Short-term Effects of Applying Olive Mill Waste on Turfgrass

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Abstract: The reuse of wastes in agriculture and landscape is often viewed as one way to conserve existing resources. Among the organic waste materials produced by agricultural activities, olive mill wastes derived from the olive oil extraction process may represent a suitable soil amendment. This study evaluated the effect of olive mill wastewater (OMW) application on turfgrass growth and quality and on soil electrical conductivity and pH. Olive mill wastewater at different doses (0, 3.0, and 6.0 L/m^2) was applied on a sodded turfgrass grown in clay loamy soil, identically irrigated with fresh water, and without any chemical fertilizer application. The results revealed that OMW application had a positive effect on the tested turfgrass, improving visual quality and increasing the dry weight of the clipping yield, in proportion to doses applied. An increase in electrical conductivity was observed in wastewater-irrigated soil while OMW did not remarkably change the initial soil pH.

Key-Words: Olive wastes, fertigation, visual quality, clipping yield, salinity.

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1 Introduction

Olive oil production represents a traditional branch of Greek agriculture. The olive oil extraction process, however, involves the generation of large amounts of olive mill wastewater (OMW), a by-product that constitutes a serious environmental problem, due to its high polluting load.

OMW is a mixture of vegetation water, water used in the various stages of the oil extraction process, and soft tissues of the olive fruit. It's characterized by intensive violet-dark brown up to black color, strong offensive smell, pH between 3 and 6, high electrical conductivity, high degree of organic pollution, high content of polyphenols, and high content of solid matter, [1], [2], [3].

Those wastes may be reused through the soil, directly (wastewaters), or following a composting process, [4], [5]. However, the direct application to agricultural soils as organic fertilizers is the most frequently used method nowadays, [2], [6].

This by-product is normally rich in Potassium and, to a lesser extent, in other nutrients (Nitrogen, Phosphorous, Calcium, and Magnesium). Therefore, they can replace the nutritional elements provided through fertilization. However, the spreading of OMW on soil could pose some disadvantages to soil properties because of the characteristics of the wastes.

OMW application effects on several agricultural crops have been well documented, [2], [3], [7] but little is known, however, about the impact of OMW on turfgrass and landscape crops.

The use of these wastewaters on soils may enhance their fertility, considering the fertilizing properties of the waste, such as organic matter, P, K, and N. It does not contain heavy metals or pathogenic microorganisms. Nevertheless, the use of this waste may lead to some disadvantages, related to acidity, salinity, lipids, organic acids, and phenolic compounds accumulation, [4].

Making the hypothesis that the high contents of nutrient levels in OMW may improve the soil's fertility, this study aims to evaluate the effects of olive mill waste application on the growth and quality of a sodded turfgrass. Also, the assessment of the effects on some soil properties, focusing on electrical conductivity and pH, parameters of direct interest to turf culture.

2 Materials and Methods

A field experiment was carried out on clay loam soil (41% sand, 20% silt, 39% clay) at the research field of the University of Thessaly, Gaiopolis campus, Larissa, Greece.

Twelve 1.60 × 1.60 m plots were prepared during the early spring of 2020 and sodded with a mixture of tall fescue (*Festuca arundinacea* Schreb), perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.).

The sod, selected for this study is the most frequently used mixture in sports fields and parks in Greece, and it represents their largest area. The experimental design included three replications of three treatments, including the application of 6.0 L/m^2 of OMW (OW6.0), the application of 3.0 L/m^2 of OMW (OW3.0), and a control treatment (C) with no OMW application.

Sod was placed on the soil surface and allowed to establish for a period of 20 days, a period typical for establishing turfgrass outdoors. During the establishment period, no OMW was applied. The turf was sprinkler-irrigated (freshwater) at a 2-day frequency during the establishment period and then water was applied every 3 or 4 days based on cumulative evapotranspiration replenishment unless rainfall of at least 6 mm was measured. OMW was applied through the irrigation system in four-fold replication.

The main turfgrass characteristics considered in the study were color and shoot growth. The color is one of the best indicators of the aspect quality of turfgrass and was monitored throughout the study. Shoot growth, measured as shoot biomass production, was used to assess the status of the turf. Clippings from each plot were collected monthly at a height of 6 cm with a walk-behind rotary mower from an area of 1 m^2. The shoot biomass samples were oven dried at 65°C for 48 h and weighed. The shoot dry weight was calculated as the clipping dry weight per square meter.

Soil salinity and pH data were obtained by soil coring from the topsoil (0 - 30 cm). Soil samples were collected at three points in each plot. The samples were then blended, and one sample was analyzed. Soil electrical conductivity sampling was carried out five times over 7 months. Soil pH was measured three times, before OMW application, at the middle and the end of the experiment.

All the results were subjected to analysis of variance. A probability level of α=0.05 was chosen to establish the statistical significance among treated and control samples.

3 Results and Discussion

3.1 Characteristics of Olive Mill Wastewater

Olive mill wastewater (OMW) was collected during harvest season (December 2019) from a nearby olive mill and was stored in a plastic container. Selected parameters of OMW applied on turfgrass cultivated soil are given in Table 1. The analysis has shown that OMW is a moderately acidic liquid waste (pH = 5.8) with high electrical conductivity (EC = 8.92 mS/cm). The applied OMW has been rich in phosphorus and potassium while the content in total nitrogen has been low.

Table 1. Olive mill waste quality parameters

Parameter	Value
Electrical Conductivity (mS/cm)	8.92
pH	5.8
Solid residue (%)	6.2
Available P (mg L^{-1})	1103
Available K (mg L^{-1})	980
Mineral N [NH_4-N + NO_3-N] (mg L^{-1})	75

The OMW characteristics depend on various factors like the olive variety, the climatic conditions, the type of extraction process, the use of pesticides and fertilizers, and the ripening of olives, [1], [7], [8].

3.2 Turf Response to OMW Application

3.2.1 Visual Evaluation

Turf color is a key component of aesthetic quality and a good indicator of water and nutrient status. Therefore, color is often evaluated in turfgrass experiments. Color is traditionally evaluated by visually rating turf plots on a scale of 1 to 9, with 1 representing the lowest quality and 9 representing the highest quality turf. A rating of 6 is considered minimally acceptable, [9], [10].

Visual rating requires minimum labor and provides quick quality estimation. To avoid any differences in assessments that may occur due to the subjectivities of the raters, all visual assessments are carried out by the same individual, [11], [12].

Fig. 1 presents the turf color evaluation for each treatment. The value of each treatment is the average value of its 3 repetitive plots (which is why decimal numbers are displayed). The image is a set of diagrams made in Excel with automatic color formatting of squares, depending on their numerical value.

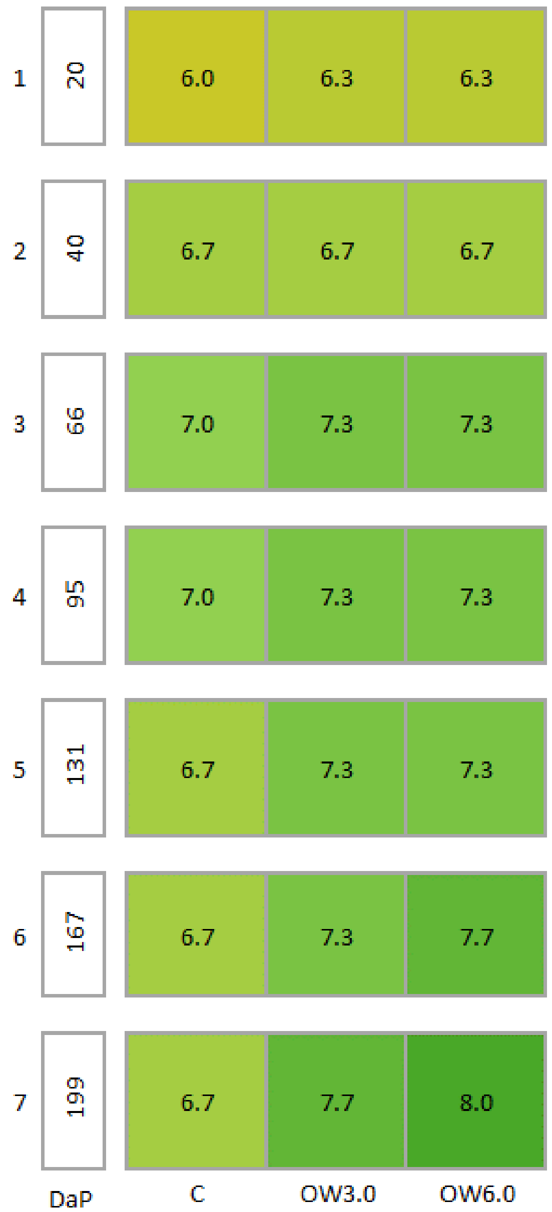

Fig. 1: Grading of turf appearance in terms of color, at each evaluation date and for each treatment

In the early stages of the experiment (April - May) there is a color balance between treatments, which begins to vary from June onwards. It is observed that control (C) consistently shows the lowest score until the end of the experiment. OMW application treatments show better scores than the control, systematically from May onwards, reaching grade 7.7 (OW3.0 treatment) and grade 8 (OW6.0 treatment) in the last month of the experiment.

3.2.2 Turfgrass Growth

The growth rate of the turfgrass was measured at regular intervals, with a cut at a height of 6 cm. A total of 6 cuts were made during the period from May to October 2020.

Table 2 gives the measured dry biomass for each treatment. After the first cut where there was a balance without statistically significant differences, the OMW treatments, are superior to the control, in all subsequent cut-collections, presenting even statistically significant differences from the third cut onwards.

OMW application influenced dry weight production, which was higher than the control, mainly in the last part of the experimental period.

The treatment of OW application with the dose of 3.0 L/m^2 (OW3.0), is superior to the control from the 3rd cut onwards, however showing statistically significant differences only in the last cut. The OW6.0 treatment prevailed with statistically significant differences from the control in the last two cuts.

The overall (average) yield picture is presented in the diagram of Fig. 2 as the calculated dry biomass production daily for each treatment. OW treatments were superior to that of the control, without differing statistically significantly. The 6.0 L/m^2 (OW6.0) application treatment yielded 1.43 g of dry biomass per m^2 per day, while the 3.0 L/m^2 (OW3.0) application treatment yielded 1.38 g/m^2/day. The OW6.0 yielded a total of 15.9% more than the control, while the OW3.0 was slightly behind the previous one, yielding 12.0% more than the control.

The potential use of OMW on cultivated crops was examined in a review. The results reported in the literature are not consistent. The application of OMW appears to modify soil/plant relationships, [2].

The effects of untreated and treated olive mill wastewater on seed germination, plant growth, and soil fertility were studied. Tomato, chickpea, bean, wheat, and barley were tested for the germination index and growth in soil irrigated by olive mill wastewater The treated plants showed an improvement in seed biomass, spike number, plant growth, and a similar or even better dry productivity than plants irrigated with water, [6].

Table 2. Clippings' dry weight as affected by OMW application

Cutting	DaP	Treatment					
		C		OW 3.0		OW 6.0	
		Dry weight (g)					
1st	40	23.1	(1.6)	24.8	(1.6)	22.2	(1.5)
2nd	70	48.2	(4.3)	48.7	(4.5)	46.1	(4.9)
3rd	102	30.8	(2.7)	35.7	(4.7)	35.9	(5.1)
4th	137	39.9	(3.7)	43.2	(1.7)	45.3	(5.5)
5th	175	48.0	(3.2)	58.2	(2.6)	64.6	(3.3)
6th	206	38.0	(3.3)	46.1	(4.3)	55.1	(5.2)
DaP: Days after planting; Numbers in parenthesis represent the Standard Deviation							

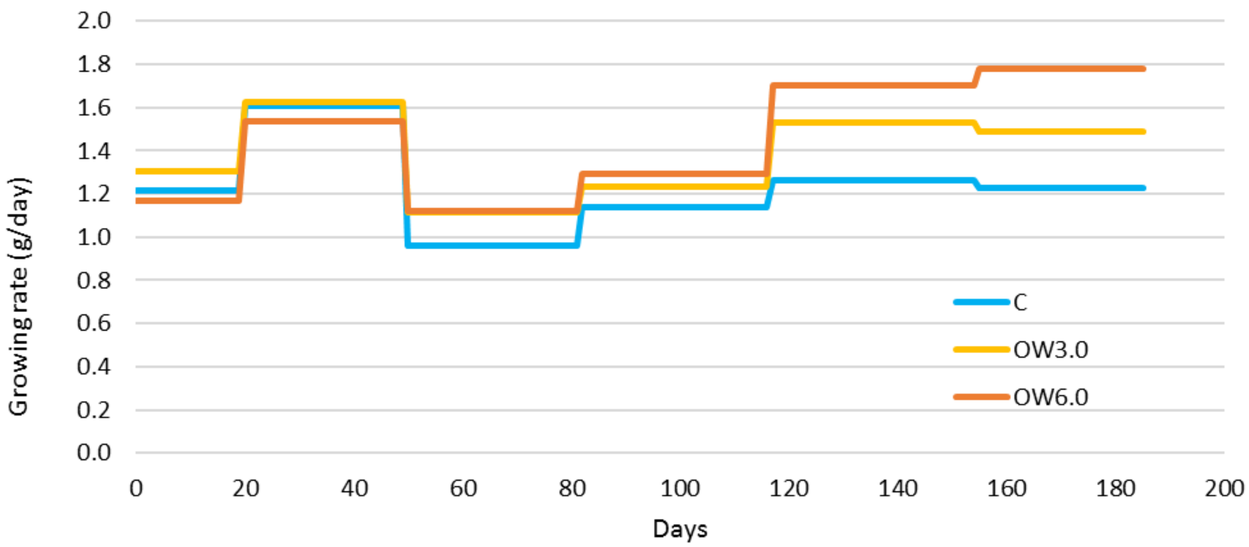

Fig. 2: Turfgrass growing rate over time as affected by OMW application

In the irrigation of maize planted in a pot experiment, the results indicated that untreated OMW reduced plant growth, while the treated OMW improved plant growth, [13].

In turfgrass culture, olive waste has been tested in a few studies either in treated or untreated form. The OMW application as an organic fertilizer gave increased rye-grass growth parameters (fresh and dry weight, and LAI) in comparison with unfertilized treatment, [14].

In a short paper, focused on nutrient absorption by ryegrass, which was grown with a variety of compost and fertilizer treatments conducted in pot culture, the researchers concluded that olive mill compost increased ryegrass fresh weight, [15].

In a 2-year field, study evaluated composted olive mill waste as a soil amendment in bermudagrass, the application resulted in a minor reduction in plant visual quality during the cold periods but in a slight improvement during the warm periods. The clipping dry weights were increased by composted olive mill waste amendments in the first year but were unaffected in the second year, [5].

A field study examined the effects of olive mill compost soil amendment (OMC) on turfgrass establishment and growth. OMC amendment improved the visual quality of tall fescue during establishment and increased the dry weight of the clipping yield. The visual quality and clipping yield of bermudagrass did not exhibit any significant differences among the treatments, [16].

3.4 Soil Analysis

Based on the control treatment EC, an increase in such parameters was observed as a function of OMW application and time (Fig. 3). Although the electrical conductivity values during the experiment have no significant changes, the OMW treatments reached their highest levels at the end of the experiment, but within the permissible limits, that is less than 600 μS/cm (0.6 mS/cm). A significant difference in soil electrical conductivity in relation to control has been observed only in the OW6.0 treatment. This elevation can be explained mainly by the high salinity of the OMW and the richness of mineral elements. Such results were consistent with previous studies, [2], [3], [17], [18]. The EC declination in all treatments is probably because of increased rainfall events during the mid-period of the study that leached the salts.

In [19], the author lists the parameters a turfgrass manager should consider in evaluating irrigation water quality. As indicated, waters with EC values greater than 0.7 mS/cm present increased salinity problems, and suggest avoiding using any water with an EC above 3 mS/cm. Water with an EC of 1.5 mS/cm may be suitable for grass grown on sandy soil with good drainage, but the same water may prove injurious within a very short period if used to irrigate the same grass grown on clay soil.

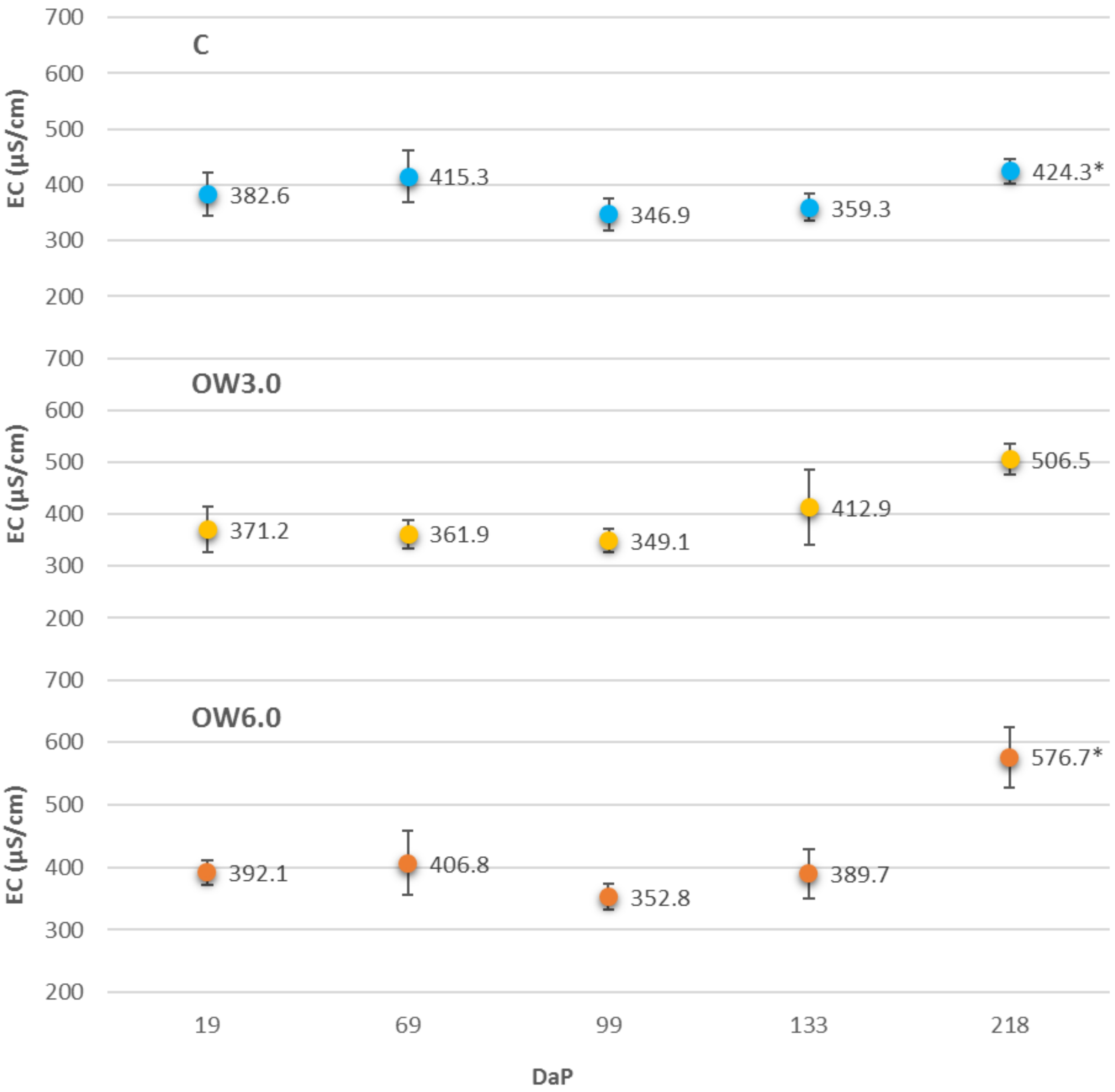

Fig. 3: Soil electrical conductivity (EC) evolution as a function of applied OMW and time. Asterisks indicate significant differences ($P < 0.05$) among data

In [19], the author also gives a general guide to the salt tolerance of individual turf grasses. Soils with EC values below 3 mS/cm are considered satisfactory for most turfgrasses. EC values between 3 and 10 mS/cm indicate soils in which only a few salt-tolerant turfgrass species can survive. As indicated, Kentucky bluegrass will tolerate a soil salinity of up to 3 mS/cm, while tall fescue and perennial ryegrass are moderately tolerant (6 to 10 mS/cm).

Other researchers, [20], reviewing the salinity tolerance of turfgrasses characterize tall fescue as moderate tolerant (6–10 mS/cm) while Kentucky bluegrass as moderate sensitive (3–6 mS/cm) and perennial ryegrass as sensitive (<3 mS/cm).

In general, most tall fescue cultivars are considered to have good tolerance to salts. Kentucky bluegrass and perennial ryegrasses offer moderate resistance to salts in the soil.

In [3], the authors refer to differences among researchers with regard to electrical conductivity, that ascribed to the differences in the kind of OMW used (treated or untreated, i.e., raw), as well as to the dose of application(s), repetition (disposal for many years or not) and soil type (the content of clay, carbonates, and organic matter).

A significant increase in soil electrical conductivity has been observed with the increase of the doses applied (25, 50, 75, and 100 m^3 /ha), [21].

Similarly, olive mill waste application increased soil electrical conductivity, and this increase was proportional to the added OMW quantity, [7], [22].

The rise of the soil EC with increasing OMW rates and the highest OMW dose applied almost duplicates the soil salinity, [4]. A gradual rise of soil EC following the application of increasing quantities of treated OMW on maize-cropped soil has been recorded also, [23].

The electrical conductivity of sandy soil increased proportionally to the increase in the OMW quantity and decreased with depth in all analysed soils, [24].

Despite the OMW's moderate acidic pH (5.8), the application does not have a significant effect on the soil's initial values, although a slight decrease in pH has been observed for the two OMW fertigated soils. Levels of pH at C treatment ranged between 7.32 and 7.38 at the begging and at the end of the experiment respectively. For OW3.0, pH values ranged from 7.37 to 7.31 and these for OW6.0 treatment ranged between 7.35 and 7.33 (Fig. 4). Thus, the pH values recorded for the different treatments after 222 days have been always slightly alkaline (< 7.5).

In [25], the authors reported that after 3 years of application, there were no significant differences in EC, between control and OMW-treated plots, and no effects were observed in the respective soil properties, indicating that the buffering capacity of the soil could counterbalance these negative effects.

The addition of treated or untreated OMW did not show any effect on the initial soil pH, [22]. Similar results have been published even with high acidity OMW (pH=4.46), [21].

In this context, [25], have recorded no difference in pH after three years of OMW application. Moreover, [24], have noticed no significant difference in the soil pH in response to the application of increasing OMW doses. Three OMW levels (50, 100, and 200 m^3/ha/year were applied over eight successive years. Despite the acidic pH of OMW, a slight increase in pH values was observed for the soil amended with a dose of 100 and 200 m^3/ha. The pH increase did not exceed 0.5 units for the soil treated with 200 m^3/ha in relation to the control soil. the pH of the soil amended with 50 m^3/ha was not statistically different from the control soil, [24].

Soil plots amended with alkaline OMW show a considerable increase of the pH, proportional to the rate of application but the pH of the treated soils did recover to the control values in about two months, [4].

In pot-planted maize untreated OMW application increased soil salinity, while treated OMW resulted in lower soil pH, [13]. This can be explained by the buffering capacity of the soil, neutralizing the acidity of the OMW, [21], [24], [26].

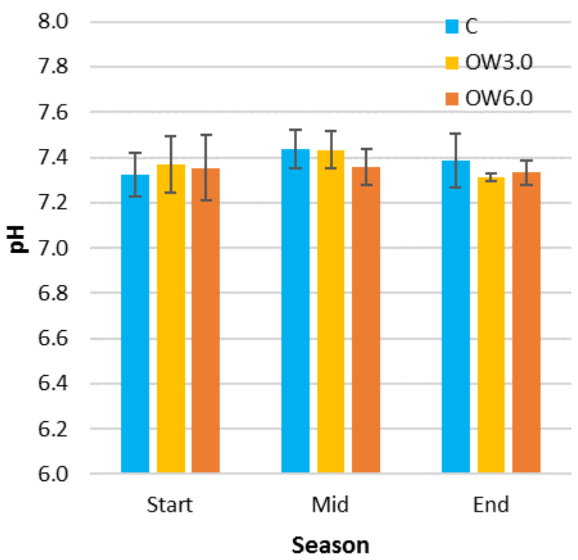

Fig. 4: Soil pH in control (C) and OMW-treated turfgrass. Data points represent the mean from 3 plots ±standard deviation

4 Conclusion

The main objective of this study was to evaluate the effects of olive mill waste application on growth and quality of a sodded turfgrass.

The results showed that the application of OMW had a positive effect on the growth and quality of turfgrass which is strongly related to the enrichment of the soil with nutrients. The dose of 6.0 L/m^2 was the most favorable for the development as well as for the quality of the tested grass.

The results also showed that the application of OMW on clay loam soil led to an increase of the soil's initial EC, yet not significantly, in proportion to the doses applied. Although its moderate acidity, the application of OMW did not remarkably change the initial pH of the soil.

Despite the promising data collected, longer experiments under different soil conditions are still required to define the long-term effects of OMW application on both plant response and soil properties.

Olive mill waste application seems to be a solution for the management of turfgrass because it could limit the use of chemical fertilizers. However, this practice should take into account the cumulative effect of soil salinization, which would with time transform the soil into an unproductive one.

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Conflict of Interest

The authors have no conflict of interest to declare.