Effect of agronomic application of Olive Mills Wastewater (OMWW) on growth and yield of Quinoa

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Abstract

This research was conducted at the Agricultural Scientific Research Center in Latakia/General Commission for Scientific Agricultural Research (GCSAR) in 2018/2019, to study the effect of Olive Mill Wastewater (OMWW) irrigation on the growth and yield of Quinoa crop. The experiment included five treatments which were investigated in a Randomized Complete Block Design (RCBD) with five replications in a greenhouse pot: T0 represents the control treatment using water only, T1 represents using 3% of untreated OMWW diluted with water, T2 represents using diluted 5% of untreated OMWW, T3 represents using diluted 3% of anaerobically treated OMWW, and T4 represents using diluted 5% of anaerobically treated OMWW. The addition of Phosphate Solubilizing Bacteria (PSB) to OMWW, with no dilution, was adopted for the application of anaerobic treatment, which was performed using a laboratory designed digester. Quinoa pots were watered periodically according to the treatments applied. At the end of the growing period, Quinoa was harvested and several indicators were compared, including: plant height (h), flower length (l), total number of crop seeds (n), total weight of crop seeds (w) and weight of 1000 crop seeds per plant (w1000).The results showed the superiority of T0 in terms of (h) and (l) compared to other treatments, followed by T4.On other hand, T4 outperformed T0, in terms (n) and (w). In terms of (w1000), the results showed that T0 outperformed all the treatments, followed by T3, T4, T1 and T2. The statistical analysis showed that there was no significant difference between T0 and T4 treatments for all the studied measurements.

Key words: Olive Mills Wastewater (OMWW), Quinoa, Irrigation, Phosphate Solubilizing Bacteria (PSB).

Introduction:

Olive Mills Wastewater (OMWW) is the liquid by-product of olive oil industry. This waste is characterized with oily texture, dark color (brown to black), bitter taste and unpleasant smell, in addition to its acidic nature (pH≤ 6) and its high salinity. It consists of water (88-94%); a high proportion of organic matter (5.5-10.5%); a good amount of metal elements (0.5- 1.5%), such as nitrogen, phosphorus and potassium, and high level of solid particles. It is mainly composed of sugars, fatty acids, complex alcohols, and volatile organic compounds. Furthermore, the presence of phenolic compounds, plus the high oxygen demand (chemical and biological), make this waste have a toxic effect against living organisms (Azbar et al., 2004; Tsagaraki et al., 2007; Peixoto et al.,2008; Badawy et al., 2009; Otles and Selek, 2012).

In terms of pollution, the effect 1 m^3 of OMWW is equivalent to 100-200 m^3 of domestic sewage. The uncontrolled disposal of OMWW leads to severe problems for the whole ecosystem and especially for the natural water bodies and ground water reservoirs. Also, OMWW dispersion on the ground affects soil porosity, and the cation exchange capacity of the soil, leading to change of environmental conditions for soil microorganisms and consequently to changes in the fertility of the soil (Cox et al., 1997; Paredes et al., 1999; Sierra et al., 2001; Fiorentino et al., 2004; Tsagaraki et al., 2007; Peixoto et al., 2008).

The direct application of OMWW to agricultural soils inhibits the germination of different seeds and early plant growth of different vegetable species, and may cause leaf and fruit abscission as well (Arvaniti et al., 2011). However, some crops may tolerate a certain amount of OMWW during early growing stages, (الديري ومعروف، 2002؛ الابراهيم و آخرون، 2007؛ بن روينا، 2007؛ رحماني، 2007؛ كسيري، 2007؛ وزاني وآخرون، 2007؛ الابراهيم و آخرون، 2008؛ كبيبو، 2008؛ ناصر وآخرون، 2009؛ الأفندي، 2010؛ كبيبو وآخرون، 2011). On the other hand, if OMWW was properly treated and managed, it can be beneficial as a source of water, organic matter and essential nutrients to the plants, and to improve soil fertility (Rinaldi et al., 2003). Several researchers have shown that application of treated OMWW to agricultural soil increased crop productivity, and enhanced soil fertility (Peixoto et al., 2008). Plant nutrients such as nitrogen, phosphorus and potassium increase with soil application of OMWW (Cereti et al., 2004).

The Syrian olive oil industry consists of 983 working olive mills (according to a statistical study performed aside to this work), mostly concentrated in the north (56% in Aleppo and Idleb), the Syrian coast (about 42% in Latakia and Tartous) and the southern region (2% in Daraa and Sweida). These mills produce around one million cubic meters of OMWW annually (النائب، 2011؛ العيسى وعباس، 2016).

Given the negative influences of this waste, mainly for the environment, it was necessary to find an appropriate solution against the random discharge in the sewage, surface and underground water resources, and on the soils (Tsagaraki et al., 2007; Tamimi et al., 2017).

Different studies have discussed the possibility of OMWW treatment to reduce its toxicity following different treatment techniques, including physical, chemical and biological ones (العفيف وآمون، 2008؛ اليازجي وآخرون، 2009؛ اليازجي وآخرون، 2010؛ حميد ومنصور، 2012), (Hamdi et 1992; Badawy et al., 2009; Arvaniti et al., 2011; Jalilnejad et al., 2011; Abd Allah et al., 2017).

The biological technique is one of the most effective treatment methods compared to others (Tsagaraki et al., 2007; Yen and Brune, 2007; Peixoto et al., 2008; Wilkie, 2008; Otles and Selek, 2012; Aslanzadeh, 2014; Merlin Christy et al., 2014). It includes the anaerobic treatment method which is mainly based on converting organic compounds to carbon dioxide and methane (Moller et al., 2004). This method has been reported as one of the most promising technologies for OMWW treating. In addition to the renewable energy which is generation in form of biogas, anaerobic digestion presents some other appealing advantages, since it produces small amounts of sludge, low nutrient requirements, reduction of greenhouse gases emissions and production of a liquid fertilizer, (Sampaio et al., 2011; Athanasoulia et al., 2012).

Quinoa is an annual seed-producing flowering plant grown as a grain crop. It is known for its benefits as it provides a source for vitamins, mineral salts, and more protein than in brown rice, barley and millet. In addition, Quinoa is gluten free, rich with fibers, phosphorus, magnesium, iron and calcium in its leaves and seeds. Because of the nutritious, agricultural and economical value of Quinoa it is expected to become a major food for the coming generations and an important substitute to face climate change challenges as it is salt, frost and drought tolerant. Quinoa is also needed to be considered for the efforts sets against hunger, malnutrition and poverty. It adapts with well drained sandy and light soils. It has a thick wooden leg that is branched or unbranched, carries wide goose-like leaves. It ends with a spike of flowers where grains that are similar in size to millet are found (Galwey, 1992; Jacobsen, 1997).

In this research, the effect of irrigation with OMWW on the growth and yield of Quinoa plants was investigated, in order to evaluate its suitability for enhancing plant growth without polluting the environment.

1. Objectives and importance of the study:

In the light of successive climatic changes, and their negative impacts on natural resources (water and soil). it is necessary to protect and ensure the sustainability of these natural resources by treating and recycling wastewater coming from various sectors.

This research was aimed to study the effect of Olive Mill Wastewater (OMWW) irrigation on the growth and yield of Quinoa crop, to mitigate the environmental impact of the negative random disposal of OMWW, and also to make use of OMWW as an inexpensive fertilizer, considering the high prices of present used fertilizers and their negative impacts on the environment.

2. Material and methods:

2.1. Material:

In this study, OMWW from a classical pressing mill in Latakia city was used. Samples were analyzed in General Commission for Scientific Agricultural Research (GCSAR) laboratories. Table (1) shows some characteristics of used OMWW. The table shows that the total phenolic content is around 1.1 g/l before treatment.

As shown in Table (1), OMWW is an acidic liquid. It has a considerable content of potassium (K), nitrogen (N), phosphorus (P), which can directly impact soil and water resources and crop production. The electrical conductivity (EC) of OMWW is moderate. The density (ρ) of OMWW is slightly higher than water density.

Table (1): Main characteristics of OMWW used in this study

Organic matter	K_2O	P	Total N	pH	EC	ρ	Total phenols
%				-	dS/m	g/cm^3	g/l
5	0.71	0.13	0.16	5.66	6.26	1.06	1.1
Walkley & Black's method	Flame photo-metric method	Murphy method	Berthelot reaction	pH meter	EC meter	Calculated Mass/ volume	Folin-C method

The addition of Phosphate Solubilizing Bacteria (PSB) to OMWW, with no dilution, was considered for the anaerobic treatment experiment.

The experiment was performed using a laboratory designed digester, which was filled with 95% OMWW+ 0% Water+ 5% PSB solution, then was closed. The temperature was fixed at 35°C during the whole experiment using a water heater, and the pressure was monitored daily. At the end of the experiment, on the 47th day, a sample of the anaerobically treated OMWW was collected to determine the total phenolic content. The analysis of OMWW sample showed a reduction in the total phenolic content by 73% (0.3 g/l compared to the initial value of 1.1 g/l).

2.2. Methods:

The experimental work was carried out at the Agricultural Scientific Research Center in Latakia-GCSAR in 2018/2019.

2.2.1. Quinoa cultivation and irrigation:

The experiment was based on the use of untreated and anaerobically treated OMWW for the irrigation of Quinoa being grown in a greenhouse pot, for the purpose of determining OMWW effect on crop growth and yield. It included five treatments which were investigated in a Randomized Complete Block Design (RCBD) with five replications:

- Treatment T0: Which represents the control treatment using water only.
- Treatment T1: Which represents using 3% of untreated OMWW diluted with water.
- Treatment T2: Which represents using diluted 5% of untreated OMWW.
- Treatment T3: Which represents using diluted 3% of anaerobically treated OMWW.
- Treatment T4: Which represents using diluted 5% of anaerobically treated OMWW.

The 3 and 5% of OMWW was selected following the Syrian ministry of agriculture and agrarian reform issued Decree No. 190 of 2007, which define the rate of using untreated OMWW for irrigation as 50-80 m^3/ha/year.

Quinoa seeds were cultivated within pots (25cm x 25cm), 10 pots per treatment, which were weighed every other day to calculate the amount of water necessary to maintain approximate field capacity water content (45%),then watered accordingly.

Several indicators were compared in this experiment including:

- Plant height (h).
- Flower length (l).
- Total number of crop seeds (n).
- Total weight of crop seeds (w).
- Weight of 1000 crop seeds per plant (w1000).

At harvest, on the 90th day of the experiment, plants height and flowers length were measured, then the plants were picked and dried. The seeds were counted for each plant in each treatment. The weight measurements were taken for 10 seeds each, to be converted later to weight readings for 1000 seeds (dry weight).

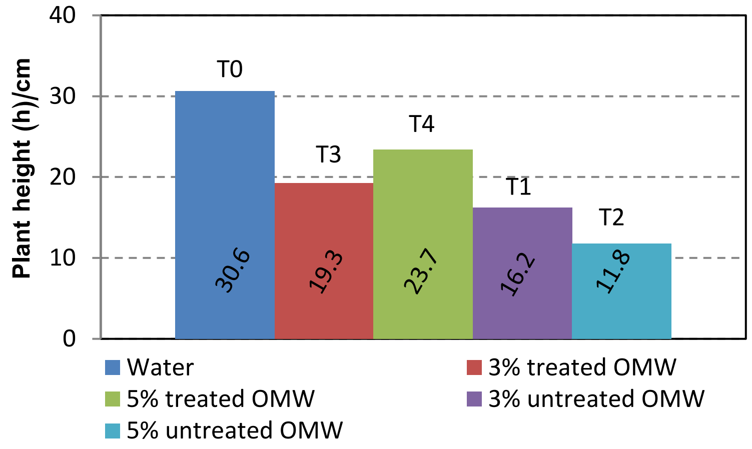
2.2.2. Statistical analysis:

The experiment results data were statistically analyzed using the Statistical Package for the Social Sciences (SPSS 24) program. The one-way Analysis of Variance (ANOVA) and the Least Significant Difference (LSD) tests were carried out to determine whether there are any statistically significant differences between the means of the experiment results at a level of significance 5%.

3. Results and discussion:

Figure (1-A) shows the mean plant height (h), and Figure (1-B) shows the mean flower length (l) for all the treatments. The results showed the superiority of the control treatment T0 (water only) in terms of plant height (h) and flower length (l) compared to other treatments, followed by treatment T4 (diluted 5% anaerobically treated OMWW) with a difference 23% and 17% respectively.

A



B

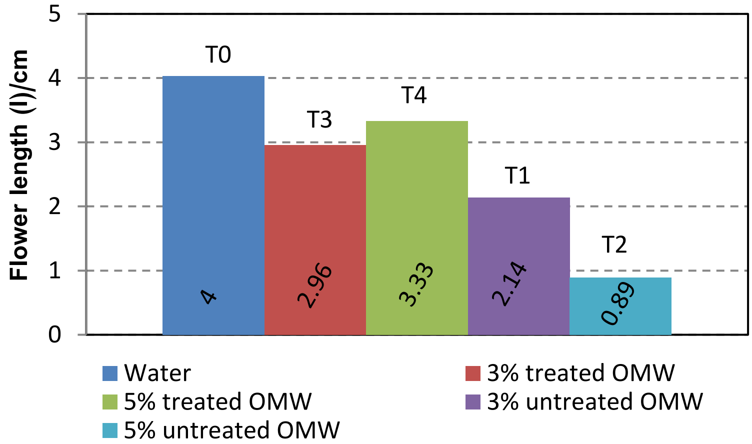
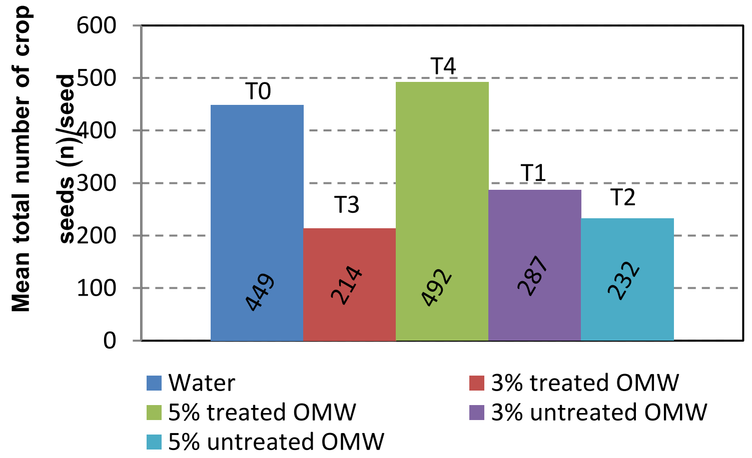


Figure (1): A: Mean plant height (h), B: Mean flower length (l) for all the treatments.

Figure (2-A) shows the mean total number of crop seeds (n) and Figure (2-B) shows the mean total weight of crop seeds (w) for all the treatments. The results showed that the treatment T4 outperformed the control T0, in terms of the mean total number of crop seeds (n) and the mean total weight of crop seeds (w), with a difference 8.7% and 12.8%, respectively.

A



B

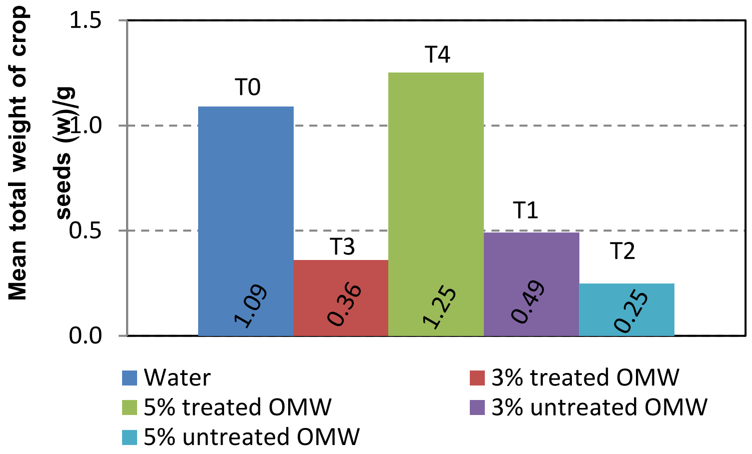


Figure (2): A: Mean total number of crop seeds (n), B: Mean total weight of crop seeds (w) for all the treatments.

Figure (3) shows the mean weight of 1000 crop seeds per plant (w1000) for all the treatments. The results showed that the control T0 outperformed all the treatments, followed by T3, T4, T1 and T2 with a difference equal to 12, 16, 25, 44% respectively.

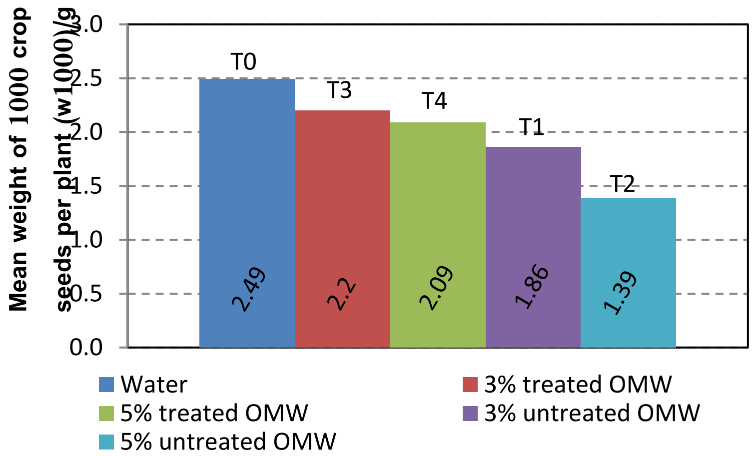


Figure (3): Mean weight of 1000 crop seeds per plant (w_{1000}) for all the experiments.

Table (2) shows the mean for plant height (h), flower length (l), total number of crop seeds (n), total weight of crop seeds (w) and weight of 1000 crop seeds per plant (w1000) for all the treatments. The results showed the following:

- ❖ There was no significant difference between T0 and T4 treatments for all the studied measurements. This can be explained by the fact that irrigation of quinoa with diluted 5% anaerobically treated OMWW, did not cause toxicity symptoms in plants, in terms of plant height (h), flower length (l), total number of crop seeds (n), total weight of crop seeds (w) and weight of 1000 crop seeds per plant (w1000).
- ❖ There was no significant difference between T0 and all the treatments in terms of the total number of crop seeds (n), i.e., the irrigation of quinoa with 3-5% diluted untreated and anaerobically treated OMWW did not cause toxicity symptoms in plants, in terms of the total number of crop seeds (n).
- ❖ There were significant differences between T0 and T1 and T2 treatments in terms of h, l, w and w1000, i.e., the irrigation of quinoa with diluted untreated OMWW may have caused toxicity symptoms in plants, in terms of plant height (h), flower length (l), total weight of crop seeds (w) and weight of 1000 crop seeds per plant (w1000).

❖ There were significant differences between T0 and T3 treatments in terms of plant height (h) and total weight of crop seeds (w). Similarly, there were significant differences between T4 and T3 treatments in terms of plant height (h) and total weight of crop seeds (w). This may be due to different nutrient content (e.g., potassium, nitrogen, phosphorus, etc.) within the two solutions of the two treatments T4 and T3.

Table (2): The mean for plant height (h), flower length (l), total number of crop seeds (n), total weight of crop seeds (w) and weight of 1000 crop seeds per plant (w_{1000}) for all the treatments.

Treatment	h (cm)	l (cm)	n (seed)	w (gr)	w1000 (gr)
T0	30.63a±11.81	4.03a±2.77	449.23a±414.09	1.09a±1.08	**2.49a±0.67**
T1	16.23b±8.41	2.14b±1.67	287.12ab±292.33	0.49b±0.46	**1.86b±0.92**
T2	11.8bc±7.24	0.89bc±0.49	232.29abc±318.75	0.25bc±0.34	**1.39bc±0.56**
T3	19.25bd±11.89	2.96abcd±2.55	213.82abcd±251.77	0.36bcd±0.41	**2.2abd±0.9**
T4	23.36abd±14.5	3.33abcd±3.36	492.08abcd±676.49	1.25ab±2.1	**2.09abd±0.86**
L.S.D	13.65	4.51	556.52	1.54	**1.24**
***The different symbols (a, b, c, d) indicate that there are significant differences (P≤0.05).**					

Conclusion and recommendation:

The result of Quinoa cultivation and irrigation using untreated and anaerobically treated OMWW showed the superiority of the control treatment T0 (water only) in terms of plant height (h) and flower length (l) compared to other treatments, followed by treatment T4 (diluted 5% anaerobically treated OMWW) with a difference 23% and 32% respectively.

On other hand, the treatment T4 outperformed the control T0, in terms of the mean total number of crop seeds (n) and the mean total weight of crop seeds (w), with a difference 8.7% and 14%, respectively

In terms of the mean weight of 1000 crop seeds per plant (w1000), the results showed that the control T0 outperformed all the treatments, followed by T3, T4, T1 and T2 with a difference equal to 11, 16, 25, 46% respectively.

The statistical analysis showed that there was no significant difference between T0 and T4 treatments for all the studied measurements and there was no significant difference between T0 and all the treatments in term of the total number of crop seeds (n). However, there were significant differences between T0 and T1 and T2 treatments in term of (h), (l), (w) and (w1000), and there were significant differences between T0 and T3 treatments in term of (h) and (w).

Accordingly, we find that the use of diluted 5% of anaerobically treated OMWW achieved promising results that are comparable to results obtained when using water only. Therefore, we recommend adopting this conclusion, and supporting it with more studies that target different crops, and accompanying it with studies on soil properties changes with the long-term use of anaerobically treated OMWW.

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تأثير الاستخدام الزراعي للمياه الناتجة عن عصر الزيتون (الجفت) في نمو وإنتاجية نبات الكينوا

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الملخص

أجري هذا البحث في مركز البحوث العلمية الزراعية في اللاذقية/الهيئة العامة للبحوث العلمية الزراعية عام 2019/2018، لدراسة تأثير الري بمياه الجفت في نمو وإنتاجية نبات الكينوا. تضمنت التجربة خمس معاملات وفق تصميم القطاعات العشوائية الكاملة بواقع خمس مكررات وباستخدام الأصص: المعاملة T0 الشاهد والتي تمثل الري باستخدام الماء فقط، المعاملة T1 والتي تمثل الري باستخدام 3% من مياه الجفت غير المعالجة والممددة بالماء، المعاملة T2 والتي تمثل الري باستخدام 5% من مياه الجفت غير المعالجة والممددة بالماء، المعاملة T3 والتي تمثل الري باستخدام 3% من مياه الجفت المعالجة لاهوائياً والممددة بالماء، والمعاملة T4 والتي تمثل الري باستخدام 5% من مياه الجفت المعالجة لاهوائياً والممددة بالماء. تمّ اعتماد إضافة البكتريا المحللة للفوسفات (PSB) إلى مياه الجفت بدون تمديد بالماء، لتطبيق المعالجة اللاهوائية، والتي تمّ إجراؤها باستخدام مخمر مخبري. تمّ ري أصص الكينوا بشكل دوري وفقًا للمعالجات المطبقة. في نهاية التجربة، تمّ حصاد الكينوا وتمّت مقارنة عدة مؤشرات، تشمل: ارتفاع النبات (h)، طول النورة (l)، العدد الكلي للبذور (n)، الوزن الكلي للبذور (w) ووزن 1000 بذرة (w1000). أظهرت النتائج تفوق المعاملة T0 فيما يتعلق بالمؤشرين (h) و(l) مقارنة بالمعاملات الأخرى تليها المعاملة T4. من ناحية أخرى تفوقت المعاملة T4 على المعاملة T0 بالنسبة للمؤشرين (n) و(w). فيما يتعلق بالمؤشر (w1000)، أظهرت النتائج تفوق المعاملة T0 على جميع المعاملات، تليها T3، T4، T1 وT2. كما أظهرت نتائج التحليل الإحصائي عدم وجود فروق معنوية بين المعاملتين T0 وT4 لجميع المؤشرات المدروسة.

الكلمات المفتاحية: مياه الجفت، الكينوا، الري، البكتريا المحللة للفوسفات (PSB).