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Cultivation of irrigated tomatoes with ozonised water under a Mediterranean climate in Algeria

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Cultivation of irrigated tomatoes with ozonised water under a Mediterranean climate in Algeria

Abstract: This study presents the results of an experimental work carried out on tomato seedlings of the same varietal type, grown under a Mediterranean climate and irrigated with ozonised water at different ozonisation durations that vary from zero to 30 seconds. In order to assess the impact of aqueous ozone on the agronomic performances and the physicochemical characteristics of fruits. The tomatoes responded differently between themselves and the control batch. The results obtained showed precocity of germination, an increase in growth, development, and vigour in the experimental plants compared to the controls. The yield is proportional to the increase in the ozonisation time of irrigation water. During the reproductive phase of the plants, no negative effects were observed. The physicochemical characteristics of fruits could be evaluated; they are distinguished from higher sugar contents in the experimental tomatoes compared to controls, no great difference for the other criteria analysed, the latter were generally in accordance with the standardized values of the literature as well as with the applicable national regulations. Ozonisation of irrigation water is an effective and promising alternative method, which improves germination time and increases fruit yield without negatively affecting their marketability.

Key words: chemical properties; ozone; performances; sustainable land use; yield

Gojenje paradižnika zalivanega z ozonirano vodo v razmerah mediteranskega podnebja v Alžiriji

Izvleček: Raziskava predstavlja rezultate poskusa izvedenega na sadikah paradižnika iste sorte, gojenega v mediteranskem podnebju in namakanega z ozonirano vodo, tretirano z ozononom od 0 do 30 sekund. Namen raziskave je bil ugotoviti učinek ozonizirane vode na agronomske in fizikalnokemijske lastnosti plodov. Odziv rastlin paradižnika se je razlikoval med posameznimi obravnavanji in glede na kontrolo. Rezultati so pokazali zgodnejšo kalitev, hitrejšo rast in hitrejši razvoj ter večjo vitalnost obravnavanih rastlin v primerjavi s kontrolo. Povečanje pridelka je bilo proporcionalno povečanju časa ozonizacije vode za zalivanje. V reproduktivni fazi rastlin ni bilo opaženih nobenih negativnih učinkov ozonizacije. Ocenjene fizikalno-kemijske lastnosti plodov so pokazale večjo vsebnost sladkorjev v obravnavanih rastlinah v primerjavi s kontrolo. V ostalih analiziranih parametrih ni bilo večjih razlik v primerjavi s kontrolo in so bile nasplošno v skladu s standardnimi vrednostmi iz literature kot tudi z veljavnimi nacionalnimi standardi. Ozoniranje vode za zalivanje je učinkovita in obetavna alternativna metoda, ki izboljšuje čas kalitve, povečuje pridelek plodov paradižnika brez negativnih učinkov na njihovo tržno vrednost.

Ključne besede: kemijske lastnosti; ozon; uspevanje; trajnostna raba tal; pridelek

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1 INTRODUCTION

The tomato cultivation occupies an important place in the Algerian agricultural economy nearly 33.000 hectares are devoted annually to the cultivation of market garden and industrial tomatoes (MADR – Ministère de l'Agriculture et du Développement Rural, s. d.). its cultivation has adapted to different climates and the production of fresh tomatoes in Algeria has grown steadily over the past ten years, increasing from 64 million tonnes in 2009 to 164 million tonnes in 2020 (FAOSTAT, s. d.), the same for tomatoes intended for processing, they recorded exceptional performances during the year 2019-2020, with a global production of nearly 1.3 million tonne. In Algeria, the industrial tomato has experienced a considerable development in terms of area and production, going from 0.92 million tonne in 2013 to 1.65 million tonne in 2019. This notable performance made it possible to reduce imports and by therefore, to create added value to the national economy (MADR – Ministère de l'Agriculture et du Développement Rural, s. d.). Indeed, Algeria, the largest country in Africa, with an area of 2.4 million km² and it opens along 1200 km of coastline on the Mediterranean. The climatic areas are very diverse and the climate varies from the Mediterranean's type to the Saharan's type. On the Mediterranean coast, the summer is hot and dry; the winter is mild and rainy. Total annual rains falls increases along the coast from west to east, but decreases rapidly from the coast southward to the interior. Rains falls decreases after crossing the Atlas Mountains to the south (Algeria | Flag, Capital, Population, Map, & Language, s. d.).

Due to the nutritional qualities and antioxidants contained in tomato such as lycopene, β-carotenes and phenolic compounds, its consumption has been linked to the prevention of several types of cancer, such as breast cancer, coronary cancer, lung cancer, colon cancer and prostate cancer, in addition to protective effects against cardiovascular disease in the form of antiplatelet aggregation (Ajilogba & Babalola, 2016; Cámara et al., 2020). It helps to fight against the development of degenerative human diseases (Ilahy et al., 2018). In addition to these properties, the lycopene contained in tomatoes has been shown to modulate the immune system, stimulate hormones and other metabolic pathways, and regulate cell growth and the induction of detoxifying enzymes. A significant inverse correlation between lycopene levels and systolic and diastolic blood pressure has been observed in hypertensive patients. The tomato contributes to the reduction of hypertension (Medina-Remón et al., 2013) Foods rich in antioxidants reduce the risk of Alzheimer's disease by inhibiting oxidative stress, lycopene intake results in improved memory retention, attenuation of oxidative mitochondrial damage, and reduced neuro-inflammation (Min and Min, 2014; Prakash and Kumar, 2014).

In agriculture, ozone has been used for crop protection against pests that cause bacterial plant wilt and reduce yields, thus causing significant economic losses, it has also been used for foliar treatment, for the decomposition of pesticide residues in soils and to improve the microbiological quality of irrigation water (Díaz-López et al., 2021; Guo et al., 2019; Landa Fernández et al., 2019; Mitsugi et al., 2017). Indeed, ozone (O_3) is an unstable triatomic allotrope of oxygen, its half-life in water at room temperature is about 20 minutes, it is characterized by a high oxidation potential (2.07 volts) higher than that of chlorine (1.36 volts) (Holah et al., 2016). It decomposes rapidly into oxygen without leaving toxic residues or halogenated compounds (Isikber & Athanassiou, 2015; Segat et al., 2014). Due to these properties, ozone is used in various fields, such as drinking water disinfection, the treatment of industrial wastewater, the disinfection of medical equipment, in the food industry, in the agricultural sector, as a substitute for antibiotics and pharmaceuticals, in the textile and paper sector, for post-harvest treatment to increase the shelf life of fresh products stored in warehouses and cold rooms by reducing their enzymatic activities and destroying microorganisms (Remondino & Valdenassi, 2018; Rizzo et al., 2020; Wang et al., 2019; Wei et al., 2017), and in fish, meat and poultry processing plants (Al-Qadiri et al., 2019; Fundo et al., 2018; Habibi Najafi & Haddad Khodaparast, 2009; Zhang et al., 2016).

Ozone does not generate harmful by-products, it can be used in agriculture without any risk of soil and groundwater pollution (Remondino & Valdenassi, 2018), it is a non-thermal and green technique, environmentally friendly and promising for agriculture and the food industry.

The objective of this study is to evaluate the effect of irrigating tomato seedlings with ozonized water OZ1, OZ2 and OZ3 corresponding respectively to different durations of ozonisation of 10 seconds, 20 seconds and 30 seconds on agronomic characteristics (germination time, growth, development and yield) and physicochemical (titratable acidity, ash, soluble dry matter, carbohydrates, total and reducing sugars, etc.) characteristics by comparing them with irrigated plants only with non-ozonized tap water called controls (TW) of the same varietal type and grown under the same conditions.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN

Experiments were carried out March-December period, during 2020 in the north-western region of Algeria, exactly in the region of Oran, on tomato seedlings of the same varietal type 'Saint-Pierre' and in undetermined port.

Seeds were sown in March in individual pots filled with potting soil, divided into four batches coded as follows: batch I (OZ1), batch II (OZ2), batch III (OZ3) and finally batch IV (TW), (see Figure 2). No phytosanitary treatment was used throughout the trial period.

Pot referenced as TW in Figure 1(a) was irrigated using tap water only, while pots OZ1, OZ2 and OZ3 were irrigated using tap water exposed to different gaseous ozone duration (OZ1: ozonized water during 10-s, OZ2: ozonized water during 20-s, OZ3: ozonized water during 30-s). Ozone generator FM-C900 (BEYOK ozone, China) was used for aqueous ozone generation for immediate use in the tests, as shown in Figure 1(b). Temperature was controlled during the preparation of the ozonized water. The frequency of irrigation was twice a week for the duration of the experiment.

The first germinations were observed after only five days of sowing for OZ1, OZ2 and OZ3 with the same appearance as the control, on the other hand, the germination of the TW pots was prolonged until the ninth day after sowing, i.e. approximately four days after the experimental plants. The plantlets were transplanted after five weeks of cultivation, in the month of April into large pots, the latter were transplanted deeply at the level of the cotyledons which will allow the development of a very important root system, and will ensure a good anchoring to the ground. All the plants were then staked and placed outdoors in a well-lit and sunny place (Figure 1(a)). Staking maintains the aerial part of the plant and offers better exposure of the leaves to light in addition to limiting losses by breakage of the branches under the weight of the fruits. Monthly average temperatures during the test period fluctuate between 20 °C to 30 °C, as shown in Figure 2, while the average monthly humidity changes between 76 % and 67 % (Nomades, s. d.).

During the crop cycle, the height of the tomato plants was measured, from ground level to the point of insertion of the bouquet, the averages as well as the height of the plants OZ1, OZ2 and OZ3 are compared to the control plants and the trends vegetative revealed, likewise, the following items are reported:

-The colour of the leaves, their length and smell;

-The duration of flowering after transplantation;

-The precocity of germination;

-Growth, vigour and development.

As the fruits ripen, the tomatoes were harvested by hand for each batch, the mass and the numbers of fruits were counted. The yield of the crops was evaluated at the end of the crop.

All ripe fruits were harvested between July and mid-December, corresponding respectively to the 3rd and 8th month after transplanting.

2.2 THE GENERATOR AND ITS OPERATION

To generate ozone by the corona discharge (CD) method, the generator refers to a high-energy electric discharge which, with the passage of a gas flow between

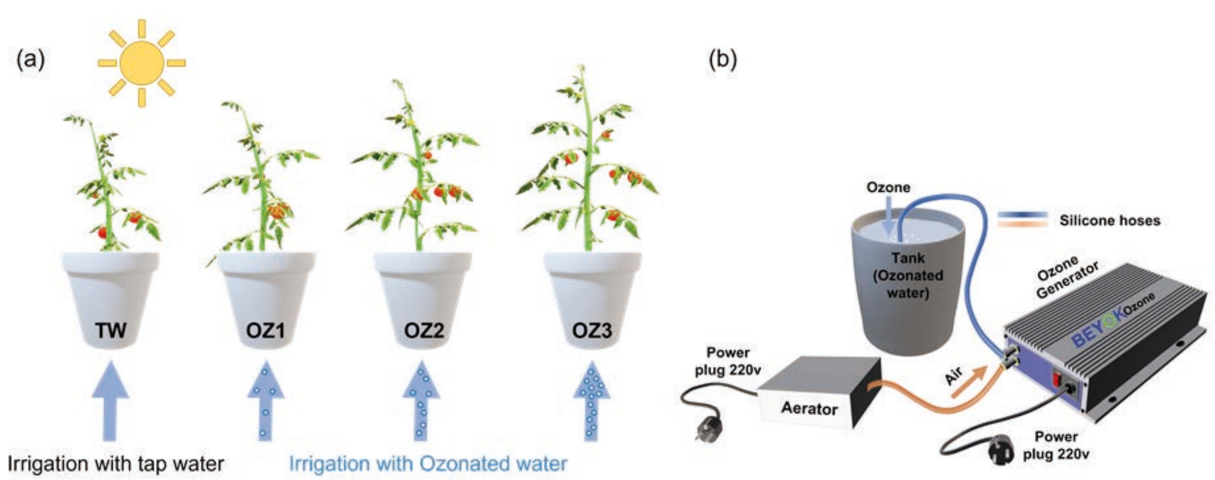

Figure 1: Experimental setup illustrating the trials

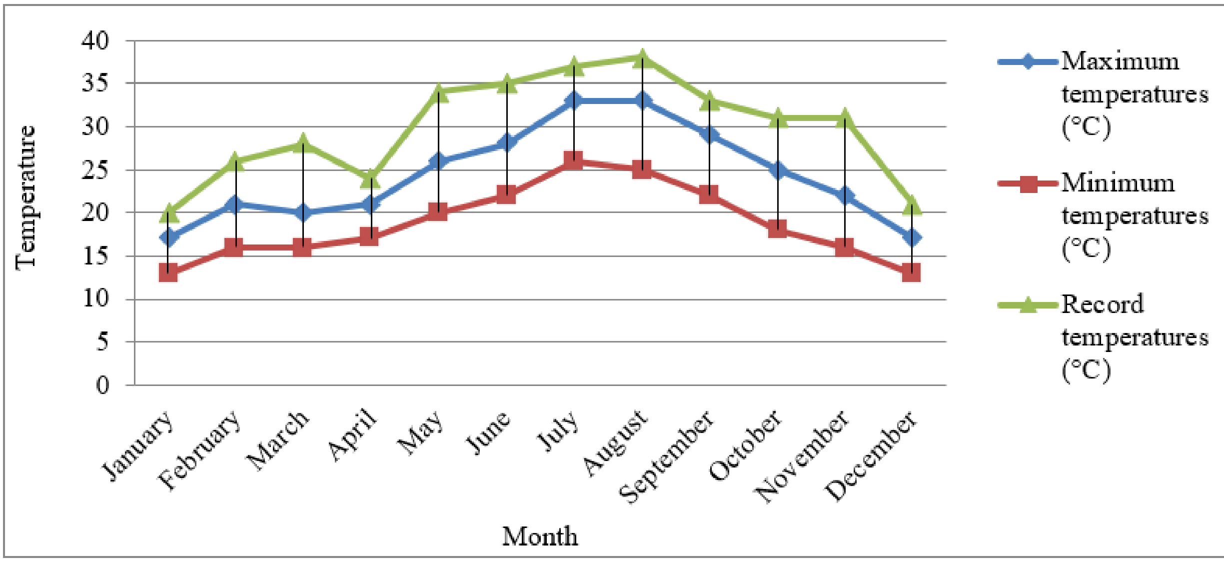

Figure 2: Temperature evolution during the experimental test period of the year 2020 (Nomades, s. d.)

two electrodes with asymmetric geometry and separated by a dielectric material between which a non-symmetrical field (crown) is established, thus causing the dissociation of the oxygen molecules (O_2) into free radicals of oxygen (O:). The latter are unstable, combined with other diatomic oxygen molecules, will form ozone (O_3), as shown in the below equations.

$$O_2 \rightleftharpoons 2[O^{\cdot}]$$

$$2[O^{\cdot}] + 2\,O_2 \rightleftharpoons 2O_3$$

Ozone production varies depending on oxygen concentration in feed gas, dielectric material property, discharge gap, current frequency and voltage. The electrodes are often cooled to remove excess heat and prevent the decomposition of ozone generated (Oner & Demirci, 2016; Pandiselvam et al., 2017).

2.3 SAMPLES PREPARATION AND PHYSICO-CHEMICAL ANALYSIS

The specificity of fresh fruits and vegetables (unprocessed), grown under the same conditions, is their evolutionary heterogeneity, their seasonality, their difference in shape, size, mass, density, growth and development. The analyses carried out in this study give objective indications on the quality of the experimental and control tomatoes and make it possible to compare the batches between them. They also make it possible to observe anomalies related to the quality of horticultural products and to ensure food safety for consumers. Tomato samples were randomly taken from equal quantities of fruit from each lot for chemical analysis. The tomatoes were washed and equilibrated under ambient temperature and pressure conditions, the fruits were cut into pieces and crushed before analysis. The analyses were carried out according to standardized methods in order to assess the quality of tomato fruits through the following parameters:

-The water content determined according to standard NA1133 / 1990;

-The pH measurements at 20 °C were carried out using a digital laboratory pH meter (inoLab pH 7310) according to standard NA 751/1990 corresponding to standard AOAC 981-12

- The titratable acidity according to the method (NA 691 Fiju N ° 3) in accordance with the ISO 750 recommendations;

-The ash contents determined according to standard NA 732/1990 in accordance with standard ISO 3595/1981;

-The soluble dry matter content (MSS) carried out at 20 °C using a refractometer according to ISO 2173-2003;

-Carbohydrate content; the total sugars and the reducing sugars determined by the method of G.Bertrand;

-The sodium chloride content determined according to the standard approved in Algeria, (Inter ministerial decree, Official Journal No. 49, 2013) in accordance with the ISO 3634-1979 standard.

2.4 UNCERTAINTIES AND SHORTCOMINGS

Our research work was carried out in pots and put in outdoor conditions, in a well-lighted sunny place. Throughout the cultivation cycle of the tomato seedlings, irrigation was carried out regularly and periodically in the evening, in order to guarantee a better result and ensure greater efficiency of the effect of ozone on the seedlings.

Gaseous ozone degrades spontaneously, it cannot be stored or transported from one place to another, and therefore it is preferred to be produced in site. The half-life time of ozone in water is related to certain parameters such as pH, temperature, light intensity and others. The pH and temperature control of ozonised water to limit ozone depletion was performed regularly during the preparation of ozonised water and before each use.

Ozone generators require very dry air; air humidity leads to reduced ozone production. The increase in water vapour in the feed gas leads to the formation of a large quantity of nitrogen oxide during electrical discharges. Nitrogen oxides can form nitrogen acids, which on the other hand lead to nitrates as fertilizers. On the other hand, the acids can cause corrosion over a long period. Therefore, an economic and financial evaluation would have been appropriate to assess the costs and benefits and take into account the natural depreciation of the value of the generator to determine the duration of the amortization of the investment.

3 RESULTS AND DISCUSSION

3.1 AGRONOMICS RESULTS

The results obtained following the irrigation of the tomato plants with ozonised water (OZ1, OZ2 and OZ3) and compared to the control plants (TW), are discussed according to the following criteria:

3.1.1 VIGOUR AND HEIGHT OF PLANTS

The height of the tomato plants irrigated with ozonised water was significantly higher than that of the control plants irrigated only with tap water. An increase in vigour in favour of experimental plants was observed. The heights and vigour of experimental tomatoes plants

Figure 3: Photo of tomatoes plants irrigated with: (a) ozonized water at 10-s (OZ1); (b) ozonized water at 20-s (OZ2); (c) ozonized water at 30-s (OZ3) and tap water (d) non-ozonized (TW)

Table 1: Average size of the four lots of experimental and control tomato plants

Designation	Size during transplantation (called Initial Size) (cm)	Size after two months (cm)	Growth from initial size
Control tomato plants (TW)	14	38.21	1.73
Tomato plants OZ1	15	43.08	1.87
Tomato plants OZ2	16.4	49.26	2.004
Tomato plants OZ3	18.8	57.5	2.06

increase with increasing irrigation water ozonisation durations (Figure 3).

The size of the plants for the four batches of tomatoes two months after transplanting reached heights varying between 38 cm and 57cm (see Table 1).

Plant's vigour showed a marked difference between batches (see Figure 3); while for size, growth appears to be favourable to OZ3 and OZ2 plants (Table 1). This heterogeneity in the height and vigour of the plants is due to the irrigation of the crops with ozonized water that favours the oxygenation of the roots. The conversion of ozone into oxygen provides plants and soil with a natural fertilizer since it contributes to the improvement of plant growth. Rozpądek et al. (2015) reported that aqueous ozone treatments on broccoli plants firstly showed accelerated growth and secondly, they reached marketable level faster.

The number of leaves and the leaf area of the experimental plants are higher compared to the control plants (Figure 3). This promotes photosynthesis thus accelerat-

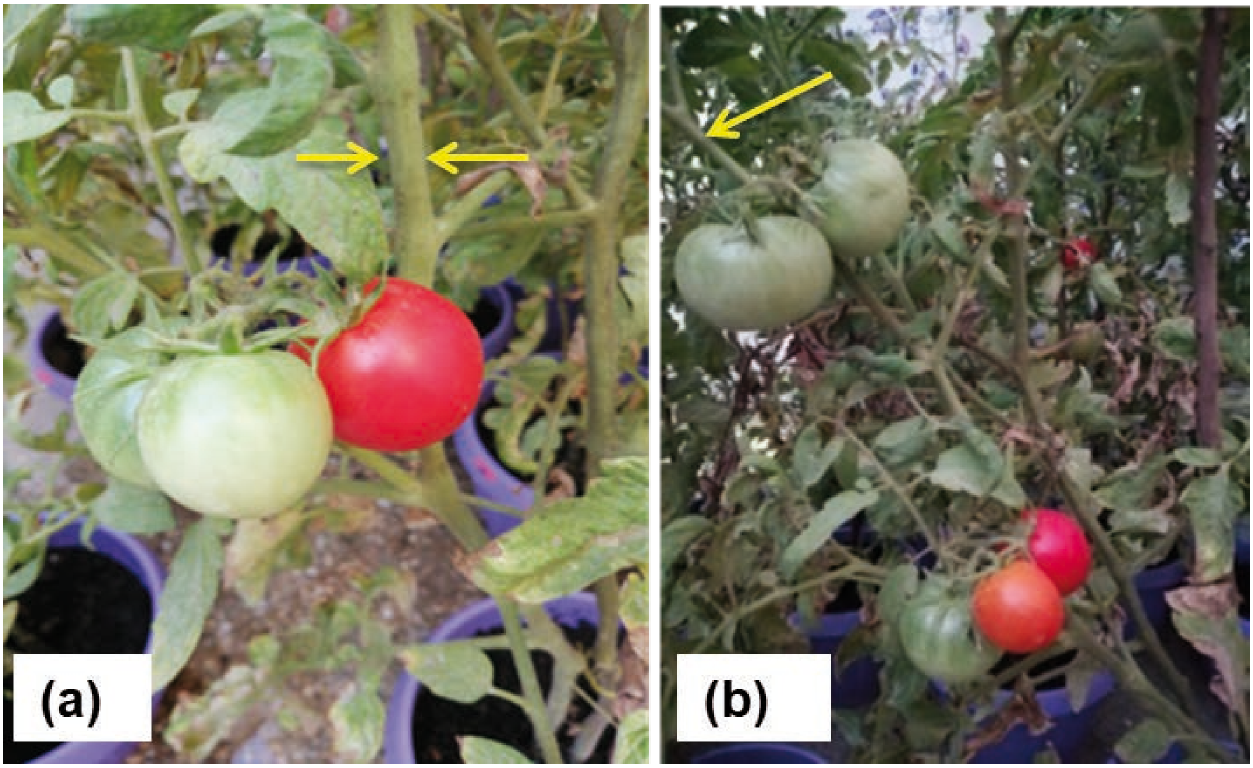

Figure 4: Represents (a): tomatoes plants irrigated with ozonized water; (b): tomatoes plants irrigated with non-ozonized water (control plants)

Figure 5: Photo of a ripe tomato irrigated with ozonized water; (a) The external view shows the persistent calyx with five sepals; (b, c) Longitudinal and transverse sections show that the berry originates from a bicarpellate ovary with axile placentation

ing growth, flowering and leading to an increase in yield. No negative impact was observed on the morphology and quality of fruits irrigated with ozonized water (Figure 4 and 5). These results corroborate with those obtained by Ohashi-Kaneko et al. (2009) , the latter demonstrated the non-toxic effect of ozone in the root system and described that treatment with ozonised water improves root respiration and increases the absorption of nutrients and the biomass production of tomatoes. The work of Martínez-Sánchez & Aguayo (2019) reported that the treatment of irrigation water with ozone improved the growth of pepper seedlings and increased the number of leaves and the development of secondary roots of plants, this facilitates adaptability and improves the yield of seedlings when they are transplanted into fields.

In addition, ozone oxidizes the organic matter present in the soil, inhibits the growth of pathogens in the root zone (Graham et al., 2011). Increases the availability of soil nutrients found in organic matter, improves soil structure and increases the rate of soil aeration. All of this collectively contributes to increase the growth of tomatoes irrigated with ozonised water (Najarian et al., 2018).

All these observations prove the influence of irrigation with ozonized water on tomatoes plants.

The tomato plants showed a difference in stems diameter ranging from 13.24 mm to 18.24 mm for the four batches (see yellow arrow in Figure 4) and no significant difference was observed concerning leaves colour and flowers colour (Figure 4).

3.1.2 PRECOCITY

Plants irrigated with ozonised water showed better precocity than the control plants. The difference in flowering and first harvesting times was significant. For the flowering time, the plants (OZ1, OZ2 and OZ3) flowered 85 days after sowing, on the other hand the control plants (TW) the duration was 100 days after sowing. Likewise for the first harvests, the tomatoes were obtained after 127 days for the OZ1, OZ2 and OZ3 and 142 days for the control tomatoes, i.e. around two-weeks (15 days) of difference compared to the experimental tomatoes. Flowering continued until November (i.e., 7 months after transplanting) for the four lots of tomatoes.

3.1.3 TOTAL YIELD

The total yield of harvested tomatoes fruits per unit area is summarized in Figure 6. The yield of the plants (OZ1, OZ2 and OZ3) is significantly higher compared to the control plants. Results are represented graphically in Figure 6 and indicate that yield increases with increasing the ozonisation time of the irrigation water. The highest

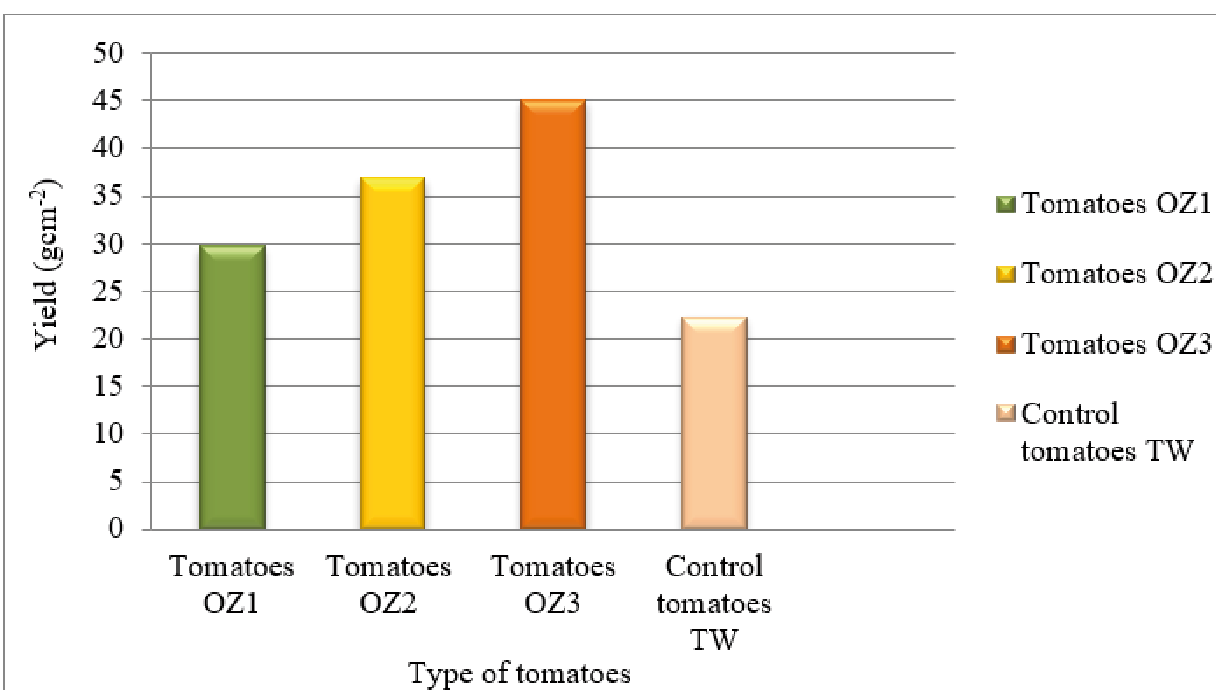

Figure 6: Yield of tomatoes irrigated with ozonized water (OZ1, OZ2 and OZ3) and non-ozonized (TW) water

yield was observed in OZ3 tomatoes with 33.62 % followed by OZ2 tomatoes with 27.57 % then OZ1 tomatoes with 22.19 % and finally 16.62 % for the TW control tomatoes.

The yield of OZ3 tomatoes is significantly higher compared to the other lots (OZ1, OZ2 and TW), it is twice the yield of control tomatoes, and it exceeds the yield of OZ2 tomatoes by 22 %, and the yield of OZ1 tomatoes by 50 %. On the other hand, the OZ2 tomatoes gave a yield of more than 23 % compared to the OZ1 tomatoes and less (-18 %) compared to the OZ3 tomatoes with a ratio of 2 compared to the control tomatoes (Figure 6).

The difference in tomato yield for the three batches (OZ1, OZ2, and OZ3) is proportional to the concentration of the ozonised water.

Plants irrigated with ozonised water were among the best performing plants in terms of germination time, germination rate and survival rate; the latter were higher compared to controls (Figure 3). The early germination, growth, development and flowering of tomato plants OZ1, OZ2 and OZ3 are linked to irrigating with ozonised water; according to the work of (Flores et al., 2019; Terao et al., 2019; Zhuang et al., 2017), ozonised water used at appropriate concentrations, improves tomato plant growth and yield, as well as fruit quality.

3.2 PHYSICOCHEMICAL CHARACTERISTICS OF TOMATOES

The difference in physical and chemical properties between the samples of tomatoes irrigated with ozonised water compared to the samples of control tomatoes is not significant; the obtained values of titratable acidity, pH, soluble solids, ash content and water content are of the same order of magnitude as the control tomatoes (Table 2). The pH values for the four lots of tomatoes studied are in accordance with the standards (pH < 4.90 acceptance standard for fresh tomatoes) and indicate a pH below 4.5 which gives the fruit protection against microorganisms sensitive to acidic pH, it is an advantage from the point of view of sanitary quality. Organic acids are naturally present in the fruits; the contents can vary according to the cultivars and the stage of maturation of the fruit. Total acidity is expressed in relation to citric acid and malic acid. The titratable acidity contents of the experimental tomatoes (OZ1, OZ2 and OZ3) do not show any significant difference compared to the control tomatoes (TW), (Table 2). The fruits analysed are of the same varietal type and were grown under the same conditions. The results obtained are in agreement with those reported by Moresi & Liverotti (2007) who indicated values between 0.3 and 0.5 %. Irrigation with ozonised water does not alter the contents of organic acids in tomato fruit. The citric and malic acid ratio of control tomatoes is slightly higher than that of OZ3 tomatoes followed by OZ1 tomatoes and finally OZ2 tomatoes. Fruit acidity decreases as ripening comes to an end.

By their nature, tomatoes are very rich in water, they contain 93 % to 95 % water (Grasselly et al., 2000), but this content can go up to 97.1 % according to Espiard (2002); the very high water content is a parameter which translates the fragility of the fruits with regard to shocks and limits their suitability for storage at ambient temperature. The moisture content of the tomatoes studied is in agreement with those reported by Grasselly et al. (2000).

The refractometry index makes it possible to measure the fraction of soluble dry matter which is correlated with the sugar content of fruits. The values obtained show a slight difference between the batches. The Brix degree of the OZ1 tomatoes slightly exceeds that of the control tomatoes, followed by that of the OZ2 tomatoes and finally the OZ3 tomatoes. The soluble dry matter content depends on the relative amounts of water and assimilates imported by the fruit during its growth (Grasselly et al., 2000). The values mentioned in table 2 of the four lots of tomatoes studied agree with those recorded by Espiard (2002) which is of the order of 2 to 4.5 °Brix.

The carbohydrate contents of OZ2 and OZ3 tomatoes are similar to each other and slightly higher than those of OZ1 and control tomatoes. The same is for the

Table 2: Physicochemical characteristics of experimental and control tomatoes

Designation	TSS (°Brix)	Water content (%)	Ashes (%)	pH	Acidity: Citric acid (%)	Acidity: Malic acid (%)	Carbohydrate content (%)	Total sugars (%)	Reducing sugars (%)	Sodium chloride content (%)
Tomato OZ1	3.90	95.00	0.452	4.42	0.388	0.372	1.645	0.628	0.563	0.951
Tomato OZ2	3.67	94.39	0.467	4.41	0.416	0.39	2.114	2.88	0.189	1.040
Tomato OZ3	3.57	94.55	0.429	4.40	0.432	0.42	2.186	2.90	0.202	1.0397
Control tomato TW	3.86	94.91	0.519	4.43	0.418	0.40	1.720	0.795	0.74	1.085

total sugar and reducing sugar contents of OZ2 and OZ3 tomatoes, where sugars contents are similar or slightly higher compared to the contents of OZ1 and control tomatoes, this may be due to the increase in the ozonisation time of the irrigation water. The work of Onoue et al. (2018), concluded that the ozonized water treatment of *Brassica rapa* L. allowed the production of high quality vegetables with high contents of soluble sugars and L-ascorbic acid.

The ash content represents the total quantity of mineral salts present in the sample. Referring to Table 2, the results obtained from the four batches of tomatoes analysed are within the 0.3 to 0.5 % range reported by Espiard (2002). For the sodium chloride content, no significant difference was observed between the experimental tomatoes (OZ1, OZ2 and OZ3) and the control tomatoes. The mineral salts contained in the samples studied can contribute to the characterization of a geographical origin, the nature of the soil and the composition of the irrigation water.

In general, the physicochemical parameters of OZ2 and OZ3 tomatoes are slightly elevated compared to the controls while remaining within the standards, this is due to the increase in the ozonisation time of the irrigation water. Irrigation with ozonised water has no negative impact on the tomatoes studied. Overall, all the results obtained have been verified and are consistent with the work carried out on fresh tomatoes by other research.

4 CONCLUSION

The application of ozonised water in agriculture of tomato seedlings grown under a Mediterranean climate at Oran, north-western region of Algeria, was experienced by us for the first time. Knowing that Algeria is known for its diversification of climatic areas where the climate varies from the Mediterranean type to the Saharan type. This research is part of a series of studies which aims to know the impact of different concentrations of ozonised water on the agronomic and physicochemical performance of tomato plants and fruits, the aim of which will be to reduce the use of pesticides and chemical fertilizers while guaranteeing a good yield without altering the marketable quality of the fruits.

The results of our study concluded that the ozonisation of irrigation water applied to tomatoes seedlings of the same varietal type and grown under the same conditions while comparing them to controls led to earlier germination, better development and plant growth, increased vigour and yield. No phytosanitary treatment was used throughout the trial period and no detrimental effects were observed on fruit morphology and productivity. Despite the same growing conditions; the tomatoes plants gave different yields. yield increases with increasing irrigation water ozonisation time.

On the physicochemical level, the experimentation showed some differences between the batches, the sugar contents of the experimental tomatoes were higher compared to the controls and is proportional to the concentration of ozonized water. No significant difference was observed for the other criteria analysed. In general, the ozonisation of irrigation water is a promising technique for agriculture, environmental and economic challenges, thus allowing reducing pesticides, increasing qualitatively and quantitatively of crop yield and to provide consumers with healthy horticultural products. The economical profit gained by our method compensating the long-time damages to instruments.

The results obtained encourage the use of this technique by farmers in order to improve agronomic performance such as germination time, growth, vigour and yield of tomato plants and to ensure a good product that complies with health standards for consumers and exporters. Farmers can adopt this easy-to-use, low-cost technique, and thanks to renewable energy, ozone generators can be used even in remote areas of the country. In addition, ozone has proven its effectiveness and can be used as a substitute for pesticides, insecticides and fungicides. This could provide a basis for policy makers and legislators to curb the overuse of chemical fertilizers and pesticides that have deleterious effects on market garden produce.

Our research work required simple tools, pots in outdoor conditions. Greenhouse and open field conditions on a large number of samples and a large cultivated area are to be expected in our future research, this will make it possible to study on the one hand the evolution of plants, to evaluate the impact of the different concentrations of ozonised water on the plants and the fruits and on the other hand, to define the advantages and the disadvantages of each cultivation mode and compare the results obtained in order to select the best techniques from the point of view of earliness, yield and fruit quality. Cross tests of ozonised water and compost will also be recommended for the rest of the work. The compost formed from the remains of cultivation, kitchen scraps as well as fruit and vegetable peelings; is a rich source of trace elements and nutrients necessary for the development of tomato plants; likewise for poultry manure, it is generally used for acidic soils because of its high calcium content. Ozone oxidizes organic materials, decreases their toxicity and increases their biodegradability. It decomposes quickly into oxygen without generating toxic residues, hence its use in agriculture without any risk of soil and groundwater pollution.

The combination of ozone and compost can improve the composition of the soil and reduce the extensive use of chemical fertilizers and pesticides and thus open up prospects for a circular economy through the recycling of organic waste for sustainable agriculture and respectful of the environment.

Physicochemical, morphological, bacteriological, sensory and nutritional analyses will be recommended to assess the efficiency of the cultivation techniques used.

Studies must be continued in order to extend the use of ozone in the cultivation of cereals, vineyards, rice and coffee and even in the pharmaceutical industry. However, ozone concentrations must be determined for safe and effective use.

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