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Medicinal Plant Lemon Grass (*Cymbopogon Citratus*) Growth under Salinity and Sodicity

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Abstract

Salinity with sodic condition disturbs germination, retards emergence, and slow down seedling development of Lemon Grass (*Cymbopogon citratus)*.Lemongrass is a perennial grass plant widely distributed worldwide and most especially in tropical and subtropical countries. This research experiment was designed to evaluate the influences of (4 dSm^{-1}+ 13.5 (mmol $L^{-1})^{1/2}$, 5 dSm^{-1} + 25 (mmol $L^{-1})^{1/2}$, 5 dSm^{-1} + 30 (mmol $L^{-1})^{1/2}$, 10 dSm^{-1} + 25 (mmol $L^{-1})^{1/2}$ and 10 dSm^{-1} + 30 (mmol $L^{-1})^{1/2}$) on biomass produce of lemon grass against salt tolerance. The uppermost biomass yield (45.53 $gpot^{-1}$) was produced by 4 dSm^{-1}+ 13.5 (mmol $L^{-1})^{1/2}$ treatment. The increase in the intensity of salts reduced the growth of lemon grass. Lower biomass yield (79.33 $gpot^{-1}$) was gained at 10 dSm^{-1} + 30 (mmol $L^{-1})^{1/2}$**.** 5 dSm^{-1} + 25 (mmol $L^{-1})^{1/2}$ treatment performed enhanced outcome i.e. the least reduction % over control (5.87). Salinity- sodicity showed serious effect on the growth reduction from 5.87% to33.60%. This reduction gap was affected by the negative effect of salinity and sodicity on Linseed growth. Salinity- sodicity showed severe impact on the growth reduction from 5.87% to33.60%. Based on the findings, lemon Grass (*Cymbopogon citratus)*.was capable to grow up the maximum at 4 dSm^{-1}+ 13.5 (mmol $L^{-1})^{1/2}$ treatment.

Keywords: *Cymbopogon citratus*, Saline- sodic, Medicinal value and biomass yield

Major classification: Food Science (Food Nutrition)

1. Introduction

Sodicity causes structural problems in soils created by physical processes such as slaking, swelling and dispersion of clay; as well as conditions that may cause surface crusting and hard setting (Quirk, 2001). Abiotic stresses, such as salinity, always limit the growth, distribution and production of plants. According to a recent estimate, 1128 million ha of global land is affected by salinity and sodicity (Chen *et al.,* 2016; Akhtar *et al.,* 2015). Due to high evapotranspiration and low rainfall, the majority areas of Iran have been classified as arid and semi-arid. Salinity is one of the significant factors affecting the productivity of plants. Considerable attention is paid to the study of salt stress effects on the physiological symptoms in various types of plants (Munns and Gilliham 2015, Negrão *et al.* 2017).

Lemongrass is a perennial grass plant widely distributed worldwide and most especially in tropical and subtropical countries (Francisco *et al.*, 2011). The leaf height is about 100 cm in length and 2 cm in width.

When squeezed, the leaves usually produce yellow or amber colored, aromatic, essential oil (Adejuwon and Esther, 2007). It also enjoyed wide application in folk medicine (Figueirinha *et al.*, 2008). Traditionally, tea made from lemongrass leaves is popular among countries of South America, Asia and West Africa having been widely utilized as antiseptic, antifever, antispeptic, carminative and anti-inflammatory effects. Others are febrifuge, analgesic, spasmolytic, antipyretic, diuretic, tranquilizer and stomachic agent (Viana *et al.*, 2000; Negrelle and Gomes, 2007; Adejuwon and Esther, 2007; Tatiana *et al*., 2011). It is grown around the world and has a century -long record of extensive therapeutic applications in traditional and Ayurvedic medicine in a number of countries (Aftab *et al.,* 2011. Tarkang *et al.,* 2012). It is used in herbal medicine for a wide range of applications based on its antibacterial (Wannissorn *et al.*, 2005), antifungal (Nakagawa *et al.*, 2003), antiprotozoal (Holetz *et al.*, 2003), anti-carcinogenic (Puatonachokchai *et al.,* 2002), anti-inflammatory (Abe *et al.,* 2004), antioxidant (Masuda *et al.*, 2008) cardioprotective (Gazola *et al.*, 2004), antitussive, antiseptic, and anti-rheumatic activities. It has also been used to inhibit platelet aggregation (Tognolini *et al.*, 2006), treat diabetes (Mansour *et al.*, 2002), malaria (Tchoumbougnang *et al.*, 2005), flu, fever, and pneumonia (Negrelle *et al.*, 2007). Several reviews have already appeared in literature on *C. citratus*, describing its phytochemistry and is uses as a medicinal plant (Negrelle *et al.* 2011). In Brazil, for example, the tea, infusion and extracts of *C. citratus*, which are prepared with fresh or dry leaves, are often used in the popular medicine as a restorative, digestive, anti-tussis, effective drug against colds, with an analgesic, anti-hermetic, anticardiopatic, antithermic, anti-inflammatory of urinary ducts, diuretic, antispasmodic, diaphoretic and antiallergic effect (Negrelle and Gomes 2007).

Considering different techniques used to investigate toxicity, cytogenetic bioassay is an important tool to identify the effects of substances at the chromosome level and also on cell cycle (Campos *et al.* 2008, Dragoeva *et al.* 2008). Among the various available methodologies, tests that use plant roots are extremely useful in biological assays, relatively inexpensive and can easily be handled. In addition, plant cytotoxic bioassays have a good correlation with mammalian test systems (Jovtchev *et al.* 2002, Yi and Meng 2003, Celik and Aslantürk 2006, 2007, Lubini *et al.* 2008). The genus *Cymbopogon* is widely distributed in the tropical and subtropical regions of Africa, Asia and America. Comprised of 144 species, this genus is famous for its high content of essential oils which have been used for cosmetics, pharmaceuticals, and perfumery applications (Khanuja *et al.*, 2005). The leading exporter of these plants is Guatemala, trading about 250,000 kg per year and while the USSR sells about 70,000 kg per year (*Lemongrass Production: In Essential Oil Crops, Production Guideslenes for Lemongrass*; 2012). The commercial value of some *Cymbopogon* species is further enhanced by their ability to grow in moderate and extremely harsh climatic conditions (Padalia *et al.,* 2011). In environments where they are not used for cosmetics, drug or perfumery, such as in the Eastern Cape Province of South Africa, these plants have found a good application as roof thatches and grass brooms (Shackleton *et al.,* 2007).

Traditional applications of *Cymbopogon* genus in different countries shows high applicability as a common tea, medicinal supplement, insect repellant, insecticide, in flu control, and as anti-inflammatory and analgesic. *C. citratus* is ranked as one of the most widely distributed of the genus which is used in every part of the world. Its applications in Nigeria include cures for upset stomach, malaria therapy, insect repellent and as an antioxidant (tea) (Aibinu *et al.*, 2007). *C. citratus* and *C. flexuosus* are the prevailing species in Eastern and Western India and have been used locally in cosmetics, insecticides, and for the treatment of digestive disorders and fevers (Jeong *et al.*, 2009; Desai and Parikh, 2012). Cymbopogon citratus (DC.) Stapf (Poaceae family), commonly known as lemon grass, is a perennial tropical grass with thin, long leaves and is one of the main medicinal and aromatic plants cultivated in Algeria. It is also cultivated mostly for its essential oil (EO) in tropical and subtropical regions of Asia, South America, and Africa (Akhila, 2010). Steam distillation produces EO plus hydrosols or aromatic waters, which are often used against inflammatory diseases and microbial infectious (Abe *et al.*, 2003; Alitonou *et al.*, 2006; Tiwari *et al.*, 2010). LGEO has considerable commercial importance because it is used in the manufacture of fragrances, flavors, perfumery, cosmetics, detergents, and pharmaceuticals (Abe *et al.,* 2002; Tyagi and Malik, 2012). Biological research has shown that the various chemical compounds in EO possess antibacterial, antifungal, analgesic, and mosquito repellent properties (Silva *et al.,* 2008; Tyagi and Malik A. 2010; Boukhatem *et al.,* 2014).

Compared to naproxen alone, the naproxen citral combination produced similar anti-inflammatory action but with minimal gastric side effects (Ortiz *et al.*, 2010).

Cymbopogon citratus (DC) Stapf possesses strong lemony odor due to its high content of the aldehyde citral, which has two geometric isomers, geranial (citral a) and neral (citral b) (Shahi *et al.*, 2005). Normally, one isomer does not occur without the other. C. citratus is commonly used in folk medicine for treatment of nervous and gastrointestinal disturbances, and as antispasmodic, analgesic, anti-inflammatory, anti-pyretic, diuretic and sedative (Santin *et al.*, 2009). Studies on extracts from C. citratus leaves have demonstrated antioxidant, anti-microbial and anti-fungal activities (Oloyede, 2009; Pereira *et al.*, 2009; Matasyoh *et al.*, 2011).The results showed that drying method had a significant effect on oil content and composition of aromatic plants (Morsy, 2004; Okoh *et al*., 2008; Shanjani *et al.*, 2010). Different studies reported in literature (Ayars *et al.* 2006; Ayars and Schoneman 2006; Ghamarnia and Gowing 2007; Gowing et al. 2009; Ayars *et al*. 2009; Ghamarnia *et al.* 2012b; Ghamarnia and Jalili 2014 and Akmal Kh *et al.* 2014) showed that around 20–67% of crop water requirements can be met from shallow groundwater tables with different depths from 0.70 to 1.50 m. Moreover, Ayars *et al.* (2006) reported a list of different research findings on the amount of water uptakes made from shallow saline or nonsaline groundwater by different crops during the past 50 years. Ayars *et al.* (2006) have suggested that different parameters, such as groundwater depths and quality, tolerance to salinity, and irrigation depths and frequency affect shallow groundwater use by different crops.

2. Materials and Methods

A pot study was conducted to evaluate the salt tolerance of lemon grass (*Cymbopogon citrates)* as medicinal plant under different saline and sodic concentrations at green house of Land Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan during, 2017. The soil used for the pot experiment was analysed and having 6.9 pH, 2.0 ECe (dSm^{-1}), 5.0 SAR ($(mmol\ L^{-1})^{1/2}$, 23.5 Saturation Percentage (%), 0.30 O.M. (%), 7.21 Available P (mg Kg^{-1}) and 93.8 Extractable K (mg Kg^{-1}). Considering the pre- sowing soil analysis the ECe (Electrical conductivity) and SAR (Sodium Absorption Ratio) was artificially developed with salts of NaCl, Na_2SO_4, $CaCl_2$ and $MgSO_4$ using Quadratic Equation.10 Kg soil was used to fill each pot. 10 seeds of Linseed (***Linum** usitatissimum* L.) as medicinal plant were sown in each pot. Fertilizer was applied @60-50-40 NPK Kg ha^{-1}. Treatments were (4 dSm^{-1}+ 13.5 $(mmol\ L^{-1})^{1/2}$, 5 dSm^{-1} + 25 $(mmol\ L^{-1})^{1/2,}$ 5 dSm^{-1} + 30 $(mmol\ L^{-1})^{1/2}$, 10dSm^{-1} + 25 $(mmol\ L^{-1})^{1/2,}$ 10dSm^{-1} + 25 $(mmol\ L^{-1})^{1/2}$ and 10 dSm^{-1} + 30 $(mmol\ L^{-1})^{1/2)}$. Completely randomized deign was applied with three repeats. Data on biomass yield were collected. Collected data were statistically analysed and means were compared by LSD at 5 % (Montgomery, 2001).

3. Results and Discussions

Salinity seriously decreases the overall productivity of plants including crops by inducing numerous abnormal morphological, physiological and biochemical changes that cause delayed germination, high seedling mortality, poor crop stand, stunted growth and lower yields. So Biosaline agriculture (utilization of these salt- affected lands without disturbing present condition) is an economical approach. Therefore a pot study was designed to evaluate the salt tolerance of lemon grass (*Cymbopogon citratus)* at various salt concentrations. Significant difference was found among treatments on biomass yield (Table-1). Highest biomass yield (79.33 $gpot^{-1}$) was attained by 4 dSm^{-1}+ 13.5 $(mmol\ L^{-1})^{1/2}$ treatment. Biomass yield was decreased as well as the toxicity of salts was increased. Lowest biomass yield (52.67 $gpot^{-1}$) was produced at 10 dSm^{-1} + 30 $(mmol\ L^{-1})^{1/2.}$ Sodicity causes structural problems in soils created by physical processes such as slaking, swelling and dispersion of clay; as well as conditions that may cause surface crusting and hard setting (Quirk, 2001).

Table1: Effect of various salinity and sodicity levels on biomass yield of Lemon Grass (*Cymbopogon citratus*) as medicinal crop

Treatments	Biomass yield ($gpot^{-1}$)	% decrease over control
ECe= 4 dSm^{-1}+ SAR=13.5 $(mmol\ L^{-1})^{1/2}$	79.33a	-------
ECe= 5 dSm^{-1} + SAR=25 $(mmol\ L^{-1})^{1/2}$	74.67a	5.87
ECe= 5 dSm^{-1} + SAR= 30 $(mmol\ L^{-1})^{1/2}$	68.33ab	13.86
ECe= 10dSm^{-1} + SAR=25 $(mmol\ L^{-1})^{1/2}$	60.00cd	24.36
ECe= 10 dSm^{-1} + SAR= 30 $(mmol\ L^{-1})^{1/2}$	52.67de	33.60
LSD at 5%	7.88	

Table-1 also explored the % decrease in biomass yield over control. 5 dSm^{-1} + 25 (mmol $L^{-1})^{1/2}$ treatment performed better results i.e. the least reduction % over control (5.87). Salinity- sodicity showed serious effect on the growth reduction from 5.87 to33.60%. This huge fissure was impacted by the negative effect of salinity cum sodicity on lemon grass (*Cymbopogon citratus)* growth. Such problems affect water and air movement, plant-available water holding capacity, root penetration, runoff, erosion and tillage and sowing operations. Salinity causes both water stress and osmotic stress in plants and the accumulated salt ions have a toxic effect on plants. Water deficit causes a leaf turgor decrease, further causing stomata closure and decreases of stomatal conductance (gs); one of the factors limiting photosynthesis rates (Chaves *et al*. 2009).

4. Conclusion

Based on the findings, lemon grass (*Cymbopogon citratus)* was able to how more salt tolerance at 4 dSm^{-1}+ 13.5 (mmol $L^{-1})^{1/2}$ treatment. Therefore lemon grass (*Cymbopogon citratus)* is suggested to be cultivated in soil salinity farmlands.

References

Abe, S., Maruyama, N., Hayama, K., Inuoye, S., Oshima, H., & Yamauchi, H. (2004). Suppression of neutrophils recruitment in mice by geranium essential oil. *Mediators Inflamm*, *13*(1), 21-24.

Abe, S., Maruyama, N., Hayama, K., Ishibashi, H., Inoue, S., Oshima, H., & Yamaguchi, H. (2003). Suppression of tumor necrosis factor alphainduced neutrophil adherence responses by essential oils. *Med Inflamm, 12,* 323-328.

Adejuwon, A. A., and Esther, O. A. (2007). Hypoglycemic and hypolipidemic effects of fresh leaf aqueous extract of *Cymbopogon citratus* Stapf in rats. *Journal of Ethnopharmacology*, *112*, 440–444.

Aftab, K., Ali, M.D., Aijaz, P., Beena, N., Gulzar, H.J., & Sheikh, K. (2011). Determination of Different Trace and Essential Element in Lemon Grass Samples by X-Ray Flouresence Spectroscopy Technique. *Int Food Res J. 18,* 265-270.

Akhtar, S.S., Andersen, M.N., Naveed, M., Zahir, Z.A., & Liu, F. (2015). Interactive effect of biochar and plant growth-promoting bacterial endophytes on ameliorating salinity stress in maize. *Functional Plant Biology. 42*(8), 770-781.

Aibinu, I., Adenipekun, T., Adelowowtan, T., Ogunsanya, T., & Ogungbemi, T. (2007). Evaluation of the antimicrobial properties of different parts of *Citrus aurantifolia* (lime fruit) as used locally. *Afr. J. Biotechnol*, *2*, 185–190.

Akhila, A. (2010). *Essential oil-bearing grasses: the genus Cymbopogon*. CRC Press, Taylor and Francis Group, p. 108.

Akmal Kh, K., JirkaSim, U., Munir, A. H., Mirzaolim, A., and Irina, F. (2014). Effects of the shallow water table on water use of winter wheat and ecosystem health: Implications for unlocking the potential of groundwater in the Fergana Valley (central Asia). *J. Agric. Water Manage.*, *131,* 57–69.

Aliabadi Farahani, H., Lebaschi, M. H., Shiranirad, A. H., Valadabadi, A. R., and Daneshian, J. (2008). Effects of arbuscular mycorrhizal fungi, different levels of phosphorus and drought stress on water use efficiency, relative water content and proline accumulation rate of coriander (*Coriandrum sativum* L.). *J. Med. Plants Res.*, 2(6), 125–131 (in Persian).

Alitonou, G.A., Avlessi, F., Sohounhloue, D.K., Agnaniet, H., Bessiere, J.M., & Menut, C. (2006). Investigations on the essential oil of *Cymbopogon giganteu*s from Benin for its potential use as an anti-inflammatory agent. *Inter J Aromather 16*, 37-41.

Ayars, J. E., and Schoneman, R. A.(2006). Irrigating field crops in the presence of saline groundwater. *Irrig. Drain. Eng.*, 55(3), 265–279.

Ayars, J. E., Christen E. W., and Hornbuckle, J. W. (2006). Controlled drainage for improved water management in arid regions irrigated agriculture. *Agric. Water Manage. 86*(1–2),128–139.

Ayars, J. E., Shouse, P., and Lesch, S. M. (2009). In situ use of ground water by alfalfa original research article. Agric. *Water Manage*, *96*(11), 1579–1586.

Boukhatem, M.N., Kameli, A., Ferhat, M.A., Saidi, F., & Tayebi, K. (2014).The food preservative potential of essential oils: is lemongrass the answer. *J Verbr Lebensm. 9*, 13-21.

Celik, T.A., and Aslantürk, O.S. (2006). Anti-mitotic and anti-genotoxic effects of *Plantago lanceolata* aqueous extracts on *Allium cepa* root tip meristem cells. *Biologia, 61*, 693–697.

Celik, T.A., and Aslantürk, O.S. (2007). Cytotoxic and genotoxic effects of *Lavandula stoechas* aqueous extracts. *Biologia*, *62*, 292–296.

Chaves, M.M., Flexas, J., & Pinheiro, C. (2009). Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. *Annals of Botany, 103*, 551–560.

Chen, H., Diao, J., Li ,Y., Chen, Q., & Kong, B. (2016). The effectiveness of clove extracts in the inhibition of hydroxyl radical oxidation-induced structural and rheological changes in porcine myofibrillar protein. *Meat Science, 111*, 60-66.

Desai, M.A., & Parikh, J.(2012).Microwave assisted extraction of essential oil from *Cymbopogon flexuosus* (Steud.) wats: A parametric and comparative study. *Sep. Sci. Technol. 47*, 1963–1970.

Dragoeva, A.P., Nanova, Z.D., and Kalcheva, V.K. (2008).Allelopathic activity of micropropagated *Origanum vulgare* ssp. *hirtum* and its effect on mitotic activity. *Allelopath J*. *22*, 131–142.

Figueirinha, A., Paranhos, A., Pe´rez-Alonso, J. J., Santos-Buelga, C., and Batista, M. T. (2008). *Cymbopogon citratus* leaves: Characterisation of flavonoids by HPLC–PDA–ESI/MS/MS and an approach to their potential as a source of bioactive polyphenols. *Food Chemistry*, *110*, 718–728.

Francisco, V., Figueirinha, A., Neves, B. M., García-Rodríguez, C., Lopes, M. C., Cruz, M. T., and Batista, M. T. (2011). Cymbopogon citratus as source of new and safe anti-inflammatory drugs: bio-guided assay using lipopolysaccharide-stimulated macrophages. *Journal of Ethnopharmacology*, *133*, 818–827.

Gazola, R., Machado, D., Ruggiero, C., Singi, G., & Mecado, M. (2004). *Lippia alba*, *Melissa Officinalis* and *Cymbopogon Citratus* Effects of the Aqueous Extracts on the Isolated Hearts of Rats. *Pharmacol Res. 50*(5), 477-480.

Ghamarnia, H., and Gholamian, M. (2013). The effect of saline shallow ground and surface water under deficit irrigation on (*Carthamus tinctorius* L.) in semi-arid condition. *J. Agric. Water Manage*. *118*, 29–37.

Ghamarnia, H., and Gowing, J. W. (2007). Root water uptake modeling in the presence of surface irrigation and saline shallow water table. .ICID 22nd European *Regional Conf., Razi Univ., Kermanshah, Iran.*

Ghamarnia, H., Gholamian, M., Sepehri, S., and Arji, I. (2011a). Shallow groundwater use by safflower (Carthamus tinctorius L.) in a semi-arid region. *J. Irrig. Sci., 29*(2), 147–156.

Ghamarnia, H., Gholamian, M., Sepehri, S., Arji, I., and Rezvani, V. (2012b). Groundwater contribution by safflower (*Carthamus tinctorius* L.) under high salinity, different water table levels, with and without irrigation*. J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000389, 156–165.

Ghamarnia, H., Khosravy, H., and Sepehri, S. (2011a). Yield and water use efficiency of (*Nigella sativa* L.) under different irrigation treatments in a semi-arid region in the west of Iran. *J. Med. Plants Res., 4*(16), 1612–1616.

Gowing, J.W., Rose, D. A., and Ghamarnia, H.(2009). The effect of salinity on water productivity of wheat under deficit irrigation above shallow groundwater. *Agric. Water Manage. 96*(3), 517–524.

Holetz, F.B., Ueda-Nakamura, T., Filho, B.D., Cortez, D.G., Morgado-Diaz, J.A., & Nakamura, C.V. (2003). Effect of Essential Oil of *Ocimum Gratissimum* on the Typanosomatid *Herpetomonas Samuelpessoai*. *Acta Protozool*, *42*, 269-276.

Jeong, M.-R., Park, P.B., Kim, D.-H., Jang, Y.-S., Jeong, H.S., & Choi, S.-H. (2009). Essential oil prepared from *Cymbopogon citrates* exerted an antimicrobial activity against plant pathogenic and medical microorganisms. Mycobiology, 37, 48–52.

Jovtchev, G., Stergios, M., and Schubert, I. (2002). A comparison of *N*-methyl-*N*-nitrosourea-induced chromatid aberrations and micronuclei in barley meristems using FISH techniques. *Mutat Res 517*, 47–51.

Lubini, G., Fachinetto, J.M., Laughinghouse, H.D., Paranhos, J.T., Silva, A.C.F., and Tedesc, O. S.B. (2008). Extracts affecting mitotic division in root-tip meristematic cells. *Biologia*, *63*, 647–651.

Mansour, H.A., Newairy, A.S., Youse,t M.I., & Sheweita, M.I. (2002). Biochemical Study on the Effects of Some Egyptian Herbs in Alloxan-Induced Diabetic Rats. *Toxicology, 170*(3), 221-228.

Masuda, T., Odaka, Y., Ogawa, N., Nakamoto, K., Kuninaga, H. (2008). Identification of Geranic Acid, a Tyrosinase Inhibitor in Lemongrass (*Cymbopogon citratus*). *J Agric Food Chem, 56*(2), 597-601.

Matasyoh, J.C., Wagara, I.N., Nakavuma, J.L., & Kibural, A.M. (2011). Chemical composition of Cymbopogon citratus essential oil and its effect on mycotoxigenic Aspergillus species. *Afr. J. Food Sci. 5* (3), 138–142.

Montgomery, D. C. (2001). *Design and Analysis of Experiments* (5th Ed.). New York, USA : John Willey and Sons, p. 64-65.

Morsy, N. F. (2004). Quality evaluation of the essential oil of basil plant dried by different methods. M. Sc. Thesis, Food Sci. and Techno. Dept., Fac. of Agric., Cairo Univ., Egypt.

Munns, R., and Gilliham, M. (2015). Salinity tolerance of crops – What is the cost*? New Phytologist*, *208*, 668–673.

Nakagawa, T., Mazzali, M., Kang, D.H., Kanellis, J., Watanebe, S., & Sanchez-Lozada, L.G. (2003). Hyperuricemia causes glomerular hypertrophy in the rat. *Am J Nephrol*, *1*, 23-27

Negrelle, R.R., & Gomes, E.C. (2007). *Cymbopogon citratus* (DC) Stapf: Chemical Composition and Biological Activities. *Revista Brasileira De Plantas Medicinais, Botucatu*, *9*(1), 80-92.

Okoh, O.O., Sadimenko, A.P., Afolayan, A.J. (2008). The effects of drying on the chemical components of essential oils of *Calendula officinalis* L. *Afr. J. Biotechnol. 7* (10), 1500–1502.

Oloyede, O.I. (2009). Chemical profile and antimicrobial activity of *Cymbopogon citratus* leaves. *J. Nat. Prod. 2*, 98–103.

Ortiz, M.I., Gonzales-Garcia, M.P., & Ponce-Monte, H.A. (2010). Synergistic effect of the interaction between naproxen and Citral on inflammation in rats. *Phytomedicine. 18*, 74-79.

Negrão S., Schmöckel S.M., & Tester M. (2017). Evaluating physiological responses of plants to salinity stress. *Annals of Botany*, *119*, 1–11.

Padalia, R.C., Verma, R.S., Chanotiya, C.S., & Yadav, A. (2011). Chemical fingerprinting of the fragrant volatiles of nineteen indian cultivars of *Cymbopogon* Spreng (Poaceae). *Rec. Nat. Prod. 5*, 290–299.

Pereira, P.P., Puntel, R.L., Boschetti, T.K., & Morel, A.F. (2009). Antioxidant effects of different extracts from *Melissa officinalis*, *Matricaria recutita* and *Cymbopogon citratus*. *Neurochem. Res. J., 34*, 973–983.

Puatonachokchai, R., Kishida, H., Denda, A., Murata, N., Konishi, Y., & Vinitketkumnuen, U. (2002). Inhibitory Effects of Lemon Grass (*Cymbopogon citratus* Stapf) Extract on The Early Phase of Hepatocarcinogenesis after Initiation with Ethyinitrosamine in Male Fischer 344 Rats. *Cancer Letters, 183*, 9-15.

Quirk, J.P. (2001). The significance of the threshold and turbidity concentrations in relation to sodicity and microstructure. *Australian Journal of Soil Research, 39*, 1185–1217.

Santin, M.R., Dos Santos, A.O., Nakamura, C.V., Filho, B.P.D., Ferreira, I.C.P., & Ueda-Nakamura, T. (2009). In vitro activity of the essential oil of Cymbopogon citratus and its major component (citral) on Leishmania amazonensis. *Parasitol. Res. J. 105,* 1489–1496.

Shackleton, C.M., Timmermans, H.G., Nongwe, N., Hamer, N., & Palmer, N.R. (2007). Direct-use values of non-timber forest products from two areas on the Transkei Wild Coast. *Agrekon 46*, 113–134.

Shahi, A., Kaul, M., Gupta, R., Dutt, P., Chandra, S., & Qazi, G. (2005). Determination of essential oil quality index by using energy summation indices in an elite strain of Cymbopogon citratus (DC) Stapf [RRL(J)CCA12]. *Flavour Frag. J. 20*, 118–121.

Shanjani, P.S., Mirza, M., Calagari, M., & Adams, R.P. (2010). Effects drying and harvest season on the essential oil composition from foliage and berries of Juniperus excels. *Ind. Crop. Prod. J. 32*, 83–87.

Silva, C.D.B.D., Guterres, S.S., Weisheimer, V., & Schapoval, E.E. (2008). Antifungal activity of the Lemon grass oil and citral against Candida spp. *Braz J Infect Dis. 12*, 63-66.

Silva, P.O., Medina, E.F., Barros, R.S., & Ribeiro, D.M. (2014). Germination of salt-stresses seeds as related to the ethylene biosynthesis ability in three *Stylosanthes* species. *J. Plant Physiol. 171*, 14-22.

Soppe, R.W.O., and Ayars, J. E. (2003). Characterizing ground water use by safflower using weighing lysimeters. *J. Agric. Water Manage. 60*(1), 59–71.

Tarkang, P.A., Agbor, G.A., Tsabang, N., Tchokouaha, R.Y., Tchamgoue, D.A., & Kemeta, D. (2012). Effect of Long-Term Oral Administration of The Aqueous and Ethanol Leaf Extract of *Cymbopogon citratus* (DC. Ex Ness) Stapf. *Ann Biol Res..3*(12), 5561-5570.

Tatiana, F. B., and José, M. S. (2011). Lemongrass and citral effect on cytokines production by murine macrophages. *Journal of Ethnopharmacology*, *137*, 909– 913.

Tiwari, M., Dwivedi, U.N., & Kakkar. P. (2010). Suppression of oxidative stress and pro-inflammatory mediators by Cymbopogon citrates DC. Stapf extract in lipopolysaccharide stimulated murine alveolar macrophages. *Food Chem Toxicol. 48*, 2913-2919.

Tognolini, M., Barocelli, E., Ballabeni, V., Bruni, R., Biandi, M., & Impicciatore, M. (2006). Comperative Screening of Plants Essential Oils, Phenylpropanoid as Basic Core for Antiplatelet Activity. *Life Science, 78*(13), 1419-1432.

Tomlinson, T.R. (2015). Promoting the worldwide use of medicinal plants: Medicinal plants: their role in health and biodiversity.1- 206. University of Pennsylvania press Philadelphia.

Tyagi, A.K., and Malik, A. (2010). Liquid and vapor-phase antifungal activities of selected essential oils against Candida albicans: microscopic observations and chemical characterization of Cymbopogon citratus. *BMC Complement Alternat Med*. *10*, 65.

Viana, G. S. B., Vale, T. G., Pinho, R. S. N., and Matos, F. J. A. (2000). Antinociceptive effect of the essential oil from *Cymbopogon citratus* in mice. *Journal of Ethnopharmacology 70*, 323–327.

Yi, H.L., and Meng, Z.Q. (2003). Genotoxicity of hydrated sulfur dioxide on root tips of Allium sativum and Viccia faba. *Mutat Res, 537,* 109–114.