**The effect of sugar beet molasses and olive mill wastewater (OMWW) on some soil physical and hydrodynamic properties and on potato productivity**

**ABSTRACT**

Agro-industrial residues are a good alternative to reduce the dependence on large quantity of chemical fertilizers, leading to lower production costs and higher soil productivity. The research evaluated the effect of sugar beet molasses and OMWW by-products of sugar and olive oil production, on potato productivity as well as some physical and hydrodynamic characteristics of a silty clay soil in the Syrian Coastal Area. A randomized complete block design field trial was conducted using four rates of OMWW (M0=0, M1=5.4, M2=10.8, M3=16.2 L m-2) and four levels of sugar beet molasses (B0=0, B1=75, B2=150, B3=225 L ha-1). The results showed that soil bulk density (BD) and pores containing unavailable water (PUW) followed a declining trend with rising levels of OMWW and molasses towards gaining the maximum decrement at the treatment B3M3 (16.2 L m-2 of OMWW and 225 L ha-1 of molasses) versus the control (B0M0). Soil water retention curves showed that using OMWW and molasses together at the treatment B3M3 increased water content. The total porosity (TP), macropores >10 μm, pores containing plant-available water (0.2-10 μm) (PAW), and potato productivity experienced the same upward trend with increasing amendment levels separately or together (molasses and OMWW), reaching 63.17, 25.97, 18.87%v and 4551 kg dunum-1, respectively, at the treatment B3M3.

**Keywords:** Molasses–Olive mill wastewater (OMWW)– Soil physical properties –Potatoes- Productivity.

1. **INTRODUCTION**

The soil's physical status is responsible for the optimal functioning of chemical and biological properties of the soil. For instance, the transportation and storage of plants nutrients within the soil profile (Guber, 2007), is guided by its physical state hence the importance of the balance between the liquid and gaseous phases within this system.

Soil organic matter (SOM) plays a key role in improving the soil 's physical properties, which improves the water and nutrient absorption (Neelam et al., 2011), soil structure (Dermiyati, 2015), soil moisture content, and reduces soil compaction and bulk density (BD) (Papini et al., 2011). The decrease in BD may be due to increased macropores and soil aeration as well as the formation of better soil aggregates, ultimately improving soil total porosity (TP) and water holding capacity (Gangwar et al., 2006).

There are multiple sources of organic matter added to the soil for example: animal manure, chicken droppings, green manure that can be mixed into the soil (Soomro et al, 2013). Studies recommend cautious and sustainable use of organic soil amended materials and sources as best for the improvement of soil physical properties. The sugar beet molasses (a by-product of the sugar industry from sugar beet) represents a source of organic material for the soil. It provides an easy-to-use and transportable source depending on its low application rates and has proven to improve soil physical and chemical properties (Demir & Cimrin, 2011). Long and short-term studies revealed that the amendment with sugar beet molasses increased organic carbon (OC), decreased BD, as well as increased soil aggregates stability, and root growth (Bai *et al*., 2010).

Using sugar beet molasses as an organic source improves soil physical status by improving soil aggregate stability and reducing soil compaction, leading to lower bulk density, higher total porosity, and better soil infiltration (Zeleke et al., 2004). This is reflected in saturated hydraulic conductivity that increases with increasing molasses doses (Ijaz et al.,2015).

The OMWW's high organic carbon and humic compound content, as well as its richness of macronutrients, makes it a great soil conditioner with high fertilization potential (Aranda et al., 2016; Vella et al., 2016). OMWW also improves soil physical parameters such as structure, TP, BD, and saturated hydraulic conductivity (Belaqziz et al., 2008; Kavvadias et al., 2015).

Mahmoud et al. (2012) indicated that using OMWW for a period of 5-15 years resulted in increasing soil TP and aggregate stability due to increasing the soil organic carbon content from 0.79% in the control to 3.28 and 3.20% after 5-15 year of OMWW application because OC acts like ligand binding small aggregates to form bigger ones (Emerson, 2008).

The SOM affects potato productivity mostly through different mechanisms (Rawal et al., 2024). Potato crop is one of the most important economic vegetable crops globally and locally and an important source of many nutrients, mineral salts and a range of vitamins. It is also considered a clear indicator of the degree of response to the addition of organic matter and its effect on the physical environment of the soil.

The importance of this research is highlighted by the need to encourage the supply and recycling of agro-industrial residues as molasses and OMWW to the soil. This study seeks to quantify the effect of the amendment on the physical and hydrodynamic properties of the soil as well as their impact on potato productivity.

**2. MATERIALS AND METHODS**

**2.1** **Location of the research and experimental design.**

The research was carried out at the Scientific Research Station (Setkhiris), Latakia, Syria in 2022.

The experiment was designed in a Randomized Complete Block Design (RCBD) in factorial. The study had four levels of OMWW and four rates of sugar beet molasses with three replicates for each treatment. The number of experimental plots reached 16 × 3 = 48 plots of 5 m2 each with 2.5 m length and 2.5 m width with a marginal distance of 0.25 m length and 0.25 m width between treatments, making the area of the experiment 240 m2 where the number of lines in one treatment was 3 planting lines with a distance of 70 cm between them and 25 cm between tubers; the number of plants per line was 10 plants, thus the number of plants per replicate was 30 plants per replicate. The study included the following treatments (Table 1).

 And Table 2. shows the distribution and field randomization of the treatments and the combinations.

**Table 1. The experiment treatments.**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Transaction code**  | **Search parameters**  |
| Control without adding molasses | B0 | Sugar Beet Molasses |
| Adding molasses at a rate of (75) L ha-1 | B1 |
| Adding molasses at a rate of (150) L ha-1 | B2 |
| Molasses addition at a rate of (225) L ha-1 | B3 |
| Control without adding OMWW | M0 | OMWW  |
| Adding OMWW at a rate of (5.4) L m-2  | M1 |
| Adding OMWW at a rate of (10.8) L m-2 | M2 |
| Adding OMWW at a rate of (16.2) L m-2 | M3 |

**Table 2. Distribution of the experiment treatments**

|  |  |  |  |
| --- | --- | --- | --- |
| **M3B3** | **M2B2** | **M1B1** | **M0B0** |
| **M0B3** | **M3B2** | **M2B1** | **M1B0** |
| **M2B3** | **M1B2** | **M0B1** | **M3B0** |
| **M1B3** | **M0B2** | **M3B1** | **M2B0** |
|  |
| **M3B2** | **M2B3** | **M1B0** | **M0B1** |
| **M0B2** | **M3B3** | **M2B0** | **M1B1** |
| **M2B2** | **M1B3** | **M0B0** | **M3B1** |
| **M1B2** | **M0B3** | **M3B0** | **M2B1** |
|  |
| **M3B1** | **M2B0** | **M1B2** | **M0B3** |
| **M0B1** | **M3B0** | **M2B2** | **M1B3** |
| **M2B1** | **M1B0** | **M0B2** | **M3B3** |
| **M1B1** | **M0B0** | **M3B2** | **M2B3** |

M0 = 0 L m-2 of OMWW control OMWW, M1 = 5.4 L m-2 of OMWW, M2 = 10.8 L m-2 of OMWW M3 = 16.2 L m-2 of OMWW, B0 = 0 L ha-1 of molasses, B1= 75 L ha-1 of molasses, B2 = 150 L ha-1 of molasses, B3 = 225 L ha-1 of molasses.

**2.2 Materials (soil, plant, sugar beet molasses, and OMWW)**

The soil samples collected were subjected to a set of laboratory analyses to determine some physical and chemical properties. It was found that the soil type is silty clay, and that this soil has a medium bulk density in the surface layer where agricultural activities are carried out, and it has a slightly alkaline pH and a medium cation exchange capacity, and is poor in organic matter (Table 3).

**Table 3. Some physical and chemical properties of the soil of the research site before planting at the depth of 0 - 20 cm**

|  |  |  |
| --- | --- | --- |
| **Measurement method** | **Value** | **Analysis** |
| Pipette method (Bernhart, 1967) | 459.9 | Clay g/kg  |
| 505 | Silt g/kg  |
| 36 | Sand g/kg  |
| German Texture Triangle (TGL, 1985) | UT Silty clay | Soil texture |
| Wet digestion (Ryan et al (2003) | 8.2 | Organic matter g/kg  |
| Titration (Ryan et al. (2003) | 43.2 | Total calcium carbonate % |
| Dorino (Ryan et al. (2003) | 24% | Effective calcium carbonate% |
| Sodium acetate (Ryan et al (2003) | 33.7 | Cation exchange capacity. meq 100g-1 soil |
| Pressure plate apparatus | 36 | Field Capacity %Volume  |
|  | 21.7 | Permanent wilting point %vol |
| Pycnometer | 2.65  | True density g cm-3 |
| Metal cylinders | 1.21 | Bulk density g cm-3 |
| pH meter | 7.53 | pH |

Plant material. A 110-100 days medium delayed maturity Dutch potato variety named Spunta was used. It is an economic variety that have been successfully cultivated in many countries of the world; its dormancy period is medium. The tubers are elongated and large in size, their outer color is pale yellow and the inner color is light yellow, the leaves are relatively small and the flowers are white, the size of the vegetative group is good, their dry matter content is average, and seeds (tubers) were obtained from the General Organization for Seed Propagation-Latakia Branch.

Sugar beet molasses. It was taken from a sugar factory in Hama Governorate (Salhab area), where its chemical composition showed high content in potassium and calcium as shown in Table 4.

**Table 4. Proportions of material components in sugar beet molasses:**

|  |  |
| --- | --- |
| **Percentage (wt%)** | **Material** |
| 21.36 | Water |
| 34.42 | Sucrose |
| 15.18 | Fructose and glucose |
| 4.37 | Gums |
| 0.72 | Starch |
| 0.54 | Wax |
| 0.65 | Nitrogen |
| 0.27 | Soluble Silica (SiO2) |
| 0.28 | Phosphate (P2O5) |
| 3.46 | Potassium (K2O) |
| 1.05 | Calcium (CaO) |
| 1.1 | Magnesium (MgO) |
| 13.1 | Sulfurous ash |

Olive mill wastewater (OMWW). It was taken from a centrifugal olive press. Table 5. shows the components resulting from the analysis of the OMWW sample.

**Table 5. Components of Olive Mill Waste Water**

|  |  |  |
| --- | --- | --- |
| **Analysis** | **Value** | **Analysis method** |
| pH | 5.29 | pH meter |
| Electrical conductivity (mmhos cm-1) | 6.15 | EC meter |
| Organic Matter (g l-1) | 49.32 | Incineration at 550°C |
| Dry Matter (g l-1) | 69.38 | Drying at 105°C |
| Total nitrogen (mg l-1) | 850 | Digestion with sulfuric and salicylic acids H2SO4, Se in the presence of selenium |
| Absorbable phosphorus (mg l-1) | 277.6 |
| Soluble potassium (mg l-1) | 2465 |
| Calcium (mg l-1) | 215 |
| Magnesium (mg l-1) | 150 |
| Iron (mg l-1) | 31.5 |
| Copper (mg l-1) | 3.2 |
| Manganese (mg l-1) | 4.7 |

**2.3. EXPERIMENTAL FIELD**

The soil was deep plowed up to 20 cm, and then the rotary cultivator was used to level and smooth the soil surface. After that, OMWW was added according to the studied treatments to the soil using a manual sprayer and left for 40 days before planting. The planting lines were drawn at a distance of 70 cm between one line and the another.

The amount of OMWW allocated to each experimental plot was calculated as follows: 5.4 l m-2 added to M1, 10.8 L m-2 added to M2, 16.2 L m2 added to M3, and nothing added to M0.

These levels are equivalent as a percentage of field capacity as follows:

 5.4 L m-2 is equivalent to 7.5% of field capacity, 10.8 L m-2 is equivalent to 15% of field capacity, and 16.2 L m-2 is equivalent to 22.5% of field capacity, considering that the field capacity of the studied soil is 36%.

That is:

Every 36% volume is equivalent to 100% of the field capacity

Every x% volume is equivalent to 7.5% of field capacity, of which x = 2.7% volume.

The depth of water added is 20 cm =Wvol. Bt/10 =2.7×20/10 =5.4mm=5.4 L m-2 Equation 1

Bt: the depth of the soil to be moistened in cm

 10: conversion number, and in the same way for the rest of the treatments.

Molasses was added just before planting, sprayed on the soil surface after dilution with water according to the concentrations used (The amount of supplied water was determined based on the current soil moisture, which was 32%. This moisture was elevated to 36% at a depth of 10 cm to reach the field capacity, therefore we needed 4 mm/m2 using a manual sprayer), then the tubers were planted in the autumn on 22/9/2022, then the service operations of patching, irrigation, and control were carried out according to the plant requirements, and fertilization was done by adding the following fertilizer formula (250-150-200) kg ha-1 of (N-P-K), where potassium and phosphorus fertilizers were added before adding OMWW, while nitrogen was in three batches, the first during planting, the second one month after planting, and the third at flowering.

**2.4 Measured indicators**

After harvest, undisturbed soil (0–20 cm) sampling was done in between rows using metal cylinders with a volume of 100 cm3. Three replicates were taken from each treatment (one from each replicate) to calculate:

**2.4.1** Bulk density (BD)

*BD g cm-3* = Ms Vt-1 Equation 2

Where: *Ms* - oven dry weight of the sample (105 °C);

 *V*t cm3- total volume of the cylinder (100 cm 3).

**2.4.2** Soil pore size distribution (PSD)using pressure plate apparatus:

To calculate the required pressure, we entered the pore diameter in the following equation:

*Pm* = 4σw/d Equation 3

Where: *Pm* - applied pressure pascal;

*d* - pore diameter m;

*σw* - surface tension of water - newton m-1  (0.073).

By the end of each pressure related to each pore size group, we will get the volumetric water content:

*WvolpFx*=(mm pFx -Ms/vt) Equation 4

*WvolpFx* - volumetric water content at specific pressure;

 mm *pFx*- the weight of the cylinder (soil sample) at the end of specific pressure;

*Vt* - the volume of the cylinder;

*Ms* - the dry weight of the soil (105 °C).

The size of the pore groups is determined as follows:

*PV%> 50 µm* = TP-Wvol. pF1.8 Equation 5

*PV%> 10 µm* = TP-Wvol. pF2.5 Equation 6

*PAW% (0.2-10) µm* = Wvol. pF2.5-Wvol.pF4.2. Equation 7

 *PV% < 0.2 µm* = Wvol. pF4.2 Equation 8

Where: *TP%* - Total porosity;

*BD* - bulk density of the soil g cm-3;

*PD* - particle density of the soil g cm-3.

**2.4.3** Soil water retention curves (WRCs) of the studied soil parameters by metal cylinders using a pressure plate device at different levels of pressure pF1.8, pF2, pF2.5, pF3, pF3.5, and pF4.2 and then the moisture content was calculated at different moisture tension levels to obtain a relationship from the following form:

Ψ=aθb Equation 9

Where θ: moisture content was expressed as a part of one, Ψ: moisture tension, (a, b): experimental constants.

**2.4.4** Quantity of production (kg dunum-1): Tubers were collected at the end of the season and the total production of the three planting lines was calculated for each replicate; then the average production of one plant per replicate was calculated, from which the production of an area of 5 m2 was calculated, and then the production ratios to the area of one dunum (1000 m2) were calculated.

**2.5 Statistical analysis**

To evaluate the results, the study employed one-way variation analysis (ANOVA) to examine inter-group differences. The least significant difference (LSD) test was utilized with a significance level of 5% using the Genstat program.

**3. RESULTS AND DISCUSSION**

**3.1 The effect of adding different levels of sugar beet molasses and OMWW on soil BD and TP**

Table 6. revealed the soil BD and TP changes in the depth of 0-20 cm after sugar beet molasses and OMWW amendments.

TP revealed an upward trend using sugar beet molasses and OMWW amendments either alone or together.TP increased markedly by 3.74% at the third level of molasses B3M0 in comparison to the control B0M0 when increasing molasses amendment levels without OMWW amendment (Table 6).Regarding OMWW treatments without sugar beet molasses additions, TP increased significantly by 2.32v% at the third level of OMWW in comparison to the control (B0M0).TP increased significantly in the B3M3 treatment by 8.84% over the control outperforming all treatments.

BD showed a downturn while using sugar beet molasses and OMWW amendments either alone or together. Notwithstanding, the greatest significant decrease in BD value was at the treatment B3M3 (225 L ha-1 molasses-16.2 L m-2 OMWW) with a decrease of (0.26 g cm-3). Molasses doses alone had contributed to reduction in BD only at the dose (225 L ha-1) in comparison to OMWW amended doses. Furthermore, the higher the usage of the combination from Molasses and OMWW (75-150-225 L ha-1) and (5.4-10.8-16.2 L m-2) the greater the BD reductions. However, no significant changes were recorded between the treatments (M3B1, M3B2 and M2B2).

 Khalil et al. (2024), revealed that OMWW gradual rates (0, 5, 10, and 15 L m−2) decreased BD values of a clay soil. This is in line with Omara et al., (2022) who reported that increasing molasses level (140, 280, and 420 L ha-1) decreases BD of a clay soil.

This means that the addition of sugar beet molasses and OMWW to the soil surface layer clearly led to the activation of microorganisms and thus increased the secretions of these organisms, which in turn work to produce microbial gum that improves soil structure, leading to BD reductions, noting that high BD negatively affects crop productivity, and this is consistent with (petelkau ,1987), who found that increasing the soil BD by 0.3 g cm-3 causes a decrease in potato productivity by more than 40%.

**Table 6. The effect of adding different levels of sugar beet molasses and OMWW on soil BD (g cm-3) and TP(%V)**

|  |  |  |
| --- | --- | --- |
|  **TP** **(%v)** | **BD (g cm-3)**  |  **Treatment**  |
| 54.33 | 1.2 h | **B0M0** |
| 55.68 | 1.17 g | **B1M0** |
| 56.32 | 1.14 fg | **B2M0** |
| 58.07 | 1.09 de | **B3M0** |
| 55.68 | 1.17 g | **B0M1** |
| 56.65 | 1.14 fg | **B1M1** |
| 57.08 | 1.12 ef | **B2M1** |
| 59.69 | 1.05 c | **B3M1** |
| 56.27 | 1.15 fg | **B0M2** |
| 57.25 | 1.12ef | **B1M2** |
| 59.0 | 1.07 cd | **B2M2** |
| 61.38 | 1.00 b | **B3M2** |
| 56.65 | 1.14 fg | **B0M3** |
| 57.85 | 1.10 de | **B1M3** |
| 59.32 | 1.06 cd | **B2M3** |
| 63.17 | 0.95 a | **B3M3** |
| 1.173 | 0.032 | **LSD0.05** |

Explanation:BD - bulk density, TP – total porosity volume.

**3.2 The effect of adding sugar beet molasses and OMWW on the soil pore size distribution**

Table 7. shows the changes in soil pore size distribution after different additions of sugar beet molasses and OMWW.

PV >50 μm, and PAW increased markedly by 1.78, and 3.76v%, respectively, at the third level of molasses B3M0 in comparison to the control (B0M0) when increasing molasses amendment levels without OMWW amendment (Table 7). Although Macropores >10 μm (air capacity) increased to 19.38%v at the B0B3 addition level, no significant difference was recorded. PUW decreased from 21.78 v% to 20.71 v% in the treatment B0B3, reporting a significant decrease of 1.07%v compared to control.

No significant increments in PV >50 μm and macropores >10 μm were recorded compared to the control (B0M0). On the other side, PUW decreased from 21.78% in the control treatment to 21.2% in B0M3, a significant decrease of 0.58 v%..

PV >50 μm, macropores >10 μm and PAW increased significantly in the B3M3 treatment by 8.49, 7.64 and 4.65v% over the control outperforming all treatments while PUW decreased significantly to decreased to 18.33 v% in B3M3. PAW increae of 4.65 v% is significant as it is equivalent to increasing the soil stock of PAW at a depth of 20 cm by Wmm= 4.65×20/10=9.3 mm, equivalent to 93 m3 h-1.

Molasses amendment to the soil improves the overall stability of the soil by binding aggregates, leading to improved micro and macro pores of the soil due to the interaction between the positive ions in the molasses components with the negative ions on the surfaces of clay minerals and the binding forces between them (Julius, 2011). On the other hand, the addition of OMWW at increasing rates contributed to increase the soil TP, especially the medium pores, and as a result, its field capacity increases as the soil gains a greater ability to retain water (Pagliai, 1996; Mellouli et al., 1998; Colucci et al., 2002).

**Table 7. The pore size distribution in the soil at different levels of sugar beet molasses and OMWW.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **PV<0.2 μm****(%v)** | **PAW (0.2 -10 μm)****(%v)** | **PV>10 μm****(%v)** | **PV****>50 μm (%v)** | **Treatment** |
| 21.78 | 14.22 | 18.33 | 14.31 | **B0M0** |
| 21.52 | 15.38 | 18.78 | 16.42 | **B1M0** |
| 21.54 | 17.96 | 16.82 | 12.0 | **B2M0** |
| 20.71 | 17.98 | 19.38 | 16.09 | **B3M0** |
| 21.52 | 14.48 | 19.68 | 15.18 | **B0M1** |
| 21.09 | 16.5 | 19.06 | 16.02 | **B1M1** |
| 20.94 | 15.04 | 21.08 | 18.08 | **B2M1** |
| 19.95 | 16.16 | 23.5 | 17.09 | **B3M1** |
| 21.27 | 15.99 | 19.01 | 15.86 | **B0M2** |
| 20.83 | 15.21 | 21.21 | 16.51 | **B1M2** |
| 20.22 | 17.35 | 21.39 | 19.05 | **B2M2** |
| 19.2 | 17.16 | 25.02 | 20.68 | **B3M2** |
| 21.2 | 15.8 | 19.65 | 15.73 | **B0M3** |
| 20.57 | 15.43 | 21.85 | 17.34 | **B1M3** |
| 20.14 | 16.56 | 22.53 | 20.43 | **B2M3** |
| 18.33 | 18.87 | 25.97 | 22.8 | **B3M3** |
| 0.547 | 1.835 | 2.03 | 2.541 | **Lsd 0,05** |

Explanation: PV>50 μm – volume of pores larger than 50 micrometre, PV**>**10 μm– volume of macropores larger than 10 micrometre, PAW (0.2 -10 μm) –volume of pores containing available water between 0.2 and 10 micrometre,PV<0.2 μm– volume of pores less than 0.2 micrometre.

**3.3 Effect of sugar beet molasses and OMWW on WRCs and experimental soil constants**

WRCs at different levels of sugar beet molasses and OMWW are illustrated in Figure 1.

The moisture content of the soil decreases with increasing moisture retention in all studied treatments, and it was also found that the greater the addition rate of sugar beet molasses and OMWW at the same moisture retention, the higher the moisture content in the soil.

Here is the role of the large charged surface area of molasses and OMWW that increases the binding forces between soil and clay particles to form large and small pores (Ebtisam et al., 2012). Organic matter aid water holding in the soil; thus, water retention increased when organic compounds are added to the soil, which increases water use efficiency (Mosa, 2012), and this increase is greater at low moisture retention levels, which indicates an increase in the efficiency of the soil in its water retention capacity, especially that part called PAW (Table 7).

The experimental constants of the soil at different levels of sugar beet molasses and OMWW are illustrated in Table 8. The coefficient of determination (r2) was high near unity indicated a good relationship, nearly all the variations were accounted for, and the equation is a good predictor.

The experimental constants (a and b) in the soil depth of 0-20 cm rose with increasing amendment levels of both (molasses and OMWW), recording the best performance at the treatment M3B3 (Table 8). However, constant a ranged between 0.031 at (B0M0) and 0.375, while constant b ranged between -8.356 at the control (B0M0) and -6.385 at the treatment (M3B3). This could be explained by the rising amount of PAW at the same moisture retention on behalf of the reduction in permanent wilting point. Moreover, increasing the total water content of the soil at field capacity. Overall, this has a beneficial impact on the capillary's ability to transport water within the rooting zone and contributing to uptake of water by the root system, which also enhances water use efficiency and delays the onset of water shortage in the plant.

**Table 8. The experimental constants of the soil at different levels of sugar beet molasses and OMWW.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Hydrodynamic constants**  | **Determination coefficient****(r2)** | **Equation** | **Treatment** |
|  **a** |  **b** |
| 0.031 | -8.356 | 0.96 | Ψ=0.031.θ-8.356 | **B0M0** |
| 0.059 | -8.256 | 0.96 | Ψ=0.059.θ-8.256 | **B1M0** |
| 0.259 | -7.279 | 0.98 | Ψ=0.259.θ-7.279 | **B2M0** |
| 0.346 | -6.948 | 0.95 | Ψ=0.346.θ -6.948 | **B3M0** |
| 0.032 | **8.721**- | 0.98 | Ψ=0.0315.θ-8.721 | **B0M1** |
| 0.083 | -7.998 | 0.97 | Ψ=0.083.θ-7.998 | **B1M1** |
| 0.051 | -8.197 | 0.97 | Ψ=0.0506.θ-8.197 | **B2M1** |
| 0.190 | -7.082 | 0.98 | Ψ=0.19.θ-7.082 | **B3M1** |
| 0.081 | -8.005 | 0.97 | Ψ=0.081.θ-8.005 | **B0M2** |
| 0.082 | -7.888 | 0.98 | Ψ=0.082.θ-7.888 | **B1M2** |
| 0.143 | -7.346 | 0.97 | Ψ=0.1432.θ-7.346 | **B2M2** |
| 0.190 | -6.945 | 0.98 | Ψ=0.19.θ-6.945 | **B3M2** |
| 0.084 | -7.954 | 0.98 | Ψ=0.0835.θ-7.954 | **B0M3** |
| 0.098 | -7.695 | 0.97 | Ψ=0.098.θ-7.695 | **B1M3** |
| 0.182 | -7.228 | 0.96 | Ψ=0.1822.θ-7.228 | **B2M3** |
| 0.375 | -6.385 | 0.95 | Ψ=0.375.θ -6.385 | **B3M3** |

**Figure 1. WRCs at different levels of sugar beet molasses and OMWW.**

**3.4 Potato plant productivity under the effect of the addition of sugar beet molasses and OMWW**

Table 9. gives a breakdown of sugar beet molasses and OMWW effects on potato productivity.

Potato productivity increased significantly by 416-1023 and 1201 kg dunum-1 after the amendment of molasses rates alone (75, 150, and 225 L ha-1) in comparison to the control (B0M0). While potato productivity increased significantly after adding OMWW at (5.4 -10.8 and 16.2 L m2) without sugar beet molasses by 181-628 and 1898 kg dunm-1 compared to the control free of amendment (B0M0). Overall, the results showed that OMWW treatments were superior to sugar beet molasses ones in increasing potato plant productivity.

The integration usage of both amendments (molasses and OMWW) increasing levels increased potato productivity. Potato productivity reached 4551 kg dunum-1 at the addition rate (225L ha-1 molasses and 16.2 L m-2 OMWW) with an increase of 124.4% compared to the control.

The treatment (M3B3) did not differ significantly from the treatment M3B2. Similarly, the treatment (M3B2) did not differ significantly from (M2B3). OMWW amendment improved potato vegetative growth due to its good content of major nutrients (N, P, K), OM, and micronutrients (Nevens and Reheul,2003; Gavalda et al., 2005)

**Table 9. Potato plant productivity (kg dunum-1) under the effect of sugar beet molasses and OMWW.**

|  |  |
| --- | --- |
| **Productivity** |  **Treatment**  |
| 2028 a | **B0M0** |
| 2444 c | **B1M0** |
| 3051 e | **B2M0** |
| 3229 f | **B3M0** |
| 2209 b | **B0M1** |
| 3426 g | **B1M1** |
| 3727 h | **B2M1** |
| 4139 j | **B3M1** |
| 2656 d | **B0M2** |
| 3718 h | **B1M2** |
| 4152 j | **B2M2** |
| 4371 k | **B3M2** |
| 3926 i | **B0M3** |
| 3989 ij | **B1M3** |
| 4531 kl | **B2M3** |
| 4551 l | **B3M3** |
| 169.6 | **LSD0.05** |

\*Different letters within the same column and row indicate significant differences at the 5% significance level.

**4. CONCLUSIONS**

The outcomes of this research revealed that OMWW and molasses are possible approaches to improve the physical status of a silty clay soil. The highest levels of combination (225L ha-1 molasses and 16.2 L m-2 OMWW) gave a better performance which is expected of an organic input. This was translated by the improvement in (TP, PV >50 μm, macropores >10 μm and PAW and experimental constants (a and b). As a result of higher water content is the soil and better absorption conditions, potato plant productivity improved, reaching more than two times in comparison to the control (B0M0).

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**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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