REVIEW PAPER

Salinity tolerance in turfgrass species

Wendy M. Ramírez-Suárez and Luis A. Hernández-Olivera
Estación Experimental de Pastos y Forrajes Indio Hatuey,
Universidad de Matanzas, Ministerio de Educación Superior
Central España Republicana, CP 44280, Matanzas, Cuba
E-mail: wendy.ramirez@ihatuey.cu

ABSTRACT: Salinity constitutes one of the problems that affect the sustainable development of gardening in tourism areas, golf courses, public spaces and sports fields; by causing stress in the turfgrass species and deteriorating the soil structure. Turfgrass production in Cuba takes place at the Pastures and Forages Research Station Indio Hatuey (Matanzas province), and its starting point are the results obtained at international level to search for alternatives that allow higher utilization of salinization-degraded soils and the increase of the production potential of the grass with the required quality. The objective of this paper is to contribute to the knowledge of salinity tolerance in turfgrass species. It approaches the stress types in plants, especially the stress caused by saline soils; the salinity tolerance mechanisms in plants and the studies conducted in some salinity-tolerant turfgrass species. Understanding the physiological and biochemical mechanisms and evaluating turfgrass species are essential to provide a practical solution for the salinity problem and establish a correct management in the turfgrass areas.

Keywords: electrical conductivity, abiotic stress, saline soil

INTRODUCTION

The versatility and functionality of turfgrass species has had a determinant impact on the accelerated growth of the turfgrass industry in many countries, whose market value has reached up to 35 billion dollars only in the United States. The increase of the surface dedicated to the cultivation of turfgrass species increases in a directly proportional way to the increase of population nuclei in urban zones, for which the demand of plants for landscaping and recreational areas grows exponentially (Huang *et al*., 2014). In this sense, Cuba is not an exception. The main tourism areas of the country are located in the Cuban coasts, which demand large surfaces covered by turfgrass, just like the golf courses which have become a fundamental income source through international tourism (Marrero, 2006).

However, one of the main challenges faced by the turfgrass industry is maintaining a high-quality turfgrass under adverse edaphoclimatic conditions, with minimum inputs and scarce or no environmental impact. The most effective way to address this issue is the development, introduction and exploitation of germplasm that tolerates the main stress factors which affect turfgrass species (Huang *et al*., 2014).

These turfgrass species are affected by several abiotic stress factors that influence especially the turf aesthetic quality, functionality and yield. In that sense, it is not strange that most breeding programs in recent years have been aimed at obtaining varieties tolerant to abiotic stress factors, such as salinity (Abogadallah *et al*., 2010), drought (Barnes *et al*., 2014), shade (Trappe *et al*., 2011) and low temperatures (Li *et al*., 2010), among others.

Hydric stress (caused by salinity and/or drought) is one of the most studied abiotic factors, for two main reasons: first, because it causes severe damage on plants; and, second, due to the large land extension that is affected by these limiting factors (Marcum, 2014). The negative effects of this stress type are significantly increased in coastal zones because of the so-called "island effect", for the high salt content of the waters (Tang *et al*., 2013; Manuchehri and Salehi, 2014).

The current turfgrass production in Cuba is led by the Pastures and Forages Research Station Indio Hatuey (Matanzas province), which has a turfing service that includes the sale, planting, establishment, fertilization, phytosanitary attention and rehabilitation of the turf, and in turn aims at improving the quality of golf courses, sports fields, gardens and public spaces, without forgetting the mandatory respect towards the environment. Likewise, this institution works on the establishment and evaluation of salinity-tolerant grasses and aims at implementing a technology that prevents excessive water consumption, to achieve sustainable development in the new gardening.

Taking such problematic situation into account, the objective of this paper is to contribute to the knowledge about salinity tolerance in turfgrass species.

Distribution, morphology and classification of turfgrass species

Taxonomically most turfgrass species belong to the *Poaceae* family, which is considered highly important due to its cosmopolitan distribution and its usefulness (Kellogg, 2001).

The *Poaceae* family, the largest of flowering plant families, comprises more than 9 000 species practically distributed in all the ecotypes of the planet. However, only fifty of these species have the adequate agro-morphological characteristics to be exploited, because of their functional, recreational and ornamental value, as turf-forming plants. Besides acting as plant cover in public parks, gardens, landscapes, golf courses and sports fields, they are able to reduce soil erosion, eliminate dust and dirt from the air, release oxygen and act as natural filter, elimination the contaminants of underground waters (Uddin and Juraimi, 2013).

Turfgrass species are reproduced by seeds, although they can be vegetatively established through stolons, sods and/or cuttings. They have a dense and fibrous root system which is extended mainly within the first 15-30 cm of soil. In turfgrasses there are three types of stem: crown, flowering culm and creeping or lateral stems, called stolons or rhizomes (Uddin and Juraimi, 2013).

According to the adaptation ranges to the different rainfall and temperature conditions, turfgrass species can be divided into: megathermal (warm latitudes) and mesothermal (cold latitudes). The megathermal ones grow in an optimum temperature range that varies between 24 and 35 ºC and comprise perennial species such as *Buchloe dactyloides* Nutt. (buffalo grass), *Zoysia japonica* Steud. (Zoysia grass), *Cynodon dactylon* L. Pers. (bermuda), *Eremochloa ophiuroides* Munro (centipede grass), *Paspalum vaginatum* Sw. (paspalum), *Stenotaphrum secundatum* Walt. Kuntze (Saint Augustine grass), among others. On the other hand, mesothermal species grow in a temperature range between 10 and 22 ºC and comprise perennial and annual species such as *Festuca arundinacea* Schreb. (tall fescue), *Poa pratensis* L. (Kentucky bluegrass), *Lolium perenne* L. (ryegrass), *Festuca rubra* var. commutata and *Festuca ovina* var. duriuscula (sheep fescue), and *Agrostis stolonifera* L. (creeping bentgrass), (Huang *et al*., 2014).

The most important morphoagronomic characteristics that the species must have for turf formation are: fast germination and establishment, fine texture (leaf width), intense color, strong root system, resistance to trampling, adaptation to low cutting and creeping and slow growth, besides showing resistance and/or tolerance to biotic and abiotic stresses.

Abiotic stress and climate change

In biology, the concept of stress is hard to define, taking into consideration that a certain biological condition can represent stress for an organism and, at the same time, be optimum for another. In a practical way, it can be considered as any adverse strength or condition that inhibits the normal functioning of a biological system (Mahajan and Tuteja, 2005). The term stress in the framework of plant physiology "shows the magnitude of environmental pressure that forces change in the physiology of a plant" (Nilsen and Orcutt, 1996). Levitt (1980) defines stress as: "any environmental factor potentially unfavorable for living organisms".

Plants are affected mainly by two types of stress: biotic and abiotic (physical or chemical). The biotic ones are originated by living organisms and comprise allelopathies and susceptibility to pests and diseases; while the abiotic ones are environmental, such as salinity, high/low temperatures, drought, shade, atmospheric contamination and toxins, among others. Abiotic stresses are one of the main factors that limit plant distribution and productivity of agricultural crops, because they affect negatively plant growth and productivity and trigger a series of morphological, physiological, biochemical and molecular disorders (Bhatnagar-Mathur *et al*., 2008; Cheng, 2014).

In the last decades, the increase of the CO_2 level in the troposphere has triggered global warming and the so-called climate change. These conditions have brought about the increasing appearance of extreme climate conditions, such as large drought and flooding periods, prolonged heat or low temperatures; as well as the increase of soil salinization in many regions of the world, because of the elevation of sea level (Feng *et al*., 2014; Flowers and Colmer, 2015). These atmospheric phenomena drastically affect plant growth and productivity, and constitute an increasing threat for sustainability in agriculture, biodiversity and homeostasis of ecosystems (Feng *et al*., 2014).

Salinization is one of the most urgent environmental challenges to be solved, because of the disturbances it causes in the microbial communities and processes, which affects the C cycle in the soil (Rath and Rousk, 2015); this could limit the role of the soil as an important carbon sink that contributes to the mitigation of the climate change.

In this ecological context it is necessary to identify and study the mechanisms of plants that are able to survive in such complex environments.

Soil salinization. Causes and origin

At present, soil salinization and sodification threaten soil fertility and crop productivity (Singh, 2015); this phenomenon has become a worldwide problem, which affects almost one third of the lands dedicated to agriculture, and is more serious in the arid and semiarid regions, where the scarce rainfall reduces the possibility of washing out the salts that are being supplied with the irrigation waters. The increase of the water demand in the world, especially in the arid and semiarid zones, has forced farmers to use low-quality water in agriculture, mainly from wells, with a high concentration of salts which often exceed the salt-tolerance thresholds of many crops and thus limit their production (Zhang *et al*., 2013; Chen *et al*., 2014; Manuchehri and Salehi, 2014).

Soil salinization precedes the origin of human civilization and still is the main abiotic stress that hinders the productivity and quality of harvests (Lamz and González, 2013). Approximately 20 % of the cultivated area worldwide and nearly half the irrigated lands are affected by this factor (Zulkaliph *et al*., 2013; Egamberdieva and Lugtenberg, 2014); recent studies place the increase of the areas affected by salinity between 1,0 and 1,5 million hectares per year (Wu *et al*., 2014; Zhang, 2014). This situation is daily enhanced, because of the lack of environmental awareness and the irrational exploitation of water resources, besides other edaphoclimatic factors that influence directly soil salinity (Lamz and González, 2013). In this sense, Cuba has an agricultural surface of 6,7 million hectares, from which approximately 15 % (one million hectares) is affected by salinity or sodicity, and this limits the productive potential of Cuban soils (Rodríguez, 2015).

Lamz and González (2013) stated that the term salinity refers to the presence of a high concentration of salts which damages the plants due to its toxic effect and the decrease of the osmotic potential of the soil.

The salinization phenomenon may have several causes; primary or natural salinization occurs in soils which, since their formation, show accumulation of salts due to rock decomposition or volcanic activity; and it is found in sites where evaporation is higher than rainfall, in places close to the sea or which have saline streams and saline groundwater (Gómez *et al*., 2009). However, the most common is secondary salinization, mainly caused by the effects of irrigation, the use of low-quality waters, restricted drainage, low permeability of the soil, and wrong use of fertilization; which causes the accumulation of soluble salts, mainly sodium, in the upper horizons. This situation brings about the loss of land productivity and their subsequent abandonment (Egamberdieva and Lugtenberg, 2014).

Álvarez-Menéndez *et al*. (2008) stated that the natural salt sources in the salinization process in Cuba are:

- Marine aerosols carried by the atmospheric circulation of prevailing winds (East-Southeast and Southeast trade winds) and by waves of cold companion winds from the North.
- Old marine sediments north and south of the Cuban archipelago, constituted by saline gypsum and sandy rocks.
- The accumulation of continental sediments carried by the rivers from the mountains to flat areas during the quaternary period.
- Sea intrusion in calcic groundwater aquifers below the sea level.
- The wind from arid regions can also contribute to the salinization process, dragging a large amount of salts, mainly carbonates, sulfates and chlorides which are suspended (Fuentes *et al*., 2007; Wu *et al*., 2014).

The main soluble constituents of the soil related to salinity are cations (Na^+, Ca^{2+}, Mg^{2+} and K^+), anions (Cl^-), sulfate (SO_4^{2-}), bicarbonate and/or carbonate (HCO_3/CO_3) and nitrate (NO_3^-) (Nizam, 2011; Alshammary, 2013; Wu *et al*., 2014). The high salt concentrations (particularly Na^+) which are deposited can alter its basic structure; the Na^+ cations displace Ca^{2+} from the clayey-humic complex and degrade the soil structure, which leads to a decrease of porosity and, consequently, a reduction of aeration. The high salt concentrations also generate zones of low water potential, which originates more difficulty in the plant to take up water as well as nutrients. Thus, saline stress essentially causes conditions of water deficit in the plant and, subsequently, assumes the characteristics of physiological drought. The ions of higher involvement in saline stress are: Na^+, K^+, H^+ and Ca^+ (Mahajan and Tuteja, 2005).

The most widely used indexes to represent soil salinity are total dissolved solids (TDS) and electrical conductivity (EC); the latter is based on the rate at which the electrical current passes through a saline solution, which is proportional to the concentration of salts in solution. Years ago it was expressed in mmhos/cm, at present it is expressed in $dS.m^{-1}$ (dS = deciSiemens) at 25 ºC (Uddin and Juraimi, 2013); both measures are equivalent (1 mmhos/cm = 1 $dS.m^{-1}$). From the agricultural point of view a soil is classified as saline when it has high concentrations of soluble salts, with an EC of 4 $dS.m^{-1}$ or higher (Uddin and Juraimi, 2013).

Effect of saline stress on the plant processes

Most cultivated plants (cereals, horticultural ones, turfgrasses and other industrial crops, etc.) are susceptible to saline stress (EC > 4 $dS.m^{-1}$), with the subsequent reduction of productivity due to an inadequate nutrition (Egamberdieva and Lugtenberg, 2014).

The intensity with which each stress condition affects plant growth and development depends on several factors, including: the mophophysiological characteristics of the species, cultivar, phenological state, types of soluble salts, intensity and duration of the stress and edaphoclimatic conditions (Shahba *et al*., 2008; Manuchehri and Salehi, 2014). The consequences of growth in a saline medium are mainly due, according to Lamz and González (2013), Bizhani and Salehi (2014) and Manuchehri and Salehi (2014), to the individual or combined effect of the following stress factors:

- Hydric stress. The presence of solutes causes the decrease of the osmotic potential of the soil solution (osmotic stress).
- The toxicity associated to the increase of specific ions, such as sodium and chlorine (saline stress)
- The nutritional unbalance due to the high concentrations of sodium and chloride which reduce the capture of K^+, NO_3^-, PO_4^{3-}, etc.
- The accumulation of reactive oxygen species which destroy the cell membranes and affect vital molecules, such as proteins and nucleic acids.

Effect of saline stress on turfgrass species

Salinity is the main abiotic stress that influences the growth and development of turf-forming plants; affects the normal development of the plant at the morphological, physiological and biochemical levels; and, thus, decreases the visual quality and aesthetic appearance of the turfgrass. Its effects on the growth of turfgrasses are summarized in: the reduction of water assimilation due to osmotic stress, reduction of nutrient assimilation (for example, the assimilation of potassium is decreased by the entrance of Na^+) and increase of root biomass, which increases water absorption and causes interferences with the photosynthetic process (Uddin and Juraimi, 2013). Table 1 describes some studies about the most common effects provoked by saline stress in turfgrasses.

Physiological, biochemical and molecular mechanisms of salinity tolerance

The knowledge of the mechanisms of the salinity tolerance phenomenon in plants is essential to face this world problem.

Plants cannot escape the stress factors as animals do, but they must rather face the environmental changes. That is why understanding the response mechanisms of plants to stress constitutes an efficacious tool for agronomists, breeders and horticulture farmers, being the basis for the development of strategies and technologies that improve the resistance of crops to stresses (Cheng, 2014).

As a result of saline stress, plants (including turfgrasses) can respond with a wide range of physiological solutions at molecular, cellular and organism level (Huang *et al*., 2014). They include, for example, changes in the development and morphology (inhibition of the apical growth, increase in root growth and changes in the life cycle), adjustment in the ionic transport (concentration, expulsion and sequestration of ions, among which Na^+ and K^+ stand out), regulation of the antioxidant defense systems, changes in the expression of genes and proteins involved in the response to salinity, as well as other metabolic mechanisms (carbon metabolism and synthesis of compatible solutes) (Fuentes *et al*., 2007; Huang *et al*., 2014). Nevertheless, plants do not respond in the same way to saline stress. For such reason, according to their capacity of adaptation to high salt concentrations, they are classified into halophytes and glycophytes (Roy and Chakraborty, 2014).

- Halophytes: those plants native from saline soils which are capable of fulfilling their whole ontogenic cycle in that environment and having mechanisms for the elimination of salts from the internal tissues.
- Glycophytes: those plants which are affected by salt and incapable of withstanding certain salt concentrations as halophytes do.

Table 1. Effect of saline stress in turfgrasses.

Studied species	EC ($dS.m^{-1}$)*	Observed effect	Source
Cynodon dactylon	6	Loss of ions; decrease of the water and chlorophyll content, and of the photosynthetic rate in the leaves.	Manuchehri and Salehi (2014)
	33	Decrease of the leaf growth and stem weight, and negative effects on the aesthetics of turf.	Chen *et al*. (2014)
	5	Reduction of: stem size, dry and fresh weight of the plant, leaf area, photosynthetic rate and chlorophyll content.	Bizhani and Salehi (2014)
Cultivars of *Festuca rubra*, *F. longifolia* and *F. ovina*	6	Decrease of the germination percentage and vegetative growth (stem and root weight, water content).	Zhang *et al.* (2013)
Festuca spp., *Poa pratensis, Puccinellia distans*	6-10	Decrease of the germination percentage and leaf area.	Zhang *et al*. (2011)
Cultivars of *Festuca* spp., *Agrostis* spp., *Puccinellia* spp. and *Deschampsia cespitosa*	14	Decrease of the green color intensity of the foliage.	Friell *et al*. (2013)
Lolium perenne	8	Inhibition of the root growth, increase of the plant mortality; decrease of the germination rate, root and stem length, number of leaves, as well as the dry/fresh weight of the plants.	Nizam (2011)
Poa pratensis	2,5	Reduction of: stem size, dry and fresh weight of the plant, leaf area, photosynthetic rate and chlorophyll content.	Bizhani and Salehi (2014)
Zoysia japonica	36,0	Reduction of the root and stem growth and of the turf quality.	Uddin *et al*. (2010) Uddin *et al*. (2011)
Stenotaphrum secundatum	31,8		
C. dactylon (satiri)	30,9		
Zoysia teneuifolia	28,4		
Digitaria didactyla	26,4		
C. dactylon (Tifdwarf)	25,7		
Paspalum notatum	20,8		
Axonopus compressus	18,6		
Paspalum vaginatum	36,5 49,4	50 % reduction in sprout growth. 50 % reduction in root growth.	Uddin *et al.* (2010)

*It refers to the electrical conductivity (EC) or the EC range at which the effects were observed.

The response mechanisms of plants (including turfgrasses) to saline stress can be summarized in three fundamental phases: 1) osmotic adjustment, 2) ionic homeostasis (regulation of the ionic transport), and 3) elimination of reactive oxygen species. This is object of discussion in the works related to the mechanisms of tolerance to abiotic stress factors (Lamz and González, 2013; Uddin and Juraimi, 2013; Huang *et al*., 2014; Roy and Chakraborty, 2014; Flowers and Colmer, 2015; Uzilday *et al*., 2015).

Flowers and Muscolo (2015) stated that halophytes are little frequent with regards to the total number of flowering plants. The order Poales comprises 8,1 % of all the halophyte plant species. This type of plants has been classified, according to Roy and Chakraborty (2014), as salt-tolerant grasses (STGs), and constitutes the most important source of salinity-tolerant genes. The main survival mechanism of these plants in saline environments is the regulation of the ionic transport, and more specifically their capacity to eliminate the toxic Na^+ and replace it by K^+, which is known as selectivity of K^+ over Na^+ (Roy and Chakraborty, 2014). In addition, another salinity tolerance mechanism which is reported in all the *Poaceae* subfamilies, except in *Pooideae*, is the presence of salt glands; which play an important role in the regulation of the ionic balance of the species of this family (Céccoli *et al*., 2015).

In several halophyte turfgrass species the presence of salt-excreting glands in the leaves has been identified. These glands are generally identified by their morphology through conventional staining procedures, along with optical microscopy. Parthasarathy *et al.* (2015) used scanning electrochemical microscopy to identify the glands not only for their morphology, but also for their performance in the species *C. dactylon* L.

The study of the mechanisms that influence significantly the establishment and survival of halophytes provides basic information on the functioning of these plants under saline stress conditions, which will contribute to the transformation of the current crops, as well as to providing new tolerant crops (Flowers and Muscolo, 2015).

Breeding and selection for salinity tolerance in turfgrasses

In recent years the most widely used variables as selection criteria have been the appearance and the resistance or tolerance to biotic and abiotic stress factors (Florkowski and He, 2008). This has allowed such criteria to be aimed at those aspects that are close to a more ecological management of turfgrasses, such as:

- Drought tolerance (decrease of irrigation)
- Heat tolerance
- Salinity tolerance (irrigation with recycled waters)
- Shade tolerance (good growth under trees)

There is consensus on the fact that the most effective method to reduce the effect of these limiting factors is the attainment of resistant and/or tolerant varieties, through breeding programs adapted to the particular conditions of each locality (Koc *et al*., 2009; Abogadallah *et al*., 2010; Li *et al*., 2010; Patton, 2010; Trappe *et al*., 2011).

The study and evaluation of the variability regarding the salinity tolerance of the species in their natural environment (Hu *et al*., 2013; Lamz and González, 2013), as well as the search for resistance sources through the characterization and evaluation of germplasm collections (Friell *et al*. 2013; Roy and Chakraborty, 2014), are the key starting points for the development of programs of breeding and introduction of tolerant varieties. In this sense, the advances in biotechnology and genetic engineering have been successfully used in the attainment of new cultivars. Thus the tolerance to saline stress has been achieved in transgenic clones of *C. dactylon* and *Lolium multiflorum*, compared with the wild varieties (Huang *et al*., 2014). On the other hand, Ma *et al*. (2014) could express genes of *Arabidopsis thaliana* in *F. arundinacea*, with which salinity tolerance was improved.

Salinity-tolerant turfgrass species

The large quantity of studies on salinity-tolerant turfgrass species shows the preponderance acquired by this abiotic stress in recent years. Manuchehri and Salehi (2014) reported that *C. dactylon* is capable of adapting moderately to different combined salinity and drought conditions, with the activation of its osmotic adjustment mechanisms and the regulation of the enzymes that control the antioxidant activity. On the other hand, Zhang *et al*. (2013) analyzed the performance of nine *Festuca* cultivars in an EC range of 0-12 $dS.m^{-1}$ and observed a significant tolerance of the cultivars Slender and Stonewall to high salinity concentrations (9-12 $dS.m^{-1}$). In a wider study in 74 cultivars of different turfgrass species, *F. arundinacea* showed a better performance and maintained a medium quality in the green color of the foliage at an EC of 14 $dS.m^{-1}$ (Friell *et al.,* 2013).

In a comparative analysis of the tolerance to salinity in twelve turfgrass varieties, Zhang *et al*. (2011) found that *P. pratensis* had the best performance regarding the germination rate and leaf area in a medium with high NaCl content. However, Bizhani and Salehi (2014) established very low salinity tolerance ranges for *P. pratensis* (EC = 2,5 $dS.m^{-1}$) compared with other turfgrass species.

Nizam (2011) studied the germination and growth of *L. perenne* seedlings under different stress condition and found a salinity tolerance of up to EC = 8 $dS.m^{-1}$. On the other hand, Chen *et al*. (2014) identified the sources of salinity tolerance in 900 accessions of wild germplasm of *C. dactylon*, with which they established the bases for future breeding programs in this species.

Uddin *et al*. (2011) compared salinity tolerance in several turfgrass species and established a range from higher to lower degree of tolerance: *Z. japonica* > *S. secundatum* > *C. dactylon* > *Zoysia teneuifolia* > *Digitaria didactyla* > *C. dactylon* (Tifdwarf) > *Paspalum notatum*.

In a salinity tolerance study in 35 local turfgrass varieties in Malaysia, Zulkaliph *et al*. (2013) found tolerance with a concentration of EC = 24 dS.m^{-1} in the species *P. vaginatum* (UPM), local *P. vaginatum*, *Zoysia matrella*, *Z. japonica*, *C. dactylon* satiri and *C. dactylon* (Kuala Muda).

Uddin and Juraimi (2013) summarized the salinity tolerance capacity in the main turfgrass species (table 2); *P. vaginatum, Z. japonica* and *S secundatum* were the megathermal species with the best results.

On the other hand, Ruiz *et al*. (2007) evaluated the salinity of a cultivated soil with some pasture species, among them *C. dactylon*, which have salt-excreting properties, as a physiological mechanism of tolerance to this factor and found a trend to salt reduction, a decrease of electrical conductivity and of the concentration of salt-forming cations and anions. This proved that these species on salinized soils can constitute a natural ameliorator against this problem.

In plastic pots prepared with a substratum of sand and peat (9:1), Uddin *et al*. (2010) evaluated salinity

Table 2. Salinity tolerance in the main turfgrass species.

Species	Tolerance
Mesothermal	
Puccinellia spp. (Alkaligrass)	T
Poa annua L. (Blue grass)	S
Lolium multiflorum (Annual ryegrass)	MS
Festuca rubra L. spp. (Chewing fescue)	MS
Agrostis tenuis (Colonial bent grass)	S
Agrostis palustris (Creeping bent grass)	MS
Festuca rubra L. spp. rubra (Creeping red fescue)	MT
Agropyron cristatum (Fairway wheat grass)	MS
Festuca longifolia Thuill. (Hard fescue)	MT
Poa pratensis L. Kentucy (Blue grass)	MS
Loium perenne L. (Perennial rye grass)	S
Festuca arundinacea Schreb. (Tall fescue)	MT
Megathermal	
Paspalum notatum Flugge (Bahiagrass)	MS
Cynodon dactylon (Bermuda Tifdwarf)	MS
Cynodon dactylon (Bermuda Satiri)	MT
Bouteloua gracilis (H.B.K) (Blue Grama)	MT
Bouteloua dactyloides Nutt. (Buffalo grass)	MT
Eremochloa ophiuroides (Centipedegrass) Munro	S
Paspalum vaginatum (Seashore paspalum)	T
Stenotaphrum secundatum (St. Augustine)	T
Zoysia japonica (Japanese lawn grass)	T
Zoysia matrella (Manila grass)	MT
Zoysia tenuifolia (Korean grass)	MS
*Digitaria didactyla*Wild (Serangoongrass)	MT

Source: Uddin and Juraimi, 2013; S: sensitive (EC < 3 dS.m^{-1}), MS: moderately sensitive (EC = 3-6 dS.m^{-1}), MT: moderately tolerant (EC = 6-10 dS.m^{-1}), T: tolerant (EC >10 dS.m^{-1}).

tolerance taking into consideration root and sprout growth and the leaf burns in species that were subject to different salinity concentrations (0, 24, 48 and 72 dS.m^{-1}) through irrigation with seawater. The species *P. vaginatum* and *Z. matrella* were grouped as the most tolerant, capable of surviving high salinity concentrations (between 36,5 and 49,4 dS.m^{-1}). In the second group the salinity tolerance of the species was moderate: local *P. vaginatum* and *C. dactylon* were capable of tolerating EC values between 25,9 and 29,9 dS.m^{-1}; while in the group with lower tolerance the species *C. dactylon* Greenles, *E. ophiuroides*, *Axonopus compressus* and *Axonopus affinis* were included; these varieties were affected in the range of salinity concentrations between 17,0 and 26,0 dS.m^{-1}.

FINAL CONSIDERATIONS

Saline stress causes water deficit conditions in the plant, which is translated into physiological drought and a toxic effect of the ions as a result of high solute contents. That is why understanding the plant response mechanisms to this stress constitutes an efficacious tool to achieve correct management in areas affected by this limitation.

Salinity-tolerant plants are capable of growing and completing their life cycle without significantly decreasing their yields in substrata with high salt concentrations; due to morphological, physiological and biochemical changes. Salinity influences crop germination, growth and yield, in general, but a large variability has been observed in the response to this stress depending on the species, the cultivar and the phenological state of the plant.

Several studies have been conducted for the evaluation of the salinity tolerance mechanisms in turfgrass species; this knowledge is elementary for the development of tolerant cultivars that contribute to the implementation of management strategies in sites affected by salinity.

For the different saline environments, plants have developed adaptation mechanisms. The success or failure of the establishment of turfgrass species depends on the selection of the species that is best adapted to the existing salinity conditions, for which the knowledge of the tolerance mechanisms used by plants is necessary.

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