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# Farmers' Perceptions and Adoption of Using Olive-Mill Wastewater on Barley Crop in Jordan

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**Abstract:** Large amounts of olive-mill wastewater are produced in Jordan annually and impose disposal and environmental problems. Therefore, this study was an attempt to utilize olive-mill wastewater without preliminary treatments to a barley crop as a soil amendment. The experiment was carried out on the same plots for two years, 2005 and 2006 in Jordan with two treatments; untreated and treated. Olive-mill wastewater was spread during barley vegetative phase. Climatic variables were recorded during crop growth. Destructive growth analysis was carried out for every 10 days during the growth cycle of barley to measure dry matter, leaf area index, plant population and grain yield at harvest. The results indicated that olive-mill wastewater spreading without pre-treatment produced some necrosis of the leaves and cause a slow emission of secondary stems. Plant dry matter accumulation was not significantly influenced by olive-mill wastewater spreading since it occurred at the beginning of the vegetative stage. No significant differences in barley yield between the treated and untreated treatments. Furthermore; the results of the study showed that cost, relative advantage and complexity of the new innovation are the main characteristics that influence the adoption of using olive-mill wastewater innovation by farmers. Moreover; technical skill, attitude towards change, attitude towards taking risk, income level, land tenure, educational level and labor availability have an influence on using olive-mill wastewater practice by farmers.

**Key words:** Farmers' perceptions · farmers' adoption · olive-mill wastewater · yield · barley

## INTRODUCTION

Demographic and economic research perspectives have given a great deal of attention in recent years in Jordan to the adoption of non-conventional water resources in agriculture. However, very little attention has been given to the perceptions and attitudinal reasons for farmers to adopt olive-mill wastewater. Jordan, as a semi-arid country, suffers from shortages in water supply for domestic, industrial and agricultural purposes. Limited water supplies, thus, require careful management for successful agricultural production. Furthermore; the use of non-conventional water resources, such as olive-mill wastewater must be probed in agriculture and industry [1].

Like most Mediterranean countries, Jordan in the last few decades has witnessed substantial expansion in olive tree (Olea Europea) culture. This trend seems to continue as the demand for olive oil increases with good revenue and the tree is tolerant of drought conditions and requires minor care to grow. It is estimated that there are more than 15 million olive trees in the country producing about 120,000 tons of olive fruits. Every year the olive pressing industry in Jordan produces around 90,000 tons of solid waste, which is also called olive cake [2]. This process produces a large quantity of liquid waste which is considered the single most important agricultural by-product in the country at least in terms of quantity.

These amounts of waste pose a disposal problem as well as a pollution threat to the country's very limited natural resources [3]. In addition, the country has recently witnessed rising levels of awareness at both the public and government levels of the importance of sound waste utilization and management. Hence, few research initiatives have been conducted to utilize the solid waste material by burning the material in its loose form in a fluidized bed combustor [4] and utilizing the olive cake (solid waste) ash as a soil stabilization medium [5].

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The chemical composition of the wastewater is variable and depends on the fruit maturity, harvest time and processing method; the main characteristics are low pH, high polyphenols and high potassium content. Because of the adhesive and hydrophobic characteristics of olive-mill wastewater, its direct effect on soil aggregation and on soil-water properties needs to be assessed. Land application of olive-mill wastewater could be a promising solution that would prevent environmental pollution and increase soil fertility through integration of organic waste with soil constituents. Positive results were reported in the literature on the application of olive-mill wastewater as a fertilizer [6-8]. Moreover, as a considerable amount of rain or irrigation water is often lost due to the high evaporation demand in arid and semi-arid zones, olive-mill wastewater incorporated could favorably affect the soil water balance by reducing evapotranspiration [9, 10]. However, very limited work has been done in Jordan to examine the effect of olive-mill wastewater on soil physical properties and various crops. Land application of organic waste is highly beneficial to agricultural land and has been shown to improve soil structure, increase infiltration rate, hydraulic conductivity and water holding capacity, reduce runoff and decrease soil erosion [11].

The potential beneficial effects of land application of olive-mill wastewater need to be clarified under field conditions. This research project is a step in the utilization of olive-mill wastewater in Jordan and in other olive oil producing countries of the Mediterranean area. The objectives of this research were: 1) to understand the farmers' perceptions and adoption of using olive-mill wastewater in their farming system, 2) to verify the possibility of directly applying olive-mill wastewater without preliminary treatments to a barley crops in a semi-arid environment like Jordan and 3) to quantify the effects olive-mill wastewater spreading on barley plant growth and on the final yield.

## MATERIALS AND METHODS

The experiment was initiated in the fall of 2005 on a silty clay soil (5% sand, 49% silt, 46% clay) on a private farm located in North Eastern part of Jordan. The experiment was arranged in 8 plots representing four replicates for two treatments (treated and not treated). The plots were randomly selected for the treatments and each plot was 20 m wide and 20 m long. All plots received primary tillage by chisel plowing in the spring of 2005 (seven months before applying the traffic treatments) to a depth of approximately 15 cm. This was the only tillage done prior to the traffic treatments.

Table 1: Main barley crop cycle activities during the 2 experimental years

| | 2005 | 2006 |
|---|---|---|
| Planting | 1 December | 3 December |
| Emergence | 16 December | 20 December |
| Waste application | 2 February | 16 February |
| Nitrogen fertilization | 24 February | 2 March |
| Harvest | 15 June | 17 June |

Table 2: Physical and chemical composition of the olive-mill wastewater

| Parameter | Value |
|---|---|
| Potassium (mg $l^{-1}$) | 1022.0 |
| Phosphorus (mg $l^{-1}$) | 840.0 |
| Dry matter (g $l^{-1}$) | 63.5 |
| Total organic carbon (g $l^{-1}$) | 42.7 |
| Total nitrogen (g $l^{-1}$) | 1.8 |
| pH | 5.3 |
| Soluble solids (%) | 6.1 |
| Suspended solids (%) | 0.9 |
| Calcium (mg $l^{-1}$) | 105.0 |
| Sodium (mg $l^{-1}$) | 670.0 |
| Iron (mg $l^{-1}$) | 91.3 |
| Magnesia (mg $l^{-1}$) | 575.0 |

Farming practices followed at the research site were similar to those of the farmers in the region. All tillage operations were conducted in October as soon as field conditions permitted. The primary tillage operations consisted of chisel plowing at a depth of 20 cm using a 210-cm wide implement (model RCT 7) with seven curved shanks, 6.2 cm wide tines. The secondary tillage operations consisted of a 237-cm-wide mounted tandem disc harrow (model MF 520) fitted with 40-cm-diameter blades at 20-cm spacing. Table 1 shows the main crop management dates used in this study over the two experimental years.

Barley was planted in rows spaced 15 cm apart using a 300-cm-wide seed drill in all treatments and the seeding rate was 130 kg $ha^{-1}$. Conventional farming practices were performed. All tillage and planting operations were performed by an 80-kW two-wheel drive KUBOTA M8030 tractor weighing 5 tons (front tires were 14.9R30 set to recommended level of 190 kPa and rear tires were 18.4R46 bias-ply set to recommended pressure of 110 kPa).

Olive-mill wastewater was spread was spread at 40 t $ha^{-1}$ with a pneumatic tank towed by a tractor. The same plots received the olive-mill wastewater in both experimental years. At the time of spreading, the first stem node of the barley was visible in both experimental years. Table 2 shows the chemical characteristic of the olive-mill wastewater spread in the field.

Data were recorded during barley crop cycle at the experimental site. Ambient air temperature was measured by copper constantan thermocouples and recorded by a data logger (model: Doric 205). Accuracy was approximately ±1°C with repeatability of 0.1°C. Wind velocity in the field was measured by a cup anemometer. Readings were done instantaneously. Wind velocity was normally less than 2 m $s^{-1}$. Global solar radiation was measured by a solar pyranometer and integrator (Kip and Zonnen, model: CC12). It had an accuracy of ±0.1%. Humidity and precipitation data were obtained from a local weather station.

A plant sample of 0.4 $m^2$ in each plot was analyzed every 10 days. The plants were separated into stems, leaves and ears and then counted and weighed. Dry matter weight was measured after drying samples in an oven at 80°C for 48 h. An area meter was used to measure green leaf area in order to calculate leaf area index. At harvest, grain and straw yield and seed weight were recorded. Statistical analysis was performed on the experimental data using the statistical analysis software, MINITAB [12].

## RESULTS AND DISCUSSION

The effect of olive-mill wastewater on plant population during the crop cycle is shown Fig. 1 and 2 for the two years. As shown in Fig. 1, the plant population decreased in the 30 day period after wastewater spreading in the first year. This reduction is due to a lower tillering index. Figure 2 shows the plant population in the second year. A large number of secondary shoots was observed in the treated plots in the second year even though these shoots remained tall and did not produce any grain.

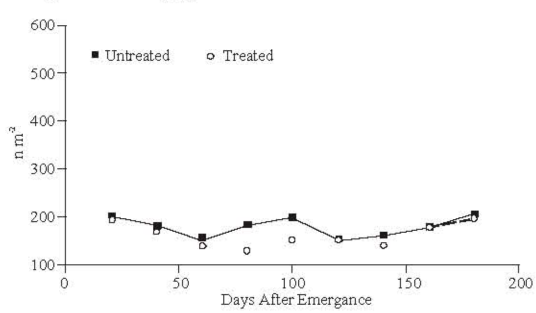


Fig. 1: Barley plant population in the first year of the experiment


Fig. 2: Barley plant population in the second year of the experiment


Fig. 3: Barley leaf area index in the first year of the experiment

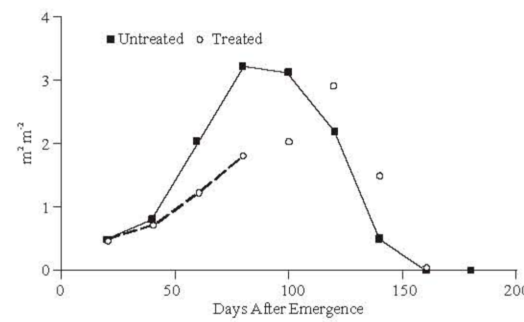


Fig. 4: Barley leaf area index in the second year of the experiment

One reason for this phenomenon could be the delayed application of wastewater in the second year. As a matter of fact, the plants were more developed at spreading and leaf formation had finished although expansion was still continuing. The effect of wastewater on the plants was of moderate phytotoxicity. The crop did not produce new leaves (as in the first year), but a greater number of secondary shoots.

Figure 3 and 4 show the leave area index of the treated and untreated plants in the first and second year of the experiment, respectively. The leaf area index was higher in the untreated than in the treated plots. This is due to a number of necrotic spots, about 40% of leaf surface, which reduced the leaf area index.

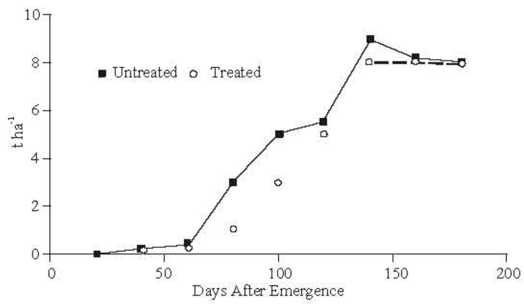


Fig. 5: Barley aboveground dry matter in the first year of the experiment

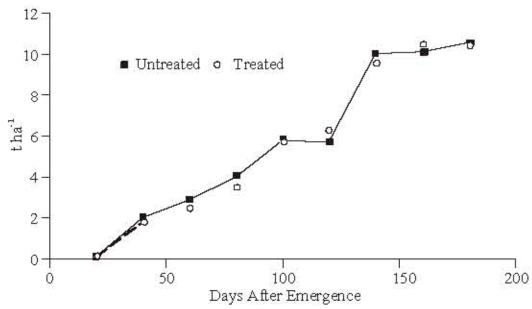


Fig. 6: Barley aboveground dry matter in the second year of the experiment

In the first year of the experiment, the maximum leaf area index was 2.6 in the untreated plots compared to 1.9 in the treated plots and reached earlier than in treated plots (Fig. 3). In the second year of the experiment, the maximum leaf area index was 3.2 in the untreated plots compared to 2.7 in the treated plots and reached earlier than in treated plots (Fig. 4).

Figure 5 and 6 show the total dry matter accumulation for the two years. Dry matter in the untreated plots initially increased and then was followed by a slower increase while in the crop in the treated plots behaved more regularly throughout the crop cycle. The dry matter was observed to be the same for both treatments at harvest. The straw yield was lower in the treated plots than in the untreated plots. This could be due to a cumulative effect of chemical substances in the soil after the application of olive-water wastewater

In contrast to the dry matter, the barley yield decreased from the first year to the second year of the experiment. As a result, the harvest index was reduced from 0.36 to 0.29 (Table 3).

The daily average temperature of the 3-week period around the flowering was 16 and 11°C in the first and second years, respectively. It could be that the reproductive organs were damaged in the second year

Table 3: Main barley characteristics*

| | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Harvest index |
|---|---|---|---|
| 2005 | | | |
| Treated | 2.69a | 4.49a | 0.37 |
| Untreated | 2.73a | 4.39a | 0.35 |
| 2006 | | | |
| Treated | 1.89a | 5.64a | 0.30 |
| Untreated | 1.96a | 5.51a | 0.28 |

*Means in rows, within a treatment type and same factor in each year, followed by the same letter were not significantly different at a 5% probability level

causing low spike fertility and lower yield in the second year. Generally, the yields were comparable with the local average and there were no statistical differences between the two treatments in yearly analysis. For each year in Table 3 different letters indicate a significant difference among the means at LSD test ($p>0.05$). The statistical analysis was performed on arcsin $\sqrt{x}$ transformed data of percentage values.

## CONCLUSIONS

The application of olive-mill wastewater without pretreatments on barley crop during tillering stage caused some necrotic spots on the leaves and a reduction in secondary stem emergence. Barley showed good capability to recover and, at harvest, no significant differences were observed for grain yield between treated and untreated plots. These results offer farmers another possibility to spread olive-mill wastewater during the winter months, especially in semi-arid environments.

Simple random sampling techniques were used to select 80 farmers in the study area. A well structured pre-tested and validated interview schedule was used to collect information from the farmers. The data in Table 4 shows the distribution of respondents by factors influencing adoption of using olive-mill wastewater practices.

The data is classified into two groups;: characteristics of the innovation, characteristics of the adopters:

**Characteristics of the innovation:** A hundred percent each identified cost, relative advantage and complexity respectively. About 93.75 identified technical appropriateness, while 87.75 percent picked divisibility.

**Characteristics of adopters:** A hundred percent each of farmers identifies technical skill, attitude towards change,

Table 4: Distribution of farmers by factors influencing adoption of using olive-mill wastewater practice

| Factors affecting adoption | Frequency | Percentage |
|---|---|---|
| A. Characteristics of innovation | | |
| 1. Cost | 80 | 100.00 |
| 2. Relative advantage | 80 | 100.00 |
| 3. Technical appropriateness | 75 | 93.75 |
| 4. Simplicity of application (i.e. complexity) | 80 | 100.00 |
| 5. Divisibility | 70 | 87.5 |
| B. Characteristics of adopters | | |
| 1. Technical skill | 80 | 100.00 |
| 2. Attitude towards change | 80 | 100.00 |
| 3. Attitude towards taking risk | 80 | 100.00 |
| 4. Income level | 80 | 100.00 |
| 5. Farmers exposure | 75 | 93.75 |
| 6. Land tenure system | 80 | 100.00 |
| 7. Years of farming experience | 60 | 75.00 |
| 8. Educational level | 80 | 100.00 |
| 9. labor availability | 80 | 100.00 |

attitude towards taking risk, income level, land tenure, educational level and labor respectively. About 93.75% identified farmer's exposure, while 75% identified years of farming experience.

We suggest, however, based both on our results and those of other studies in the same area [13, 14] that cost, relative advantage and complexity are the main characteristics of a new innovation that influence the adoption of using olive-mill wastewater practice by farmers. Furthermore; technical skill, attitude towards change, attitude towards taking risk, income level, land tenure, educational level and labor availability have an influence on using olive-mill wastewater practice by farmers.

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