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# DESALINZATION AND FORTIFICATION OF SOIL USING POTASSIUM CHLORIDE

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## ABSTRACT

This study was conducted on saline soil collected from Biosaline Research Station (BSRS) of Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad, Pakistan to determine the effect of potassium fertilizer (KCl) on growth performance of *Eucalyptus camaldulensis*. Potassium was applied at 100 and 200 kg $K_2O$ $ha^{-1}$ as KCl. Results showed that most agronomic parameters like number of branches, leaves per plant, fresh and dry weight and ionic uptake of potassium and chloride increased in *Eucalyptus camaldulensis* due to soil applied KCl. However, 200 kg $K_2O$ $ha^{-1}$ (as KCl) was more effective in producing higher biomass than 100 kg $ha^{-1}$ in salt-affected wastelands. It was concluded that application of KCl (muriate of potash) could increase the growth and nutrients uptake of *Eucalyptus camaldulensis* in salt-affected soil.

**Key-words:** K-Fertilizer, growth parameters, *Eucalyptus*, saline soil.

## INTRODUCTION

Land deterioration and lack of its utilization for food, timber, fodder and industrial raw materials is being observed all over the world but it is more acute in the developing and under developed countries. In many low rain fed areas, good soils are scanty with their on the whole output declining (Barungi *et al*., 2013) because of soil dilapidation and lack of appropriate soil and water management practices. Salt-affected soils, which are prevalent in low rain-fed and coastal counties of sub-humid areas, have low crop yield. There are 380 million hectares of salt-affected soils on earth's land surface, and of these 140 million hectares are extremely saline (IAEA, 1995) and have higher electrical conductivity (EC). In many region of the world, foodstuff, firewood and trade raw material production is harshly affected by high salt contents in soils. In many part of the southern Asia and the Near East, several million hectares of agricultural land are exaggerated by salinity (e.g. 6.3 million ha in Pakistan and 2.5 in India) causing significant losses in plant production. It is expected that nearly 10 % of the total land of the world used for agricultural production is badly affected by soil salinity (IAEA, 1995). Literature is well documented on various aspects of chemical reclamation of saline sodic soils (Vance *et al*., 2008; Sutter and Cihacek, 2009) and on efficiency and cost effectiveness of biological and chemical methods of reclamation (Ahmad and Chaudhry, 1990; Qadir *et al*., 1996a, 1996b). The recovery of salt-affected soils by chemical amendments is a well-known technology, while, traditional reclamation methods have been proved to be hard (Rafiq, 1990), derisory (Qureshi, *et al*., 1992), costly (Qureshi, 1993), and too costly on highly impervious dense saline-sodic soils in Pakistan. Further, under the on hand situations, not only the extent of this approach is limited, its sustainability is also uncertain (Qureshi, 1993; Qureshi and Barrett-Lenard, 1998). Siddiqui, (1994) stresses the need for plantation of halophytes that can produce timber, forage and fuel wood on saline land. The other approach is based on growing salt tolerant plant species and use of saline waters to utilize salt-affected soils which has been explored to a lesser extent (Qureshi and Barrett-Lenard, 1998). It appears that there is a great scope to grow salt tolerant trees for reforestation on waste land both under dry and waterlogged condition. *Eucalyptus camaldulensis* Dehnh. has been identified as a tolerant tree species to salinity and has more than 85% survival rate under saline soil conditions (Qureshi *et al.*, 2000). Hence, it is the most successful tree species under a variety of saline conditions (Qureshi, 1993). *Eucalyptus* has been planted successfully under a variety of ecological conditions of Pakistan (Siddiqui, 1994) and its survival in nutrient solution up to 50 dS $m^{-1}$ in aerobic conditions (Marcar, 1989) and up to 42 dS $m^{-1}$ in both aerobic and waterlogged conditions (Moezel *et al*., 1988) has been reported. Studies on the separate effect of salinity on growth of some *Eucalyptus* species are well documented (Sun and Yadav., 1985; Marcar, 1989; Pearce- Pinto *et al.*, 1990; Marcar, 1993; Clemen and Pearson, 1997; Qureshi *et al.,* 2007). Most studies showed that nutrients are involved in basic physiological processes related to photosynthesis and leaves growth (Suar *et al.*, 2000) and low fertility resulted in reduced growth and poor performance (Harwood *et al.*, 1993). Application of nitrogen fertilizer has been shown to enhance growth of *Eucalyptus nitens* (Williams *et al.*, 2003*)* and phosphorus fertilizer induces early vegetative phase in some *Eucalyptus* trees. K fertilization has been used for a long time to increase leaf growth (Teixeira *et al*., 2006). Despite the huge influence of K fertilization on *Eucalyptus* growth, little information is available on the consequences of K addition for growth and efficiency (Binkley *et al.*, 2004). Keeping in view the importance of K application in saline soils for sustainability of the stands, the present study is designed to investigate whether *Eucalyptus* growth could enhance by applying muriate of potash under salt-affected soils.

## MATERIAL AND METHODS

Saline soil was collected from Biosaline Research Station (BSRS) of Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad, Pakistan and the samples were then analyzed for chemical properties according to the standard methods described in U.S. Salinity Laboratory Staff Hand Book-60 (1954). The seeds of unpedigreed *Eucalyptus camaldulensis* Dehnh. were sown in the plastic pots (15 x 30 cm) containing sand for raising the nursery and at the age of 22 days, the seedlings were shifted in polyethylene bags (23 x 10 cm) containing sandy loam soil and were allowed to grow for further three months to develop healthy saplings of *Eucalyptus*. There after, these saplings were planted in pots containing 20kg soil collected from site at BSRS which were irrigated with tap water. Soil characteristics are summarized in table 1. The transplanted saplings were allowed to grow for about 8 weeks on this salt-affected soil. There after, the plants were harvested and their height and diameter were recorded. At harvesting time, the soils samples were also collected to estimate the changes in chemical properties of soil. Then the soil was dried, ground and analyzed for EC, pH, SAR, soluble anions and cations according to the methods described by U.S. Salinity Laboratory Staff, Hand Book-60 (1954).The plant height (inches) was measured with the help of meter rod from the base to the tip of the tree. The number of leaves and green branches per plant were also counted. Fresh weights of whole aerial plants were noted at the time of harvest and dry weight after oven drying the plant material at 70 $^{o}$ for 48 hours.

### Plant analysis

The well ground plant samples (0.2 gram) in triplicate were kept over nightly for digestion after adding 2ml of concentrated $HNO_3$ and then after addition of 6 ml of distilled water the material was boiled for 15 minutes. The supernatant liquid was transferred in a 50 ml volumetric flask following by 3 more washing with hard distilled water and volume was made up to 50 ml (Hand book 60 USDA). Potassium in the plant extract was determined by Flame Photometer (Jenway PFP-7). Chloride in the plant extract was determined by using titration method in which 2 gram ground sample with 20ml distilled water was titrated against $AgNO_3$ by using potassium chromate as indicator with brick red end point.

### Soil analysis

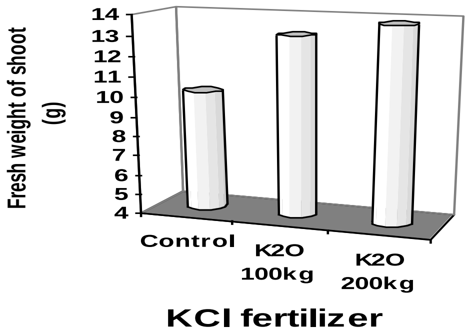
The pH of saturated paste of soil samples with two replicates was recorded by using HANNA digital pH meter 8520. The saturated soil paste was transferred to Buckner's funnel with a filter paper in place then vacuum was applied and extract was collected in tube. Electrical conductivity ECe was measured by using digital conductivity meter (WTW L 538). Soluble sodium (Na) was measured by using Jenway PFP-7 flame photometer. Calcium + magnesium was determined by titration with 0.01 N EDTA solution using Eriochrome Black-T as an indicator. Sodium adsorption ratio (SAR) was calculated by the following formula $SAR=Na/ (Ca+Mg/2)^{1/2}$. The data obtained were subjected to analysis using Duncan's New Multiple Range Test (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

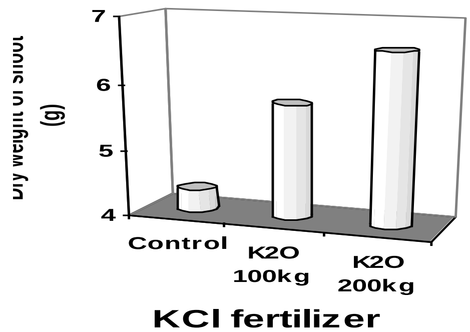
### Influence of KCl fertilization on plant growth parameters

Fresh and dry weights of shoot, number of branches and leaves, enhanced by application of K2O @ 100 and 200 kg as KCl in Fig. 1(a, b, c & d).The difference in mean plant height between the two treatments was not marked. Potassium fertilization enhanced the fresh weight of the shoot by 23% and 26%, respectively (Fig. 1, a) and it was the lowest in control treatment. However, shoot dry mass (Fig.1, b) was enhanced by 24% and 34%, respectively. Basile *et al.* (2003) showed a significance increase in photosynthetic biomass on addition of K-fertilizer in deciduous species. In contrast, a large response of KCl fertilization was observed. Potassium chloride addition led to an increase (20 %) in number of branches in both the treatments as compared to control (no $K_2O$) (Fig. 1, c) however, response of plant height to 100 kg $K_2O$ was limited and somewhat negative at 200 kg $K_2O$ as compared to control (Fig. 1, e). Many scientists have discussed similar results for Eucalyptus growth on potassium fertilization. Laclau *et al*. (2008) observed an improvement in growth while Whitehead and Beadle (2004) reported broad leaf growth and physiological regulation in *Eucalyptus*. A positive effect of K addition on *Eucalyptus grandis* was observed by Basile *et al.* (2003). Binkley *et al.*, (2004) recommended addition of potassium and Almedia *et al.*, (2010) nitrogen+potassium for commercial plantation of *Eucalyptus grandis*. Leaf production was significantly enhanced by KCl addition in both the treatments (Fig. 1, d) however; the increase in number of leaves was higher @

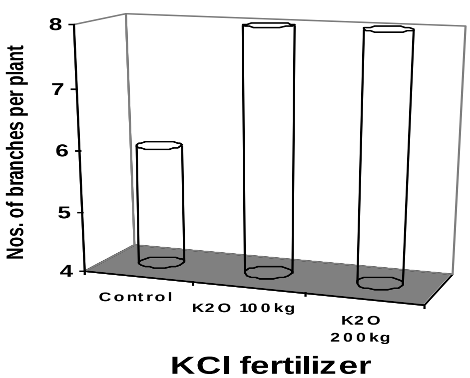
200 kg than 100 kg of $K_2O$ and increased by 40% and 42%, respectively. Fife *et al.* (2008) reported substantial internal re-translocation of K in Eucalyptus leaves. Growth of *Eucalyptus* and soil fertility enhanced in Brazil with K fertilization (Goncalves *et al.*, 2008). Kitajima *et al*. (2002); Escudero and Mediavilla (2003) also discussed the increase in photosynthesis rate with K availability. Oikawa *et al.*, (2006) showed increase in leaf production by addition of potassium fertilizer.



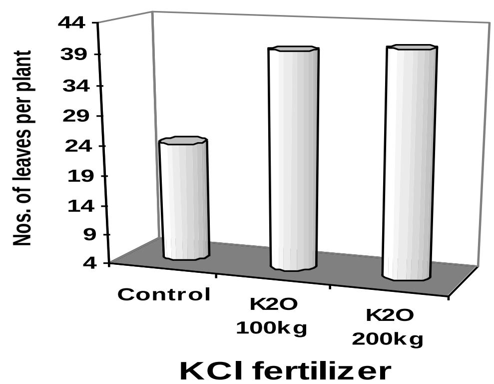

(a)



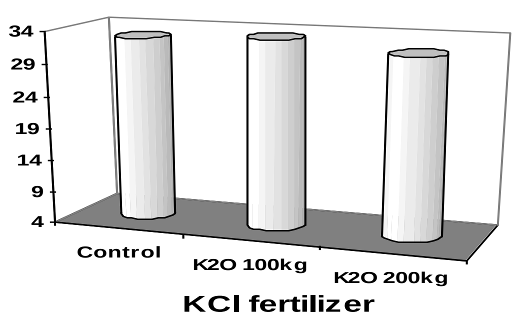

(b)




(c)




(d)




a) Fresh weight of shoot
b) Dry weight of shoot
c) Nos. of branches per plant
d) Nos. of leaves per plant
e) Plant height

(e)

Fig. 1. Agronomic data of Eucalyptus camaldulensis after eight weeks of growth in saline-sodic soil fertilized with 100 and 200kg $K_2O$ as KCl.

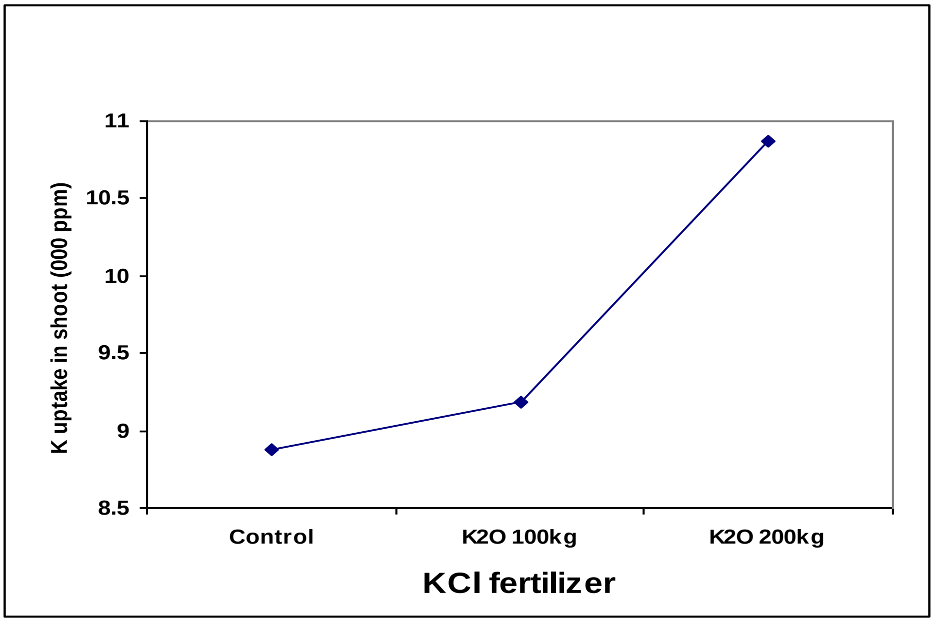



Fig. 2. Potassium uptake in *Eucalyptus camaldulensis* after eight weeks of growth in saline-sodic soil fertilized with 100 and 200kg $K_2O$ as KCl.

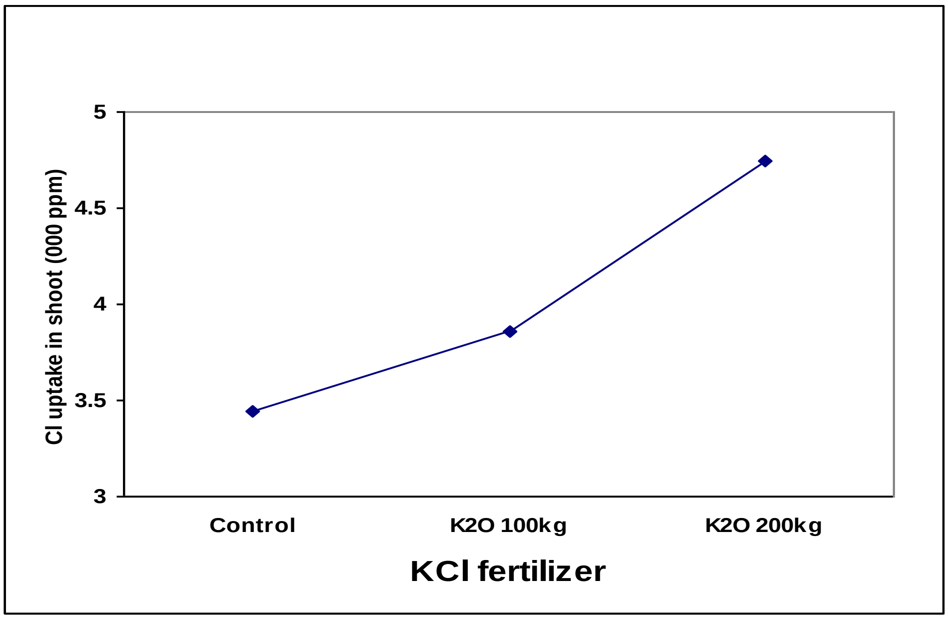



Fig. 3. Chloride uptake in *Eucalyptus camaldulensis* after eight weeks of growth in saline-sodic soil fertilized with 100 and 200kg $K_2O$ as KCl.

**Potassium and chloride uptake in Eucalyptus**

Potassium controls plant functions including photosynthesis, respiration, assimilate translocation and many enzymatic systems which results in great influences on growth and quality of plant and fruit. The effect of K can also be indirect as a result of its positive interaction with different plant nutrients and production practices (Stewart *et al*., 2005, Wang *et al.*, 2013). The present study showed positive effect of K addition in shoot content of Eucalyptus. Potassium uptake in shoot increased gradually in both the treatments, however, it was maximum in the treatment applied @ 200 kg (18%) followed by 100 kg (3%) of $K_2O$ $ha^{-1}$ as compared to control (Fig. 2). Potassium dynamics in the leaves were consistent in all the plots where K fertilizer was applied (Laclau *et al.*, 2008). The increase in K content in plant could be due to luxury consumption (Qureshi *et al.*, 2007). Potassium concentration and its uptake were increased significantly with its increasing application rates (Chahabra, 1985). Chloride concentration varies widely between plant species and cultivars. Chlorides of plants generally accumulate in vegetative parts, mainly in the leaves. Generally, woody plant is susceptible to Cl toxicity. The present investigation showed chloride concentration in shoot were increased with the increasing levels of KCl application i.e. more uptake was observed at 200 Kg followed by 100 Kg of $K_2O$ as compared to control and its concentration in Eucalyptus enhanced by 27% and 11.7% respectively. (Figure3). Yang and Blanchar, (1993) observed KCl increased the Cl concentration in soybean plant. Christensen *et al.,* (1981) reported increase in Cl content of plant when applied 355 kg Cl ha-1 of soil. The chloride content of grain, fruit and seeds were very low and hardly affected by the Cl concentration of the soil solution and its concentration in sugar beet leaves increased from 9.8 to 54.1 g $kg^{-1}$ (Zhou and Zhang, 1992). Schumacher and Fixen, (1989) also described residual effect of Cl on wheat and corn crops.

Table1. Changes in soil characteristics with soil applied KCl

| Soil properties | Treatments | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | | | | KCl @ 100 kg $K_2O$ | | | | KCl @ 200 kg $K_2O$ | | | |
| | Min | Max | Av | SD | Min | Max | Av | SD | Min | Max | Av | SD |
| pHs | 8.52 | 8.69 | 8.6 | 0.08 | 8.52 | 8.85 | 8.6 | 0.1 | 8.5 | 8.7 | 8.6 | 0.1 |
| $EC_e$ ($dSm^{-1}$) | 6.48 | 9.61 | 7.7 | 1.35 | 6.48 | 8.27 | 7.5 | 0.7 | 6.62 | 9.63 | 7.7 | 1.3 |
| Na ($meqL^{-1}$) | 110 | 181 | 142.3 | 30.58 | 108 | 133 | 124.3 | 10.5 | 108 | 142 | 123.2 | 14 |
| Avail. K (ppm) | 165 | 176 | 170 | 4.65 | 168 | 184 | 178 | 6.6 | 177 | 201 | 181 | 11 |
| Ca + Mg ($meqL^{-1}$) | 36 | 50 | 43.5 | 5.8 | 36 | 41 | 36.9 | 2.6 | 26.2 | 53 | 36.9 | 11 |
| Cl ($meqL^{-1}$) | 18 | 26 | 21 | 3.56 | 30 | 52 | 48 | 10 | 41 | 56 | 52 | 6.3 |
| SAR (cmol $L^{-1}$)$^{1/2}$ | 29.3 | 30.5 | 30.2 | 1.1 | 28.3 | 30.1 | 28.9 | 0.9 | 24.6 | 30.6 | 27.6 | 2.6 |

**Post harvest changes in soil characteristics**

Results indicated marked changes in soil physico-chemical properties with *Eucalyptus* plantation when $K_2O$ applied @ 200 and 100 kg $ha^{-1}$. Sodium decreased from 142.3 meq $L^{-1}$(control) to 123.2 and 124.3 meq $L^{-1}$ in both the treatments respectively. Available K increased with the increase in rate of applied K2O with having concentration 181 and 178 ppm (when $K_2O$ applied @ 200 and 100 kg) as compared to 170 ppm (control). Chloride concentration showed similar trend like K and the Cl concentration was also increased with increase in K-fertilization and was 52, 48 as compared to 21 meq $L^{-1}$(control) respectively. The reduction in $Ca^{++}$ + $Mg^{++}$ content was same in both the treatments (36.9 meq $L^{-1}$) as compared to control (43.5 meq $L^{-1}$). However, the present study showed no marked changes in soil pH, ECe and SAR with addition of K-fertilizer. Plantation of *Eucalyptus* is beneficial for soil because it absorbs more Na+ and other soluble toxic ions from soil which were retained in root and limited amount of those were transferred to leaves which is typical character f salt tolerant plants (Qureshi *et al.*, 2000). On the other hand increase in Ca+Mg in soil is also a good sign to suppress the $Na^+$ ion toxicity as sulfates or chlorides of $Ca^{++}$ and $Mg^{++}$ react with $Na^+$ to form chlorides/sulphates of Na and leach down, resulting in improvement of infiltration, porosity, aeration and structure of soil (Gadallah, 1996).

**Conclusion**

Most growth parameters like number of branches, leaves per plant, fresh and dry weight and ionic uptake (potassium and chloride) increased in *Eucalyptus camaldulensis* due to the application of potassium fertilizer (KCl). The KCl @ 200kg $K_2O$ $ha^{-1}$ produced maximum biomass, K and Cl ion uptake in salt-affected wastelands. It was concluded that KCl (muriate of potash) could be used profitably for better growth of *Eucalyptus camaldulensis* as a source of potassium in salt-affected soils of Pakistan.

**REFERENCES**


Ahmad, N and G.R.Chaudhry (1990). *Strategies of Irrigated Agriculture of Pakistan*. Shehzad Nazir 61-B/2 Gulberg-3, Lahore, Pakistan.

Almeida J.C.R., J.P Laclau, J.L.D.M. Gonçalves, J. Ranger, L. S Andre (2010). A positive growth response to NaCl applications in Eucalyptus plantations established on K-deficient soils. *For. Ecol. Manag.* 259:1786–1795.

Barungi, M., D. H. Ng'ong'ola, A. Edriss, J. Mugisha, M. Waithaka, and J. Tukahirwa (2013). Factors Influencing the Adoption of Soil Erosion Control Technologies by Farmers along the Slopes of Mt. Elgon in Eastern Uganda. Journal of Sustainable Development, 6 (2): 9-25.

Basile, B., E.J. Reidel, S.A Weinbaum and T.M. Delong (2003). Leaf potassium concentration, CO2 exchange and light interception in almond tree. *Society of Horticulture*. 98: 185-194.

Binkley, D., J.L. Stapew., M.G. Ryan (2004). King about efficiency of resource use in forests. *Forest Ecology and Management*, 193: 5-16.

Chahabra, R. (1985). Crop response to P and K fertilization of a sodic soil. *Agronomy Journal*, 77: 699-702.

Christensen, N.W., R.G. Tayler, T.L. Jackson and B.L. Mitchell (1981). Chloride effects on water potentials and yield of winter wheat infected with take-all root rot. *Agronomy Journal* 73: 1053-1058.

Clemens, J. and C.J. Pearson (1997). The effect of water logging on the growth and ethylene contents of *Eucalyptus robusta*. *Oecologia*, 29: 249-255.

Escudero, A. and S. Mediavilla (2003). Decline in phytosynthetic nitrogen use efficiency with leaf age and nitrogen resorption as determinants of leaf life span. *Journal of Ecology*, 91:880-889.

Fife, D.N., E.K.S.Nambiar and E. Saur (2008). Retranslocation of foliar nutrients in evergreen tree species planted in a Mediterranean environment. *Tree Physiology* 28, 187–196.

Gadallah, M.A.A. (1996). Absisic acid, temperature and salinity interactions on growth and some mineral elements in *Carthmus* plants. *Plant Growth Regulation*, 29, 225-236.

Gonçalves J, J. Stape , J. P. Laclau , J. P. Bouillet and J. Ranger (2008). Assessing the effects of early silvicultural management on long-term site productivity of fast-growing eucalypt plantations: the Brazilian experience. *South. For.* 70:105–118.

Harwood, R. R., , M. E.Carter, R. Gomaz, S. P. Gliesman, A. Gomez-Pompa, L. S. Hardin, W. A. Hill, R. Lal, G. Levine, A. E. Lugo, A. G. Power, V. W. Ruttan, P. A. Sanchez, E. A. Wright and P. C. Serrao (1993). Sustainable Agriculture and the Environment in the Humid Tropics. National Research Council, National Academy Press, Washington DC.

IAEA. (1995). Management strategies to utilize salt affected soils: Isotopic and conventional research methods. IAEA-TECDOC-814, Vienna, Austria. Johnston A.E. 2001. Potassium and Chloride in Crops and soils. International Potash Institute, Basel, Switzerland. IPI Res.Topic. No.22.

Kitajima, K., S.S. Mulky., M. Samaniego and J. Wright (2002). Decline of photosynthetic capacity with leaf age and position in two tropical pioneer tree species. *American Journal of Botany*, 89: 1925-1932.

Laclau, J. P., J.C.R. Almedia, J. L. M. Goncalves., L.S. Andre, M.Ventura, J. Ranger, R. M. Moreira and Y. Nouvellen (2008). Influence of nitrogen and potassium fertilization on leaf lifespan and allocation of above-ground growth in *Eucalyptus* plantation. Tree physiology. 29:111-124.

Marcar, N. E. (1989). Salt tolerance of frost-resistant *Eucalyptus. Journal New Forestry*, 3: 141-149.

Marcar, N. E. (1993). Water logging modifies growth, water use and ion concentration. seedling of salt treated *E .camaldulensis, E. robusta* and *E. globules. Australian Journal of Plant Physiology*, 20:1-3.

Moezel, V. P.G., L.E. Watson, G.V.N. Pearce-Pinto and D.T. Bell (1988). The response of six *Eucalyptus* species and *Casuarina obesa* to the combined effect of salinity and waterlogging. *Australian Journal of Plant Physiology*, 15: 465-474.

Oikawa, S., K. Hikosaka and T. Hirose (2006). Leaf life span and lifetime carbon balance of individual leaves in a stand of an annual herb, *Xanthium canadense, New Phytologist,* 172: 104-116.

Pearce-Pinto, G.V.N., P.G.Vander Moezel and D.T.Bell (1990). Seed germination under salinity stress in western Australian species of *Eucalyptus*. *Seed Science Technology*, 18 (1): 113-118.

Qadir, M., R.H.Qureshi and N. Ahmad (1996b). Reclamation of a saline-sodic soil by gypsum and *Leptochloa fusca*. *Geoderma*, 74: 207-217.

Qadir, M., R.H.Qureshi, N. Ahmed and M. Ilyas (1996a). Salt tolerant forage cultivation on a saline-sodic field for biomass production and soil reclamation. *Land Degradation Development*, 7: 11-18.

Qureshi, R.H. (1993). Alternative strategies for tackling the soil salinity problem, Dept. of Soil Sci., Univ. of Agric., Faisalabad , Pakistan. P.120.

Qureshi, R.H. and E.G Barret-Lennard (1998). Saline agriculture for irrigated land in Pakistan : a hand book Australian Centre for International Agricultural Research, Canberra, Australia.

Qureshi, R.H., N. Ahmad, M. Aslam, M. Qadir and T. Ahmad (1992). Reclamation of a dense saline-sodic soil by vertical leaching and induced horizontal flushing. In: Subsurface Drainage on Problematic Irrigated Soils: sustainability and cost effectiveness (ed. Vlotman, W. F.). Proc. 5th Int. Drainage Workshop, Water and Power Development Authority-International Waterlogging and Salinity Res. Inst., Lahore, Pakistan. Pp. 687-695.

Qureshi, T. M., M.Y. Ashraf, A. Bano and F. Hussain (2007). Ion partitioning, K/Ca and K/Na ratio and growth of some provenances of *Eucalyptus camaldulensis* grown under NaCl salinity. *Pakistan Journal of Botany*, 39 (7): 2565-2574.

Qureshi, T.M., M. Aslam, M.Y.Ashraf and F. Hussain (2000). Performance of *Eucalyptus camaldulensis* under different types of salt-affected soils. *International Journal of Agriculture and Biology*, 2(1): 45-47.

Rafiq, M. (1990). Soil resources and soil related problems in Pakistan. In: Soil Physics Under Stress Environments (eds. Ahmed, M., M. E. Akhtar and M. I. Nizami) BARD, Islamabad, Pakistan. pp. 16-23.

Schumacher, W. K. and P. E. Fixen (1989). Residual effects of chloride application in a corn wheat rotation. *Soil Science Society American Journal*. 53: 1742-1747.

Siddiqui, K.M. (1994). Tree planting for sustainable use of soil and water with special reference to the problem of salinity. *Pakistan Journal of Forestry*. 44(3):97-102.

Steel, R.G.D. and J.H. Torrie (1997). Principles and Procedures of statistics: A biometrical approach. 3rd ed. McGraw Hill Book Co. Inc., New York.

Stewart, W. M., D.W. Dibb, A.E. Johnston and T.J Smith (2005). The contribution of Commercial Fertilizer Nutrients to Food Production. *Agronomy Journal*, 97: 41-47.

Suar, E., E.K.S. Nambiar and D.N. Fife (2000). Foliar nutrient translocation in *Eucalyptus globulus*. *Tree Physiology*. 20: 1105-1112.

Sun, K. and J. S. P. Yadav (1985). Response to salt stress of 16 *Eucalyptus* species. *Grevillea robusta*, Lophostkkemon confertus and Pinus caribera var. Houndarensis *Forest Ecology and Management*. 60(12): 1-14.

Sutter T. M. D and L. J. Cihacek (2009). Potential Agricultural Uses of Flue Gas Desulfurization Gypsum in the Northern Great Plains *Agronomy Journal*. 101(4): 817 - 825.

Teixeira, L. A., J.C. Riggiero. C. W. Natale and D.F.B. Manutencao (2006). Nanicao pormeio do manejo das adubacoes nitrogeadae potassicae da irrigacao. *Revista Brasileira de Fruticultura* 23: 699-703.

U.S. Salinity Laboratory Staff (1954). Diagnosis and Improvement of Saline and Alkali Soils. USDA. Handbook 60. Washington D.C.

Vance, G. F., L. A. King and G. K. Ganjegunte (2008). Soil and Plant Responses from Land Application of Saline-Sodic Waters: Implications of Management. *Journal of Environment Quality*. 37 (5 Supplement): S-139 - S-148.

Wang. M, Q. Zheng, Q. Shen, and S.Guo (2013). The Critical Role of Potassium in Plant Stress Response. *Int J Mol Sci.* 14(4): 7370–7390.

Whitehead D. and C.L. Beadle (2004). Physiological regulation of productivity and water use in *Eucalyptus*: a review. *Forest. Ecol. Manag*. 193:113–140

Williams, D.R., B.M. Potts, and P.J Smethurs (2003). Promotion of flowering in *Eucalyptus nitens* by paclobutrazol was enhanced by nitrogen fertilizer. *Canadian Journal of Forest Research.* 33: 74-81.

Yang, J and R.W. Blanchar (1993). Differentiating chloride susceptibility in soybean cultivars. *Agronomy Journal*. 85: 880-885.

Zhou, B.K and X.Y. Zhang (1992). Effect of chloride on growth and development of sugar beet. *Soil Fertility*. (Chinese) 3, 41-43.

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