# Salt Removal Potential of Turfgrass in Golf Courses in the Mediterranean Basin

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*Abstract:* In Mediterranean climates available water is the limiting factor of plant productivity. Hence, due to the lack of water in the Mediterranean regions, potable water luxurious uses – are increasingly contested. In order to solve this problem, non-conventional water resources, like treated wastewater, drainage water and brackish water resources are gaining increasing role in the planning and development of water supplies in the irrigation of golf courses. Generally all these non-conventional water resources are saline. Hence, the application of excessive amounts of freshwater in saline soils and the heavy use of fertilizers are techniques used to mitigate soil salinity and to increase the salt tolerance of turfgrass in golf courses. However, the intense use of these conventional techniques has attracted public attention due to the environmental pollution and the contamination of groundwater resources. In recent years, a new environmentally safe and clean technique, whereby the salt (ion) removing species are planted in the salt-affected soils, has been introduced to mitigate the salinity problems. The salt removal potential of several turfgrass cultivars was evaluated for their efficiency to remove salts (ions) from the soils under this study. Hence, chloride concentration of leaves was the studied indicator, once that chlorides are the most representative salts in this region, due to seawater intrusion. Plant collection was conducted in several golf courses in Algarve, the southern region of Portugal. Results of this study show that *Lolium perenne* 'Brighstar' tissues accumulated the largest amounts of chloride leaves, followed by the *Cynodon dactylon* chance hybrid 'Tifway 419'. Hence, both could become potential cultivars, which could be used to control and to combat salinity in the golf courses of the Mediterranean regions in order to rehabilitate saline soils, in association to other techniques.

*Key-Words:* soil salinity, conventional techniques, phytoremediation, salt removing turfgrass cultivars, chlorides, salt extraction.

## 1 Introduction

Salinity stress is a key factor that limits crop production world-wide and is a constraint to economic development and to the environment; the economic impacts resulting from salinity are mainly associated with a decrease in the production capacity of land [1]. The negative environmental impacts are most often the degradation of land, namely soil salinization and groundwater contamination. Moreover, soil salination is one of the most alarming process causing desertification, due to improper irrigation [2,3,4].

Soil salinization is one of the major threats to the environment and is especially problematic where human interventions have disturbed natural ecosystems [5, 6]. Anthropogenic activities have increased soil salinity by changing the natural balance of the water cycle, by allowing excess recharging of saline groundwater and salt accumulation through its concentration [7]. Moreover, groundwater contamination is also an important negative environmental impact, which is intensified due to seawater intrusion in coastal zones

Since irrigation in the Mediterranean climate is a necessity, the only way to avoid salination is to control the saline processes [8].

Soil salinity in golf courses is one of the most important issues in the Mediterranean region, mainly due to the mismanagement of water and land resources over the last forty years.

The Algarve region, in the Mediterranean basin has been selected as the case study because this region is strongly affected area by soil salination [9, 10] and a high number of golf courses is located on this area [11]. This problem has two outcomes depending on the existence or not of an impermeable layer: when there is an impermeable layer, salts are accumulated above this layer and when there is no impermeable layer, groundwater contamination can be observed [12].

The salination process may be divided into three phases, as follows: 1) Soluble salts source (local and transported salts); 2) Salt transport (due to the wind – aerosols, due water infiltration - surface water and irrigation and due to capillary rises: seawater and underground water); 3) Salt accumulation (due to natural causes – evaporation, plant extraction and and no leaching; due to human activities - soil compactation and formation of impermeable layers, increase the level of underground water and the improper irrigation using not well applied saline water. On the Mediterranean regions, in most cases the salination process is due to the irrigation management practices and to sea water intrusion. The irrigation management practices must prevent excessive salt and sodicity building up and accumulation in soil surface and in the root zone and control the salt balance in the soil-water systems; the plant type, the water quality and soil properties determine to a large degree the optimize irrigation [13]. As a result of seawater intrusion, the groundwater level is reduced as water demand exceeds annual groundwater recharge [14]. The growth rate of population in coastal zones leads to the overpumping of groundwater, which is associated with soil contamination. The key-component of the SPAC dynamic system (soil-plant-atmosphere continuum) is soil solution. Soil water and ions content varies dynamically in the water solution, and it is affected by a high number of processes, in which the most important is the evapotranspiration (more the amount of water transferred to the atmosphere by evaporation and transpiration, larger is the salt content of the soil) and the absorption of ions by the plant (high absorption of ions by the plant causes a reduction of soil salinity.

Soil salt balance is given by the following equation:

$$Sr + Si + Sg + Sm + Sf = Sd + Sp + Sc + Sl + \Delta Sa + \Delta Sc \quad [1]$$

where:

Sr – salt supplied by rainwater
Si – salt supplied by irrigation water
Sg - salt supplied by groundwater
Sf – salt supplied by fertilizers
Sd – salt removed by drainage water
Sc – salt absorbed by plants
Sl – salt removed by leaching
Sp – precipitated salt
$\Delta$Sa – variation of adsorbed ions
$\Delta$Ss - variation of the soluble salts

The effect of salinity on plant yield has been modeled with a piece-wise linear response model [15, 16]: plants produce at their full potential yield until salinity reaches a threshold value: the threshold value is the maximum average salt concentration in the root zone that does not reduce the yield (plant tolerance); above the threshold value, the yield decreases as a linear function of salinity until the plants die when it drops sharply to zero, being the function slope the plant sensitivity. Models formulating some physical aspects of the integrated processes of water intake based on transpiration and salinity have been developed by Hanks and co-workers [17, 18, 19], who have described the effect of osmotic potential on plant root extraction. Generalized results from plant yield models with saline water were developed [20, 21]. The simplified diffusion convection equation to obtain production functions, including the effects of water, salinity and nutrition conditions, was solved [22]. All these models describe the plant as a pipeline of water, and, therefore the water uptake and transpiration are synonymous terms such that the yield, which is dependent upon the transpiration rate, is given as a unique function of soil water potential or soil osmotic potential. It was assumed that water uptake depends on matric and water potentials and on a critical root water potential around – 0.3 MPa; the assumption that the major effect of soil salinity is a reduction in water uptake, was consubstantiate [23]. Later on, a model was presented in which the wilting point is a function of the soil salt content [24]: at higher salinity, the water content at wilting point is higher than at low salinity, resulting in an insufficient amount of available water, and, therefore, a reduced yield. This model shows that the movement of salts in the soil is solely dependent on the movement of water in soil; and, it shows also that the effect of salinity is simulated by its effect on the wilting point, thus reducing the soil available water content.

An alternative approach used in the Mediterranean regions to increase the salt crop tolerance of turfgrasses in the salt-affected soils is the application of huge amount of fertilizers [25]. The plant response to salt-fertilizer interactions were explained to several crops [26, 27]. In this case the tolerance of plants to saline conditions can be increased [28, 29], but at the same time contamination by hazardous chemicals will be also increased due to the higher amount of fertilizers and pesticides [30]. The use of salt tolerant turfgrass species – another conventional technique to control soil salinity - will be very useful to the plants, but does not solve the problem of soil or groundwater contamination [31, 32, 33]. On the other hand it is known that halophytes are recognizable plants which survive on high concentrations of salts in their environment, usually dominated by chloride and sodium [34]; the interests in e of economic feasibility of halophyte use increased during last decades and in several projects halophytes were cultivated for fodder and vegetables [35]; however, this halophyte use does not solve directly soil contamination. On the other hand, the intense use of the leaching techniques, the most used process to combat salinity in golf courses, attracted public awareness of environmental pollution and the impact on aquifers. Application of huge amounts of water to wash the salts from the soil may led to raise the groundwater level near the surface resulting in large amount of salts moving from the lower soil strata to the surface layers [36]. Consequently, this strategy increases the risk of re-salination in the root zone [37]. As a result, soil leaching process has to be repeated every cropping season in order to avoid build-up of high salt concentrations. Furthermore, after leaching, water runs into the drainage systems and when the salt-contaminated drainage water returns to the river, it has severe impact on the ecosystems of the river and wetlands [38]. It can be presumed that drainage water contains not only salt but also pesticide residue, fertilizers, defoliants and other agrochemicals [39], which enter the rivers, destroys the fine balance of nature and deteriorates water quality in these water bodies.

When using saline water in the Mediterranean areas, the only way to control the salination process and to maintain the sustainability of landscape (like golf courses) and agricultural is to combat the salination problems by environmentally safe and clean tes techniques, as follows: 1) Phytoremediation technique [40], which is defined as the use of plants to remove pollutants from the environment and to render them as harmless [41]. Large-scale decontamination of soils and underground water using phytoremediation techniques requires plants with high salt uptake rates, large biomass and tolerance to a wide array of environmental conditions and constraints[42]; 2) Use of drought tolerant crops species, which reduces the salt amounts of soils, once that less irrigation water is applied [43]; 3) reduction of salt application by deficit irrigation, using the minimal levels of water enough to obtain a good visual appearance GVA of the landscape [44].

Recently, a new phytoremediation technique has been introduced to address the salinity problem [45]. This includes the introduction of salt (ion) removing species to control salinity and to maintain the sustainability of ornamental and agricultural fields [46].

The main aim of this study was to evaluate the potentialities of different turfgrass salt removal species in order to rehabilitate salt-affected soils of golf courses.

## 2 Materials and methods

This study was conducted in 10 golf courses in the South Portugal, coastal area of the Algarve region, where golf courses are being built every year, and salt problems appear due to the sea salt intrusion of the aquifers, the main irrigation water source. The monitored parameters included only the chloride ion (the most representative one), due to the fact that water sources were generally aquifers, with sea intrusion problems [47]. Table 1 shows the most important climatic parameters - temperature, Penman potential evapotranspiration ETP and precipitation (40 years average) of the coastal area of Algarve, where the study was carried out.

Table 1. Climatic parameters (1970-2000).

| MONTH | TEMPERATURE (º C) | ETP (mm) | RAIN (mm) |
|---|---|---|---|
| January | 11.3 | 33 | 61 |
| February | 12.2 | 39 | 52 |
| March | 14.3 | 81 | 72 |
| April | 15.2 | 117 | 30 |
| May | 17.8 | 164 | 21 |
| June | 20.9 | 183 | 5 |
| July | 23.8 | 208 | 1 |
| August | 23.4 | 189 | 0 |
| September | 21.5 | 120 | 18 |
| October | 18.4 | 84 | 61 |
| November | 14.9 | 36 | 65 |
| December | 12.6 | 25 | 67 |
| YEAR | 17.2 | 1280 | 453 |

We may divide these soils on two categories: 1) greens and tees, where soils are constituted by sandy substrates on the root zone (0.0-0.20 m depth), with high permeability, lightly alkaline, in order to provide an adequate development of the turfgrass root system; 2) fairways and roughs, where soils are the local soils, generally *calcaric* soils, with around 30 % of clay, and therefore, with low permeability [48].

Irrigation water is generally saline, being its electrical conductivity between 1.0 and 1.7 dS $m^{-1}$, and alkaline with a pH between 7.0 and 8.5.

The studied turfgrass species were those which are more representative of the Mediterranean Basin, as follows: 1) *Agrostis. stolonifera* L., the creeping bentgrass, cultivars 'Penncross', 'Penn-A4' and 'Crenshaw', are the most used species in the greens of the Mediterranean areas, in spite of their cool-season characteristics, once that they may develop well, if the climate is dry; however these species are known as very susceptible to plant diseases; 2) *Cynodon dactylon* (L.) Pers., the Bermuda grass, cultivars 'Tifway 419' and 'Savannah' are the most used species on the mediterranean golf courses. 'Savannah' is exclusively applied on the roughs; on the other hand Bermuda 'Tifway 419', the most used turfgrass, is used on tees, fairways and greens; they are warm-season species, adapted to a wide range of soil conditions; although Bermuda grass is generally not very cold tolerant, the poleward limits of adaptation have been extended with the development of several new cultivars; its intolerance of shade necessitates the use of alternative warm-season species on sites where trees and other structures restrict sunlight penetration [49].The species are perennial, have a long life, quick growth at 18-35 ºC, but become brown when temperature decreases. Its growth is extremely vigorous, when compared to other species [50]; 3) *Zoysia sinica* 'Zenith' is a warm-season species used in the greens and tees; 4) *Poa annua* (bluegrass) species are now being also used in the greens; 5) *Lolium perenne* cvs. 'Brightstar' and 'Palmer' are cool season species used in Tees, Fairways and Roughs; 6) *Poa pratensis* 'Midnight'; 7) *Festuca rubra* spp. *commutata* are cool season species used in warm climates in mixtures and applied to the Tees, Fairways and Roughs; 8) *Pennisetum clandestinum* (kikuyu grass) is a species very tolerant to drought and used in fairways and roughs. All these species are described botanically [51].

Table 2 shows distribution of the studied turfgrass cultivars on the different component sites of the golf courses (greens, tees, fairways, and roughs). However, the most used species in the golf courses of Algarve, according to the area type, are: 1) Green (*A. stolonifera*), Tee (*Cynodon. dactylon*), Fairway (*Cynodon dactylon*), Rough (*Cynodon dactylon*, *Festuca arundinacea*, and *Poa pratensis)*

The salt removal capacity of the different turfgrass species was estimated in terms of their potential to extract chloride, the dominate ion present on the leaves. Chloride concentration of leaves was, therefore, the studied indicator, once that chloride is the most representative ion, due to the source of the irrigation water, which is related to the seawater intrusion in the aquifers [52]. Plants were harvested by the end of the year 2002 and analyzed relatively to chloride ions composition. The turfgrass leaves were mowed with scissors and collected. The leaves were weighed for yield determination, washed up with tap water and distilled water, oven dried at 60º C for 72 hours, re-weighed, finely ground in a mill and used for analysis of chloride ($Cl^-$). Dried leaves were finely ground and used for analysis of chloride ions determined by spectophotometry (ELE-Paqualab TM Photometer EL430-550). The plant chemical analysis was performed at the University of Algarve, in Portugal.

Table 2 – Studied turfgrass species and cultivars

| Green | Tee | Fairway | Rough |
|---|---|---|---|
| *Agrostis stolonifera* 'Penncross' | *Cynodon dactylon* 'Tifway 419' | *Cynodon dactylon* 'Tifway 419' | *Cynodon dactylon* 'Tifway 419' |
| *Agrostis stolonifera* 'Penn-A4' | *Agrostis stolonifera* 'Crenshaw' | *A.grostis stolonifera* 'Crenshaw' | *Cynodon dactylon* 'Savannah' |
| *Agrostis stolonifera* 'Crenshaw' | *Zoysia sinica* 'Zenith' | *Lolium perene* 'Palmer' | *Lolium perene* 'Brighstar' |
| *Zoysia sinica* 'Zenith' | *Lolium perenne* 'Brighstar' | *Festuca rubra* spp. *commutata* | *Lolium perenne* 'Palmer' |
| *Poa annua* | *Lolium perene* 'Palmer' | *Pennisetum clandestinum* | *Poa Pratensis* 'Midnight' |
| | *Poa pratensis* 'Midnight' | | *Festuca rubra* spp. *commutata* |
| | *Festuca rubra* spp. *commutata* | | *Pennisetum clandestinum* |
| | *Pennisetum clandestinum* | | *Festuca arundinacea* |

The data were analyzed using the standard One-Way ANOVA procedure of the SPSS 14.0 software for Windows (SPSS, 2005) to compare mean values of four replicated $Cl^-$ concentrations, obtained through the spectophotometric method. Differences at the $P \leq 0.05$ level were used as a test of significance and means were separated using the Duncan post hoc t-test, through the PSS software (SPSS 10.0 for windows). The number of samples was 4 for each cultivar.

The ANOVA statistical analysis was used to study the variation averages of the parameters values of N and of $Cl^-$ concentrations in citrus leaves. The number of samples was 4 in each treatment. No significant differences were observed among the analytical values.

# 3 Results and discussion

Table 3 shows leaf dry matter production of the studied turfgrass cultivars.

Table 3 – Average leaf dry matter production of several turfgrass species and cultivars in field courses of Algarve (kg $ha^{-1}$ $year^{-1}$)

| TURFGRASS CULTIVARS | LEAF DRY MATTER YIELD (kg $ha^{-1}$ $year^{-1}$) |
|---|---|
| *Cynodon dactylon* 'Tifway 419' | 10,719 |
| *Cynodon dactylon* 'Savannah' | 12,000 |
| *Agrostis stolonifera* 'Penn-A4' | 14,398 |
| *Agrostis stolonifera* 'Crenshaw' | 14,545 |
| *Agrostis stolonifera* 'Penncross' | 14,701 |
| *Lolium perenne* 'Palmer' | 13,455 |
| *Lolium perenne* 'Brighstar' | 12,736 |
| *Poa pratensis* 'Midnight' | 12,520 |
| *Poa annua* *'Bluegrass'* | 11,795 |
| *Festuca arundinacea* | 12,599 |
| *Festuca rubra* spp. *commutata* | 12,822 |
| *Pennisetum clandestinum* | 13,976 |
| *Zoysia sinica* 'Zénith' | 14,175 |

It is shown on Table 3 that the highest dry matter leaf production was obtained with *Agrostis stolonifera* cultivars 'Penn A4', Crenshaw' and 'Penncross' – 14 to 15 tons $ha^{-1}$ $year^{-1}$ whereas *Cynodon dactylon* cultivars and *Poa annua* were the less productive turfgrass – 10 to12 tons $ha^{-1}$ $year^{-1}$.

Table 4 shows the chloride concentrations of the various studied turfgrass cultivars' leaves (mMol $Cl^-$ $kg^{-1}$ leaf dry weight) on the various golf course areas.

Table 4 – Leaf chloride concentrations of the different turfgrass cultivars (mMol $Cl^-$ $kg^{-1}$ leaf dry weight)

| TURFGRASS CULTIVARS | Chloride concentration (mMol $Cl^-$ $kg^{-1}$ leaf dry weight) |
|---|---|
| *Cynodon dactylon* 'Tifway 419' | 6.428 |
| *Cynodon dactylon* 'Savannah' | 2.648 |
| *Agrostis stolonifera* 'Penn-A4' | 2.440 |
| *Agrostis stolonifera* 'Crenshaw' | 3.555 |
| *Agrostis stolonifera* 'Penncross' | 4.937 |
| *Lolium perenne* 'Palmer' | 5.701 |
| *Lolium perenne* 'Brighstar' | 8.511 |
| *Poa pratensis* 'Midnight' | 1.931 |
| *Poa annua* | 2.430 |
| *Festuca Arundinacea* | 1.884 |
| *Festuca rubra* spp. *commutata* | 2.817 |
| *Pennisetum clandestinum* | 4.090 |
| *Zoysia sinica* 'Zénith' | 2.070 |

The plant salt content analysis showed that the cultivar *Lolium perenne* 'Brighstar' accumulated the largest amounts of chloride in leaves, followed by *Cynodon dactylon* 'Tifway 419', respectively 8.5 and 6.4 mMol $Cl^-$ $kg^{-1}$ of leaf dry weight. *Festuca arundinacea* and *Poa pratensis* 'Midnight' were the cultivars in which the chloride concentration is lower, 1.8 and 1.9 mMol $Cl^-$ $kg^{-1}$ leaf dry weight, respectively. Our studies confirm the higher chloride concentration accumulated on *Pennisetum clandestinum* as well the lower concentration accumulated on *Agrostis stolonifera* 'Penn-A4' as already obtained [53]. However, on the other hand, former studies showed higher concentrations on *Cynodon dactylon* 'Tifway 419' and 'Savannah' [54].

In Table 5 it is presented the chloride removal capacity of the different turfgrass species and cultivars.

Table 5 – $Cl^-$ removal capacity of the different turfgrass species and cultivars (kg $ha^{-1}$ $year^{-1}$). Average from different areas of field courses

| TURFGRASS CULTIVARS | REMOVED CHLORIDES (kg $ha^{-1}$ $year^{-1}$) |
|---|---|
| *Cynodon dactylon* 'Tifway 419' | 244.6 |
| *Cynodon dactylon* 'Savannah' | 112.8 |
| *A. stolonifera* 'Penn-A4' | 124.7 |
| *A. stolonifera* 'Crenshan' | 183.6 |
| *Agrostis stolonifera* 'Penncross' | 257.6 |
| *Lolium perenne* 'Palmer' | 272.3 |
| *Lolium perenne* 'Brighstar' | 384.8 |
| *Poa pratensis* 'Midnight' | 85.8 |
| *Poa annua* | 101,7 |
| *Festuca arundinacea* | 84.3 |
| *Festuca rubra* spp. *commutata* | 128.2 |
| *Pennisetum clandestinum* | 200.9 |
| *Zoysia sinica* 'Zenith' | 104.2 |

It could be seen on table 5 that *Cynodon dactylon* 'Tifway 419' and *Pennisetum clandestinum* cultivars have a greater chloride removal capacity of the leaves – 200 to 250 kg $ha^{-1}$ $year^{-1}$; on the contrary, *Poa pratensis* 'Midnight' and chloride removal potential of *Festuca arundinacea* cultivars are lower potential – 80 to 90 kg $ha^{-1}$ $year^{-1}$. These values are much lower than the total salt removed because this study has considered only the $Cl^-$ removal and does not consider other ions [55]. Moreover, only the $Cl^-$ removal of the leaves was determined and not of the other plant organs, like roots and stems [56].

## 4 Conclusions

Experimental results have confirmed that the *Lolium perenne*'brighstar' tissues accumulated the largest amounts of chloride leaves, followed by *Cynodon dactylon* 'bermuda Tifway 419'. Furthermore, these two cultivars could potentially solve environmental problems in golf courses, provided that they were the those having higher salt removal potential. This technology may be not enough to solve the salinity problems. However it is a clean and a environmental safe procedures that could be associated to the conventional techniques, combining environmental, economical and social aspects, contributing therefore to increase the sustainability of the golf courses.

It was shown that in the study area, as in all Mediterranean basin, salination is an inevitable process. As expected, it was developed a new technique to control salination effects in the golf courses of the Mediterranean Basin.

As concluding remarks, in order to improve the sustainability of the system, two techniques must be applied in the golf courses of Mediterranean regions: 1 – to select salt removing turfgrasses and 2 – to develop techniques to reduce application of saline water.

Finally, it must be noted that these are preliminary results for the most studied turfgrass cultivars, and therefore, additional research is needed for better understanding of turfgrass mechanisms, associated with the removal salts from soil under various geographical and climatic conditions.

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