Effect of plant species on the performance of vegetated buffer strips to treat agricultural runoffs

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Abstract Vegetated buffer strips (VBS), have been recognized as the most common management practice for mitigating pollution caused by agricultural runoff. They serve a transitional zone between agricultural fields and receiving waters. In this study, two VBS planted with aromatic plants and one unvegetated BS, were examined for the treatment performance of simulated agricultural runoff, under real weather conditions. Specifically, *Lavandula dentata* and *Myrtus communis* were the plant species that were established in the two systems. The effluents of examined VBS were analyzed for COD, pH, turbidity, ammonium, nitrate and phosphate concentrations. The results show that VBS can reduce nutrient concentrations compared to the influent agricultural runoff, although not all parameters showed the same level of reduction compared to the unvegetated buffer strip. The *L. dentata* system showed higher nitrate concentrations than the unvegetated system. Finally, both of the plant systems effectively reduced phosphate concentrations with lower values than the unvegetated system.

Keywords: Vegetated buffer strips, agricultural runoff, diffuse pollution, nutrient removal

1. Introduction

The rapid growth of the population and the need to satisfy their increased demands for food has led to increased agricultural activities. As a result, agricultural practices over the past years have been using larger quantities of pesticides and inorganic fertilizers in order to meet the needs of the population, creating higher crop yields (Ioannidou and Stefanakis, 2020, Jing et al., 2021, Tang et al., 2021). Therefore, excess nutrients and pesticides from agricultural runoff eventually enter and pollute surface waters. Pollution from agricultural runoff is considered among the major pressures on aquatic environments and can even threaten drinking water resources (Carluer et al., 2017, Haddaway et al., 2018). In order to reduce the agricultural runoff to receiving waters, many nature-based practices have been used to mitigate water pollution. Vegetated buffer strips are widely recognized as best management practices for reducing nutrients and especially phosphorus (P) export from agricultural land, due to their easy establishment and low footprint and costs (Habibiandehkordi et al., 2018, Haddaway et al., 2018).

Vegetated buffer strips (VBS) refer to an uncultivated strip of vegetation -usually a mix of trees, shrubs and grasses- that acts as a filter for sediment and their attached nutrients and pollutants, which is placed between aquatic environments and agricultural fields (Barling and Moore, 1994, Hille et al., 2018). They are mostly designed to retain sediment, phosphorus, nitrogen and pesticide losses to off-site surface waters (Haddaway et al., 2018, Hylander et al., 2001). VBS provide benefits, other than mitigating pollution, such as enhancing the aesthetic value of the landscape and protecting biodiversity and other ecosystem services (Cole et al., 2020, Haddaway et al., 2018). They provide a rich habitat for wildlife, especially mammals and birds (Barling and Moore, 1994, Prosser et al., 2020). Also, vegetation can be harvested for economic exploitation (Haddaway et al., 2018).

Vegetation in buffer strips plays an important role in trapping sediment and nutrients and removing or accumulating pollutants (Cole et al., 2020, Hille et al., 2018). Usually, grass species are used in those types of systems, because of their quick, easily established and resistance (Arpino et al., 2023, Dosskey et al., 2010, Poletika et al., 2009, Wu et al., 2020). However, only a few studies are available that evaluate the performance of VBS systems for agricultural runoff treatment using different plant species. The aim of this study was to examine two different aromatic plant species, *L. dentata* and *M. communis*, for treating simulated agricultural runoff, in two periods with different flow rates, under real weather conditions. More specifically, the objective was to assess whether the vegetated systems could reduce nutrient concentrations compared to both the influent and the unvegetated systems.

2. Materials and Methods

Three identical experimental VBSs operated under real weather conditions (internal width: 0.60m, internal length: 2m), were installed in parallel-piped at the research facility of the University of the Aegean in Mytilene, Greece. Two of the systems containing one of the two studied plants and the other one had no plantation (unvegetated) and was used as control (Figure 1). The plant species that were studied were *L. dentata* and *M. communis* (shrub), which are used at a great extent in Greece and are well adapted in to the Mediterranean climate. Regarding the agricultural runoff, a modified synthetic agricultural solution (Edwards et al., 1999, Yates and Prasher, 2009) was used in the experiment to simulate the agricultural runoff.

Figure 1. The three systems, control UBS (left), *Lavandula dentata* VBS2 (middle), *Myrtus communis* VBS1 (right).

In addition, agricultural runoff quality parameters were measured weekly. More specifically, influent and effluent samples were analyzed for pH, turbidity and chemical oxygen demand (COD), according to APHA, (2005) and TP, ammonium (NH_4) and nitrate (NO_3) using standard test kit (HACH). Turbidity was measured using a portable Turbidity Meter (2100Q, Hach).

The systems started operating with synthetic agricultural runoff from November 2022 to April 2023. More specifically, the systems were receiving the simulated agricultural runoff (watering) weekly until February 2023, when the watering frequency was decreased to every second week. During this study, two operating periods were recorded, the first (*Period 1*) from November to January, with the first flow rate at 2.5-2.7 L/min, and the second (*Period 2*) from February to April, with a flow rate at 0.85 L/min.

3. Results and Discussion

Water quality characterization

The pH values for the influent of agricultural runoff were 7.8 ± 0.3 and for the systems was between 7.6-7.8 ± 0.3. Turbidity in *M. communis* system seems to be higher in period 1 (73.7 ± 144.0 FNU) compared to *L. dentata* system and the control (44.0 ± 45.3 and 32.0 ± 31.7 FNU respectively). Although, in period 2, the highest values are recorded from the *Lavandula dentata* system (12.4 ± 6.6 FNU), compared to the other systems (9.4 ± 6.6 FNU *M. communis* system and 7.4 ± 3.8 FNU control) (Table 1).

Table 1. Characteristics of simulated agricultural runoff and effluent of VBS systems in period 2 (Influent (agricultural runoff), VBS1 (*M. communis*), VBS2 (*L. dentata*), UBS (unvegetated system, control)).

Parameter	**Number of samples**	**Influent mean and SE**	**Effluent mean and SE**	**Effluent mean and SE**	**Effluent mean and SE**
			VBS1	VBS2	UBS
pH	12	7.7 ± 0.2	7.3 ± 0.2	7.5 ± 0.2	7.4 ± 0.1
Turbidity (FNU)	12	1.5 ± 0.9	9.4 ± 6.6	12.4 ± 6.6	7.4 ± 3.8
COD (mg/l)	12	10 ± 10	19 ± 17	16 ± 15	13 ± 11
Ammonium (mg/l)	12	17 ± 3	13 ± 3	13 ± 2	11 ± 2
Nitrate (mg/l)	12	26 ± 2	20 ± 2	23 ± 4	23 ± 5
Posphate (mg/l)	12	22 ± 3	17 ± 2	18 ± 5	18 ±1

Concerning the ammonium concentrations in period 1, the vegetated systems showed lower concentrations (7.1 ± 3.6 mg/L, 7.9 ± 3 mg/L) than the control (9.6 ± 4.4 mg/L). That fact indicates the capability of the vegetated systems to remove the concentration compared to the unvegetated system. Nonetheless, in period 2, the concentrations of the vegetated systems may seem to be lower than the influent (13.4 ± 2.8, 12.4 ± 1.9 mg/L), but they are still higher than the control system (11.1 ± 1.6 mg/L) (Figure 2). This may indicate that as the growing conditions were better in period 2, the plants could absorb higher concentrations (Salazar et al., 2015). Indeed, *L. dentata* system by the end of the measurements, visually had formed a more developed root system, which could be justified by the higher reduction compared to the *M. communis* system.

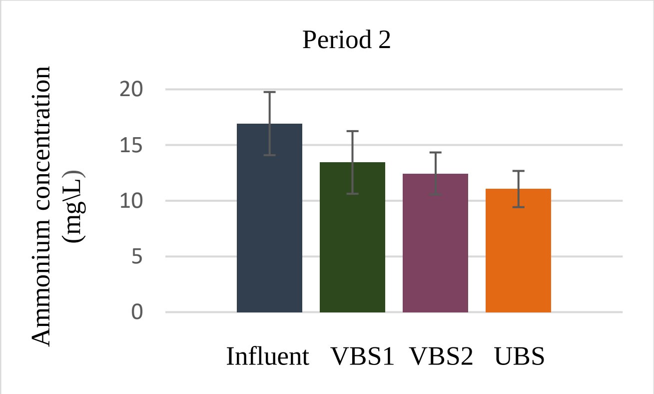

Figure 2. Ammonium concentration during period 2: Influent (agricultural runoff), VBS1 (*M. communis*), VBS2 (*L. dentata*), UBS (unvegetated system).

Nitrate concentrations, in period 1, in vegetated systems seem to be higher (16.7 ± 4.6, 16.5 ± 5.9 mg/L) than the control (16.0 ± 3.6 mg/L) and even the influent agricultural runoff (16.3 ± 4.6 mg/L). In period 2, there is a decrease in nitrate concentration in the systems and especially in the *M communis* system, which records the lowest values (20.4 ± 2.2 mg/L). Conversely, the *L. dentata* system has higher concentration than the control (23.1 ± 3.9mg/L, 22.6 ± 4.9 mg/L, respectively) (Figure 3). In period 2, the lower concentrations may be due to better-growing conditions for the plants, such as higher temperature, solar radiation etc. than the period 1 (Salazar et al., 2015). Previous studies show that permanent grass-vegetated buffer strips are more effective in reducing nitrate concentrations, compared to shrubs or trees (Borin and Bigon, 2002, Hefting and de Klein, 1998, Salazar et al., 2015).

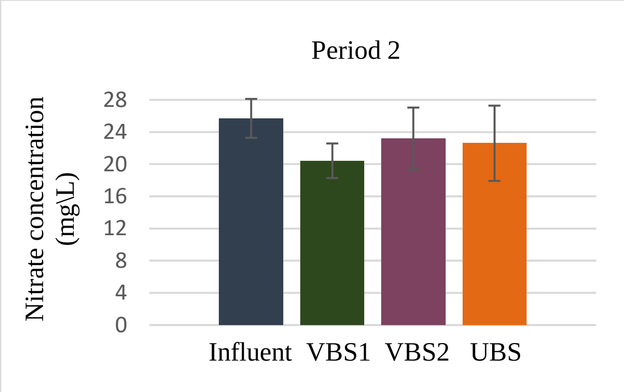

Figure 3. Nitrate concentration during period 2: Influent (simulated agricultural runoff), VBS1 (M. *communis*), VBS2 (*L. dentata*), UBS (unvegetated system).

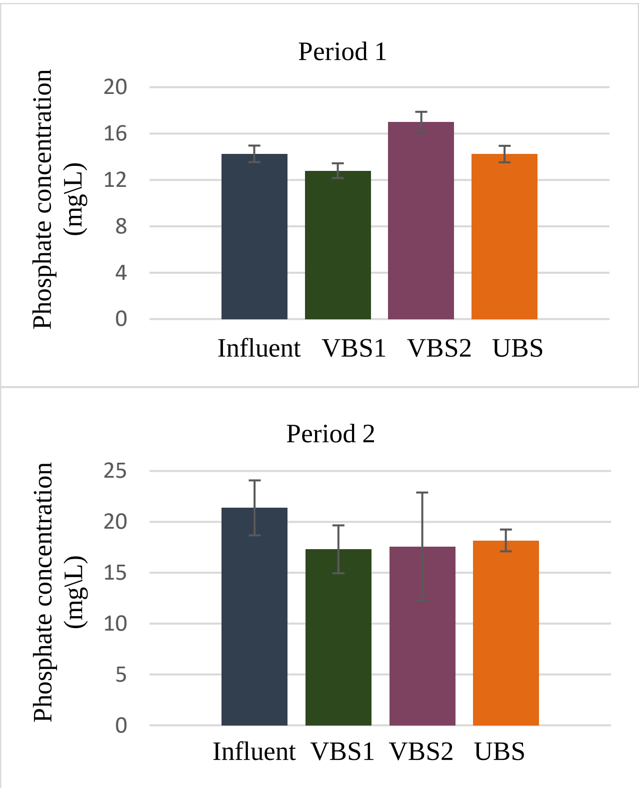

Figure 4. Phosphate concentration during the two periods: Influent (agricultural runoff), VBS1 (*M. communis*), VBS2 (*L. dentata*), UBS (unvegetated system).

Finally, in period 1, the lowest phosphate concentrations are observed in the *M. communis* system (12.8 ± 5.1 mg/L) and the highest in the *L. dentata* system (17.0 ± 8. mg/L). Though, in period 2, the concentrations seem to be decreased in the vegetated systems (Figure 4). The reduction may attribute to the retention of phosphate by physical retention processes of the plants (Roberts et al., 2012). Thanks to the bio-assimilation in which dissolved phosphorus is adsorbed to the soil particles, buffer strips seem to be more efficient in removing phosphates than nitrates (Cole et al., 2020).

4. Conclusions

This study aimed to assess two different aromatic plants, *L. dentata* and *M. communis,* in treating simulated agricultural runoff, in two periods with different flow rate, under real weather conditions. In period 1, both plants seem to reduce ammonium concentrations, whereas the nitrate concentration for both was higher than the influent and the control system. Phosphate concentrations seem to be reduced compared with the influent agricultural runoff, especially for *M. communis* system. Although VBS systems seem to reduce nutrient concentrations compared to influent agricultural runoff, in period 2, the concentrations of both plant systems are higher than the control system (unvegetated), except for the phosphate concentrations where they are lower. It appears that in period 2, the plant better-growing conditions, may have led to reducing nutrient concentrations in general, compared to the influent agricultural runoff. However, ammonium concentrations at the VBS and nitrate concentrations of the *L. dentata* system, were higher than the unvegetated buffer strip.

5. Acknowledgements

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