



# A lysimeter study under field conditions of nitrogen and phosphorus leaching in a turf grass crop amended with peat and hydrogel

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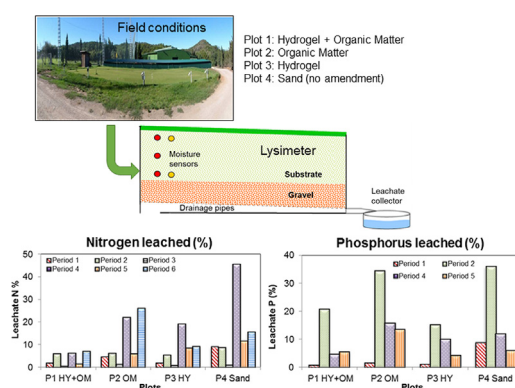
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## HIGHLIGHTS

- Hydrogel amendment reduces N and P leaching as well as water percolation.
- Peat amendment does not impact the percentage of leached N.
- The largest amount of N and P leached is detected in the plot no amendment.
- A larger irrigation rate (>10 mm) favors leaching of N and P, and water percolation.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Golf courses represent an agricultural activity wherein grass is intensively cultivated using large quantities of fertilizers. In the present study, nitrogen and phosphorus leaching was analyzed over two years in an experimental green under actual field conditions. The green contained four plots with distinct amendments (P1: hydrogel + peat, P2: peat, P3: hydrogel, and P4: no amendment). The applied doses of nitrogen ranged from 5 to 103 kg/ha and of phosphorus from 9 to 31 kg/ha. The irrigation level varied as a function of the rainfall regime and the water requirements of grass; overall water intake varied from 1550 to 2080 mm/year. Daily, leached water volume was calculated, and samples were taken for chemical analysis. Nitrogen and phosphorus mass balances were calculated for different periods based on the collected data.

The plot amended with peat and hydrogel (P1) had reduced water flow; the percentage of drainage water varied from 8.4 to 29%. As a result, the dissolution and leaching of nitrogen (N) and phosphorus (P) were the lowest in comparison to the other plots. According to the calculated mass balances, the lowest leaching values were also recorded in this plot (P1), ranging from 0.5 to 6.3% for N and from 0.8 to 20.9% for P. The plot without amendment (P4) drained the most water (25.9–44.8%) and leached the highest quantities of N and P, ranging from 9.1–45.7%, and 6–35.9%, respectively. The use of double amendments (hydrogel and peat) therefore represented optimal operating conditions for the green. Moreover, a relationship was found between increasing rates of fertilization and increasing percentages of N and P leaching as well as between higher irrigation levels and greater leaching.

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## 1. Introduction

The installation and maintenance of golf courses constitute a demanding agricultural activity involving the intensive cultivation of large areas of cespitose plants that require quantities of water similar to those required by citric crops, sunflower, and rice (Morell, 2006; Shuman, 2006). As demand for water in golf courses is extremely high, drainage also represents a key variable to consider because substrates are porous. In addition, large quantities of agrochemicals (fertilizers and pesticides) are used. The high solubility and excessive application of these products, as well as inefficient management practices, lead to the transport of their contained compounds to deep soil layers. These compounds may then reach aquifers or discharge to surface water bodies through run-off (Siyal et al., 2012; Krčmář et al., 2014; Filipović et al., 2015). The maximum permissible limits of such compounds established to protect the quality of water resources, including both drinking water and aquatic life, are commonly exceeded (Wong et al., 1998; Shuman, 2001, 2003; King et al., 2012).

The rate and system of irrigation, the quantity and type of applied fertilizers, and the frequency of fertilization, additionally affect the leaching of contaminants (McLeod et al., 2001; Shuman, 2001, 2003, 2005, 2006; Krčmář et al., 2014). Studies of agrochemical leaching in golf courses have been based on the use of lysimeters or have been carried out in greenhouses (Wong et al., 1998; Shuman, 2001, 2003; Aamlid et al., 2009), yet few studies have been carried out under actual field conditions.

Wong et al. (1998), for example, simulated irrigation and fertilization conditions characteristic of a golf course using a lysimeter to evaluate the behavior of fertilizers. According to the results, the rate of application of fertilizers in greens leads to adverse environmental impacts on surface water and groundwater because of phosphate and nitrate release. Shuman (2001, 2003) evaluated nitrate and phosphate leaching in golf courses using columns constructed according to the specifications of the United States Golf Association (USGA). The application of fertilizers was controlled considering soluble compounds and controlled-release compounds. The results showed that phosphate leaching is a potential problem only following an excessive increase in the application rate of soluble compounds. However, nitrate is a continual problem because it is easily leached.

In this respect, King et al. (2012) studied different types of fertilizer and application methods in a golf course in Duluth, USA. These authors found that the application of controlled concentrations of organic fertilizers during certain periods decreased the quantity of reactive dissolved phosphorus and total phosphorus in contrast to traditional techniques using synthetic fertilizers. In another study carried out in a golf course in Idaho, USA, under normal operating conditions (Johnston and Golob, 2002), the state of the grass was found to determine whether groundwater was contaminated as a result of nitrate leaching. Specifically, leaching was reduced when grass was maintained in good conditions.

Overall, several research studies in golf courses have concluded that it is necessary to improve irrigation techniques and fertilizer application (Barton and Colmer, 2006; Filipović et al., 2015) to guarantee the maximum use of fertilizers by plants and to avoid contamination problems. One improvement technique is the use of compounds such as peat, hydrogels, or surfactants to increase the efficiency of water and agrochemical use (Aamlid et al., 2009; Ullah et al., 2015). Hydrogels are super-absorbent hydrophilic polymers that are added to the soil to improve porosity, aeration (oxygenation), infiltration, transport and liberation of nutrients, and water absorption; these factors subsequently improve plant growth (Akhter et al., 2004; Abedi-Koupai et al., 2008; Anna et al., 2011; Bai et al., 2013; Savi et al., 2014; Ramos-Campos et al., 2015). In addition, a couple of studies have reported that hydrogels can control fertilizer leaching (McAvoy, 1994; Ullah et al., 2015).

Based on the abovementioned context, the objective of the present study was to evaluate and analyze nitrogen and phosphorus leaching

in an experimental green simulating a golf course under actual conditions. Distinct irrigation levels and amendments (peat and hydrogel) were considered. Nitrogen and phosphorus mass balance were calculated to establish the optimal operating conditions that would avoid contaminating ground water or receiving water bodies.

## 2. Study area

An experimental green with an approximate area of 278 m<sup>2</sup> is located at the Club de Campo del Mediterráneo along the Mediterranean coast of Spain (Fig. 1). It contains four experimental plots of approximately 40 m<sup>2</sup>.

The substrate is composed of a 26–40 cm sandy baseoverlying a 10-cm gravel layer containing drainage pipes that collect leached compounds and drain them toward the exit. At the exit, recipients collect leachates for control purposes. Each plot is coated on the bottom and sides with a geomembrane that independently collects and channels all infiltrated water toward the drainage exit (Fig. 1).

Each plot has a construction design and is composed of distinct substrates, which are described in Table 1. One plot (P2) was constructed according to USGA requirements (USGA, 2004) specifying that greens contain sand and organic matter in an 80:20 ratio. The other construction designs were proposed to evaluate their influence on drainage and contaminant transport. Several of the plots contain peat (organic matter) and TerraCottem® (hydrogel). TerraCottem® is an additive formed from a mixture of different acrylamide and acrylic acid copolymers, fertilizers, and volcanic rock and absorbs water up to 45 its weight, so it is capable of forming water reserves in the soil. These compounds are used to improve the efficiency of water and nutrient use and to therefore improve grass quality and decrease the risk of contaminating receiving surface water bodies and groundwater.

The experimental green was equipped with a Rain Bird Smart Weather meteorological station that recorded data on rainfall, solar radiation, maximum and minimum temperature, wind velocity, and relative moisture. From these data, reference evapotranspiration (ET<sub>0</sub>) was calculated using the FAO-Pennman-Monteith equation (Smith et al., 1992; Allen et al., 1998).

Organic matter content, bulk density, porosity, field capacity, and infiltration rate are shown for each plot in Table 1. Amendments affect field capacity and infiltration and, therefore, possibly influence contaminant leaching. The most remarkable difference between the plots is that the P4 (100% sand) has the highest infiltration rate, whereas the plots containing organic matter (P1 and P2) have the lowest infiltration rate. The USGA (2004) recommends a minimum infiltration rate of 0.25 cm/min in new greens. However, Gaussoin (2012) highlighted that, in the first three years, the infiltration rate of greens is between approximately 0.46 and 1.33 cm/min.

Agronomic activities performed in the plots are described next:

- a) *Planting*: *Agrostis stolonifera* L-93 was selected for planting. This grass variety is green throughout the year and is used by Club de Campo del Mediterráneo. It requires a high level of maintenance because of its rapid growth during summer and its high water requirement. It is sensitive to stress from lack of water and shade and endures cuttings of up to 3 mm.
- b) *Irrigation*: irrigation water originates from a well located in the vicinity. Eight pop-up spray sprinklers (model 6406-ADV, Nelson Turf®) were installed at a height of 15 cm with 7370 Multi-Arc nozzles at an optimal working pressure of 2 bar. The sprinklers were located around the perimeter and each separated by 4 m. The irrigation systems are independent in each plot and controlled by an electric pump and meter, allowing distinct irrigation doses to be quantified and tested.
- c) *Fertilization*: diverse types of fertilizers were applied uniformly to all plots, as described in Table 2. The periods and types of fertilization were congruent with the agricultural practices of the golf course.

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