (Ghoulam and Fares, 2001) and *Opuntia ficus-indica* (Gersani *et al*., 1993). Djanaguiraman (2006) noticed the accumulation, more of Na^+ and K^+ in the leaves than the roots of rice. Many physiological studies have demonstrated that Na^+ toxicity is not only due to toxic effects of Na^+ in the cytosol, but also because of K^+ homeostasis which is disrupted possibly due to the ability of Na^+ competing for K^+ binding sites (Bartels and Sunkar, 2005). From the present investigation it appears that an increase in sodium content of the leaves of the grass could be attributed to an adaptive feature of the plants to the unfavourable conditions caused by the excess of NaCl in the rooting medium.

It is also clear from the results that the concentration of chloride was increased in the leaves at all levels of salinity and showed a perfect positive correlation with the increasing concentration of NaCl salinity. It was increased by 127.99% at 300 mM NaCl. Ashraf and Mc-Neily (1990) noticed the higher amount of chloride ions in roots of salt sensitive variety of *Brassica* as compared to the shoots. Kohl (1997) observed the chloride accumulation in green leaves of *A. maritima* as compared to sodium at all salt treatments. Agarwal and Pandey (2004) also recorded the accumulation of Na^+ and Cl^- in senna seedlings under NaCl stress. Similar results were reported in sugarbeet cultivars (Ghoulam and Fares, 2001), soyabean (Essa, 2002), cowpea (Murillo-Amador *et al*., 2002), *Vicia faba* (Gadallah, 1999) and *Sorghum bicolor* (Colmer *et al*., 1996). Huwyzeh *et al*. (2008) observed an increase in Cl^- content in shoot and root of *Saccharum officinarum* L. and concluded that to avoid absorption of harmful Na^+ and Cl^- ions, transport and exclusion were the mechanisms could be used to tolerate higher salinity levels by *Saccharum officinarum* L. From the present investigation it is clear that chloride was accumulated to a higher degree in the leaves of the grass as compared to that of Na^+ and such an increase in chloride content could be an adaptive feature of the plant under saline conditions. The highest level of increase in the Ca^{++} content was observed at 100 mM salt concentration as 18.28% over the control. The formations of calcium bonds in plants gives stability to a variety of cytoplasmic structures and enzymes and have apoplastic importance in cell membranes, cell walls and their adhesion (Jarunee, 2004). Salinity was shown to inhibit root hair elongation via alterations in the tip focused Ca^{++} gradient that regulates root hair growth (Halperin *et al*., 2003) and by a reduction in cytosolic Ca^{++} (Cramer and Jones, 1996) in *Arabidopsis* roots. Ca^{++} reduces the adverse effect of Na^+ by controlling the intake of toxic ions through the selectivity of the cell membrane (Volkmar *et al*., 1998; Munns, 2002).

The maintenance of higher concentrations of shoot K^+ and Ca^{++} has been observed in many salt tolerant grass species (Donovan and Richards, 2000). Calcium uptake in the saline soils is often disturbed, it is not the rule, but often calcium concentration in the leaves of sensitive species is decreased with increasing soil salinity, whereas in the resistant species it is increased or remains unchanged (Marosz, 2004). Increase in Ca^{++} content under salinity stress has been reported in a halophyte *Suaeda fruticosa* (L.) Forssk (Khan *et al*., 2000a), maize (Cramer *et al.,* 1991) and in *Vicia faba* (Gadallah, 1999). From the present results it is quite clear that lower levels of salinity favour uptake of calcium, which can be considered as an adaptive feature of the grass to tolerate the saline environment. It is very clear from the results that the concentration of potassium was increased in the leaves of *Vetiveria* at all salt concentrations. Potassium is essential in nearly all the processes needed to sustain plant growth and reproduction. It plays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, activation of plant enzymes, control of ionic balance and regulation of plant stomata. Peng *et al*. (2004) noticed that alkali grass resists salt stress through high K^+ and an endodermis barrier to Na^+. Khan *et al*. (2000) observed an increase in K^+, Na^+, Ca^{++} and Cl^- contents of a halophyte *Atriplex griffithii* with increasing level of salinity. The principle electrolyte for plants is K^+ and even in ecosystems where there is a predominance of Na^+, plants still exhibit a strong preference for K^+ (Walker *et al*., 1996). Regulation of Na^+ content and ability to maintain high K^+ concentrations in leaves have been proposed as an important mechanisms in plant adaptation to salinity, by decreasing the toxic effect of salts (Volkmar *et al*., 1998). Salt tolerance in the members of the family Triticeae is associated with enhanced ability to discriminate between Na^+ and K^+ in the soil solution and to preferentially accumulate K^+ and exclude Na^+ (Ali *et al*., 2004). The literature reports that low Na^+ and high K^+ uptake and a high K/Na ratio show a positive relationship with salt tolerance (Ashraf *et al*., 1997; Sherif *et al*., 1998). The elevated levels of potassium in the grass under stress might be involved in osmotic regulation, protein synthesis, and many essential enzymes activation.

Table 1: Effect of Sodium Chloride on Mineral Content of the Leaves of *Vetiveria zizanioides* (mg/kg)

NaCl (mM)	Na^+	Cl^-	Ca^{++}	K^+	Mg^{++}
Control	1495.30 (±31.02)	1841.10 (±16.05)	3275.67 (±17.95)	14583.0 (±53.33)	1777.40 (±16.97)
25	1466.87 (±27.68) -1.90	2075.40*** (±14.0) +12.73	3302.0 (±15.72) +0.80	15110.0*** (±76.71) +3.61	1629.56*** (±22.29) -8.32
50	1521.73 (±18.01) +1.77	2181.70*** (±33.0) +18.50	3555.67*** (±26.08) +8.55	26589.77*** (±154.77) +82.33	1711.30 (±18.24) -3.72
100	1626.37*** (±27.15) +8.77	3050.03*** (±23.02) +65.66	3874.33*** (±24.54) +18.28	35386.67*** (±101.48) +142.66	1880.45 (±22.56) +5.80
200	1861.27*** (±27.42) +24.47	3562.60*** (±59.88) +93.50	3425.33*** (±18.56) +4.57	31364.67*** (±98.68) +115.08	1250.30*** (±21.21) -29.66
300	2141.03*** (±17.52) +43.18	4197.60*** (±67.54) +127.99	2835.40*** (±19.79) -13.44	18341.67*** (±145.45) +25.77	1013.80*** (±13.15) -42.96

Each value is expressed as mg kg^{-1}
Values in parenthesis indicate standard deviation
Each value is a mean of three determinations

* Significant (p = 0.01 to 0.05)
** Very Significant (p = 0.001 to 0.01)
*** Extremely Significant (p < 0.001

Table 2: Effect of Sodium Chloride on Mineral Content of the Leaves of *Vetiveria zizanioides* (mg/kg)

NaCl (mM)	Fe^{+++}	Zn^{++}	Cu^{++}	Mn^{++}	Ni^{++}	Pb^{++}
Control	324.70 (±6.65)	102.75 (±3.61)	17.0 (±1.13)	83.85 (±2.76)	21.35 (±0.21)	23.90 (±0.71)
25	291.90* (±9.33) -10.10	106.85 (±7.71) +3.99	16.10 (±0.71) -5.29	93.35 (±1.20) +11.33	22.70 (±0.99) +6.32	23.15 (±1.06) -3.14
50	345.54 (±5.71) +6.42	118.30 (±4.38) +15.13	18.95 (±0.64) +11.47	106.70** (±3.54) +27.25	28.15** (±1.06) +31.85	18.30** (±1.56) -23.43
100	365.30** (±5.80) +12.50	103.50 (±3.25) +0.73	19.65 (±0.64) +15.59	97.30* (±2.97) +16.04	32.85*** (±0.92) +53.86	16.05** (±0.49) -32.85
200	377.35** (±6.72) +16.21	82.20* (±2.83) -20.0	11.85** (±0.92) -30.29	71.30* (±1.56) -14.97	17.05* (±1.34) -20.14	14.70** (±0.14) -38.49
300	214.90*** (±6.65) -33.82	46.55*** (±4.31) -54.70	9.70*** (±0.71) -42.94	53.15*** (±3.61) -36.61	15.30** (±0.42) -28.34	9.0*** (±1.13) -62.34

Each value is expressed as mg kg^{-1}
Values in parenthesis indicate standard deviation
Each value is a mean of three determinations

* Significant (p = 0.01 to 0.05)
** Very Significant (p = 0.001 to 0.01)
*** Extremely Significant (p < 0.001)

Figure 1: *Vetiveria zizanioides* (L.) Nash with complex root system

The concentration of Mg was slightly increased in the leaves of this plant and that at the lower levels of salinity. The level of 300 mM NaCl appears to be inhibitory in the uptake of magnesium. Very little attention has been paid towards the role of Mg^{++} in the plants in their salt tolerance. In *Pongamia pinnata*, Mg^{++} content did not exhibit any definite relationship with the increase in salinity (Singh and Yadav, 1999). Khan *et al*. (2000a) noticed that the leaf Mg^{++} concentration decreased with increasing salinity in halophyte, *Suaeda fruticosa* L. Forssk. Similar observations were made in *Sporobolus virginicus* (Marcum and Murdoch, 1992), alfalfa (Eschie and Rodriguez, 1999), cowpea genotypes (Murillo-amador *et al*., 2002), bittler almond (Shibli *et al.,* 2003) and in *Pinica granatum* (Naeini et al., 2004). El-Katony (1998) reported increase in Mg^{++} in all parts of *Linum ustitatissium* where most of it was allocated to stem. Increase in Mg^{++} under salinity stress has been reported in *Salvadora persica* (Dagar *et al.,* 2004), barley (Cramer *et al.,* 1991) and in tomato (Grava *et al.,* 2001).

The influence of NaCl salinity on iron content of the leaves of *Vetiveria zizanioides* is shown in the same table. From the results it is evident that leaf iron concentration was increased with increase in the level of salinity upto 200 mM NaCl. However it was decreased drastically at 300 mM concentration of NaCl in the rooting medium. The highest increase in the concentration of Fe for the *Vetiveria* was 16.21% at 200 mM NaCl. Lazof and Bernstein (1999) have found that salinity had no effect on leaf Fe^{+++} content in lettuce. The root Fe^{+++} content did not change with the salt applications in wheat, rice (Alpaslan *et al*., 1998) and zucchini (Villora *et al*., 2000). However, El-Hamdaoui *et al*. (2003) have recorded that salinity caused to reduce iron content in pea plants, where it is an important nutrient for plant growth and development particularly for symbiotic nitrogen fixation. Sanchez-Raya and Delgado (1996) reported that Fe^{+++} transport decreased from seed to seedling and to aerial parts by NaCl applications in sunflower. Similar observations were made by Eschie and Rodriguez (1998) in alfalfa and by Shibli *et al*. (2003) in bitter almond. Cramer *et al*. (1991) recorded an increase in Fe^{+++} concentration with time in the barley plant under salt stress. The elevated levels of iron in the leaves of this grass under lower levels of salinity might be involved in photosystem regulation, growth and development of plant and more particularly in protein synthesis while the decreased level of iron at extreme stress i.e. at 200 and 300 mM NaCl might be due to the nutritional imbalance caused by the toxic Na^{+} and Cl^{-} to compete with others.

It is also evident from the table that, in general, there was an increase in zinc concentration in the leaves of this grass at lower levels of salinity. The highest increase being that for *Vetiveria* was 15.13% at 50 mM NaCl. Frans and Maathuis (2006) suggested that there might be an important link between ionic aspects of salinity stress and transition metal homeostasis and it appears that uptake of transition metals like Fe^{++}, Zn^{++} and Cu^{++} is reduced during salinity stress whereas their active extrusion is promoted. The increase in concentrations of zinc in the selected grass at elevated levels of salt concentration might be involved in maintenance of plant growth. The influence of NaCl salinity on copper content of the leaves of *Vetiveria zizanioides* is also shown in Table1. It is evident from the results that, in general, there was an increase in copper concentration in the leaves of the grass upto the 100 mM levels of salinity. The highest increase in the Cu content was 15.59% at 100 mM NaCl but later it was decreased drastically at 200 and 300 mM levels of salinity. Copper is found in a variety of enzymes, including centers of cytochrome oxidase and the enzyme superoxide dismutase (containing copper and zinc). In addition to its enzymatic role, copper is used for biological electron transport. It reacts with amino acids, proteins and other biopolymers producing stable complexes. It plays a vital role in reproductive growth and its requirement is well known in photosynthesis. However, little attention that has been given to this essential micronutrient may be due to its less contribution in ionic balance and osmoregulation in plants under stress conditions. Copper content did not change with salt applications in aerial parts of the plants in two varieties of strawberry ‘Camarosa’ and ‘Osogrande’. However, its content was increased in the root of Camarosa (Kaya *et al*., 2002). Cu^{++} concentration was found increased by increasing salinity levels except for 164 mM NaCl in barley while in wheat higher levels of salinity (240 mM) resulted in an increase in Cu^{++} content (Akman, 2009). Increase in copper content was also recorded by Shibli *et al*. (2003) in bitter almond. Similar results were obtained in different plants like rice and wheat (Alpaslan *et al*., 1998), zucchini (Villora *et al*., 2000) and alfalfa (Esechie and Rodriguez, 1998). Average Cu^{++} levels were found to be greater than 8 ppm in Bermuda grass grown in saline environment (Kaffka, 2001). It appears that an increase in copper concentration in the leaves at lower levels of salinity might be involved in proper functioning of enzymes, biological electron transport and photosynthesis under saline conditions.

Manganese concentration of the leaves of *Vetiveria zizanioides* was increased upto 100 mM levels of salinity. The highest increase in its concentration was 27.25% at 50 mM NaCl but later it was decreased drastically at 200 and 300 mM levels of salinity. Cramer *et al*. (1991) observed the reduced uptake and internal concentration of Mn by salinity in barley plants. Maas *et al*. (1972) found that Mn uptake was increased slightly in tomato and soybean with increasing salinity, but declined significantly in squash. Turhan and Eris (2005) observed that manganese content of corn plants was decreased more with NaCl salinity. Decrease in manganese content due to salinity stress has also been recorded by Gaikwad (1995) in *Catharanthus roseus*. Siddiqui *et al*. (1996) reported no change in manganese content of garlic. An increase in Mn^{++} content was found in wheat and rice (Alpaslan *et al*., 1998) and in zucchini (Villora *et al*., 2000) grown under saline conditions. Increase in manganese content upto 100 mM levels of salinity in the leaves indicates that it might be actively involved in proper functioning of photosynthesis, carbohydrate metabolism and growth of the grass showing an adaptive feature towards salt tolerance capacity. The nickel concentration of the leaves of *Vetiveria zizanioides* was increased upto 50 mM levels of salinity but showed a perfect negative correlation with further increase in the level of salinity. The highest increase in it was 53.86% at 100 mM NaCl but later it was decreased drastically. Ni is a component of urease enzyme (Dixon *et al.*, 2004) playing a vital role in nitrogen metabolism in higher plants (Brown *et al.*, 1987). Nickel deficiency depresses urease enzyme activity (Eskew *et al.*, 1983) and other enzymes responsible for nitrate reduction (Brown *et al.*, 1990). One of the carbon monoxide dehydrogenase enzymes contains of a Fe-Ni-S cluster (Jaouen, 2006). Other nickel-containing enzymes include a class of superoxide dismutase (Szilagyi *et al*., 2004) and a glyoxalase (Thornalley, 2003). The effect of salinity on nickel content of plants has rarely been studied. Ni uptake was clearly depressed by salinity in *Plantago coronopus*, from 633 mg Kg^{-1} in the no-salt treatment to 305 mg kg^{-1} at 9 dSm^{-1} and 152 mg kg^{-1} at 18 dS m^{-1} (Zurayk, 2001). Lead content of the leaves of *Vetiveria zizanioides* has shown a prefect negative correlation with increasing levels of salinity might be due to the non-essential nature in plant growth and development.

CONCLUSION

From the present investigation it appears that an increase in sodium content of the leaves could be attributed to an adaptive feature of the plants to unfavourable conditions caused by the excess of NaCl in the rooting medium. The chloride was increased in the leaves at all levels of salinity and showed a perfect positive correlation with the increasing concentration of NaCl salinity while uptake of calcium at lower levels of salinity can be considered as an adaptive feature of the grass. Similarly, elevated levels of potassium in the experimental species under stress might be involved in osmotic regulation and many essential enzymes activation. The elevated levels of iron in the leaves under lower levels of salinity might be involved in photosystem regulation, growth and development of plant. The increase in concentrations of zinc at elevated levels of salt concentration might be involved in maintenance of plant growth while increase in copper concentration at lower levels of salinity might be involved in proper functioning of enzymes and photosynthesis under saline conditions. Increase in manganese content might be actively involved in proper functioning of photosynthesis, carbohydrate metabolism and growth. In contrast to the ions the nickel and lead showed perfect negative correlation with further increase in the level of salinity and might be due to the non-essential nature in plant growth and development.

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CONFLICT OF INTEREST : Nothing