



Field and Modeling Study for Integrated N-Fertilization and Organic Mulching to Improve the Productivity and Water Productivity of Tomatoes under Arid Egyptian Conditions

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ABSTRACT

Due to the limited water resources in Egypt and its occurrence in the driest areas in the world, in addition to climatic changes and rising temperatures, which negatively affect the increase in water needs required to irrigate crops, it was necessary for us to think about applying the most sustainable technologies available, which will face all these challenges in an environmentally friendly manner. One of the most sustainable, cheap and available techniques is the recycling of organic agricultural waste, from which organic fertilizers can be produced and also can be used as organic mulching as a sustainable alternative to plastic mulching. Soil moisture content (SMC), Water application efficiency (WAE), soil organic matter content (SOMC), and activity of microorganisms (AM), soil electrical conductivity (SEC), yield (Y_{Tomato}) and water productivity of tomato (WP_{Tomato}) are investigated with organic mulching and integrated N-fertilization treatments under dry Egyptian conditions and also, the previous evaluation criteria were modeled using the SALTMED simulation model. The results indicated that, using of organic mulching also led to a decrease in the evaporation rate thus, the soil surface remains moist for as long as possible, and the accumulation of salts in sandy soils decreases which mean, protecting the soil surface and the root zone from increasing water and salt stress. The results also showed the importance of the integrated nitrogen fertilization, which increases the proportion of adding the organic component. Using of organic mulching and integrated nitrogen fertilization led to an increase in the SMC, WAE, SOMC and an increase in biological activity, as well as a decrease in the accumulation of salts in the soil. It combines with the application of these techniques all the encouraging benefits of sustaining, increasing and improving the productivity of tomatoes and any other crop in dry sandy soils with limited irrigation water and drought. The study concluded that relying on organic mulching and integrated nitrogen fertilization increased the productivity and water productivity of tomatoes, where the highest values were when using organic mulching and adding 50% of organic nitrogen + 50% of mineral nitrogen fertilizers. The results also showed the accuracy of the SALTMED simulation model in simulating the evaluation criteria that were studied using drip irrigation system under sandy soils in Egypt.

Keywords: Organic mulching, N-Integrated fertilization, Rice straw, Biological activity, Yield, Water productivity, Tomato, SALTMED model

1. Introduction

The problem and crisis of global water resources have drawn focus and attention in most countries of the world on increasing the efficiency of using and rationalizing limited water resources, especially water used in agriculture, in order to increase the production of many crops and achieve and provide food security. In the areas that suffer from drought problem, namely, arid and semi-arid areas

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with high population density and limited water resources, there is high and great pressure on the agricultural sector level to reduce consumption of fresh water intended for irrigation and its use in other non-agricultural sectors (Hozayn *et al.*, 2016; Abdelraouf *et al.*, 2020 a,b). The problem of water scarcity is a very serious problem facing food production in Egypt with arid regions. It is very important to reduce the consumption and save irrigation water through the modernization and development of innovative sustainable technologies. (El-Metwally *et al.*, 2015). In the Arab Republic of Egypt, the sector concerned with the agricultural process faces a difficult and serious challenge of how to increase crop production by irrigation with less water, which is currently called increasing the water productivity of crops. (Abdelraouf and Abuarab 2012). Increasing the productivity of the water unit for irrigating crops is an important and necessary goal in order to increase the growing demand for food with the turbulent rise in population growth (Okasha *et al.*, 2013; Bakry *et al.*, 2012; Abdelraouf and Ragab 2018 a,b,c; Eid and Negm, 2019). The available water resources in Egypt are suffering and facing severe shortages and scarcity, this suffering increase with the increase in the population growth rate. With the turbulent and increasing competition for limited water resources, most of the new irrigation techniques are also competing to increase water productivity and improve and increase the productivity and quality of crops (Marwa *et al.*, 2017). The productivity of the water unit for irrigating agricultural crops in Egypt is considered a very important issue, given the scarcity and limited sources of water and the low annual rate of rainfall. (Hozayn *et al.*, 2013). The application of the techniques of new irrigation methods systems and the various related techniques is one of the important concepts that must be adopted, followed and applied in arid and semi-arid areas, as it exists in Egypt, in order to provide a large portion of irrigation water. (El-Habbasha *et al.*, 2014). The biggest challenge facing the environment is the agricultural sector, which is to produce and grow more crops and produce food with less water, and what can be achieved by using all available technologies to increase the water productivity of crops. (WP) (Zwart and Bastiaaenessen, 2004).

Mulch is a protective layer consisting of organic or even inorganic materials that can be spread over the soil surface in order to: 1) reduce moisture loss from the soil surface by preventing or varying the rate of evaporation caused by sunlight and drying due to wind, 2) reducing and preventing the growth of Weeds and weeds, 3) Protection and rescue of earthworms from natural enemies in the soil and 4) Reducing soil compaction due to the effect of heavy rainfall. Mulch generally helps in regulating and lowering the temperature of the surface layer of the soil by covering it in the summer and making it cool, and the mulching process helps isolate the soil from the cold winds in the winter. This process helps the effective systemic effect of temperature to promote growth and efficiency of plant roots, as well as prevent soil surface erosion (USDA). It also improves the filtration of most nutrients and the retention of water in the root zone of the soil (Liu *et al.*, 2002; Hu,*et al.*, 995). Several research results confirmed that organic mulching with agricultural residues led to an increase in soil water retention and prevented evaporation from the soil surface. (Kar and Singh 2004). By using organic mulching, the soil properties are improved as it improves the physical as well as chemical and biological properties of the surface layer of the soil. This organic cover slowly decomposes and increases the organic content of the soil. This also helps in preserving the organic contents as food for beneficial soil worms and other soil microorganisms. It also extracts and absorbs nutrients from the topsoil layer. It also improves the growth of crop roots and increases the moisture holding capacity of the soil. Rice straw in Egypt is the largest in relation to the total volume of organic agricultural residues, as this percentage ranges between 20-25% of the total volume of agricultural residues (Haitham *et al.*, 2014). In order to confirm and ensure a high yield, it is important to keep the soil fertile through the sustainability and continuity of providing the necessary and appropriate elements for growth, and the importance of adding and increasing organic matter is due to the increase in the activities of microorganisms and the activity of biological content and also improving the acidity of the soil, and the addition of organic matter leads to the disintegration of Soil granules deeply, with the aim of improving the water and aerobic regime within the root zone (Vliegen- Verschure, 2013). It is sometimes called the process of preparing microbial organisms for many different microorganisms that are able to change and transform most of the plant nutrients within the agricultural soil from the unavailable form to the valid, accessible and available form, where it is called biofertilizer. The results also confirmed that it increases crop productivity by about 30% in addition to providing beneficial and good biological activity conditions for the soil (Mosa *et al.*, 2015). The appropriate level of SOM, by means of continuous additions of various organic sources such as organic fertilizers, is very important (Gasparatos *et al.*, 2011). It has been confirmed that

decomposing plant residues release huge levels of nutrients as well as beneficial organic matter into the soil. (Yih-Chi *et al.*, 2009). According to Lal, (1997), the most important and one of the necessary and main conditions for increasing and improving soil productivity in the sub-Saharan region is the ease and guarantee of infiltration of irrigation or rain water and its storage within the root zone of the soil where the water capacity of the soil to hold water is related to its high content of organic matter, where the depletion of organic matter is the main and important reason for the deterioration and collapse of the ecosystem, as well as the system's loss of environmental resilience (Feller *et al.*, 2012). Several research results confirmed the possibility that the application of the integrated plant nutrition management (IPNM) approach is preferable when an alternative approach to fertilization is followed in order to improve and increase crop production in addition to maintaining soil health and ensuring its sustainability. Within the framework of the implementation of the IPNM system, the different sources of nutrients are used collectively and in a sustainable manner. The combination of both organic manure and chemical mineral fertilizers helped to improve the physical and chemical properties of the soil and also to reduce the leaching and escape of nutrients and thus increase the effectiveness of the different forms of mineral fertilizers. (Tadesse *et al.*, 2013; Bodruzzaman *et al.*, 2010). The addition of organic manure led to an improvement in the ability of the soil to retain water, an increase in the capacity for cation exchange, in addition to aeration of the soil and an increase in seed germination and growth rate of cultivated plants (Sultani *et al.*, 2007). Increasing the organic content of the soil also led to the availability of nutrients in the soil by improving most of the chemical, physical and biological properties inside the soil and also reducing the loss of nutrients. (Naeem *et al.*, 2009; Akhtar *et al.*, 2011). Studies have shown that the dynamic process of soil nutrients may vary depending on the type and shape of the organic source as well as the rate of mineral fertilization.

The tomato crop (*Solanum lycopersicum*) is considered one of the most important export crops that are available and suitable for climatic conditions, which can be grown during periods of time throughout the year. The volume of exports reached about 23.69 thousand tons, and represents about 0.34% of the volume of international and global exports of fresh tomatoes, which reached 6991.2 thousand tons, representing about 0.3% of local production. The total value of exports amounted to about \$11.23 million, and the price of a fresh ton reached about \$739.9/ton. (Haitham *et al.*, 2018). The results of several studies showed that the SALTMED model has given high-precision simulations in simulating the production process of crops and dry matter as well as soil moisture content (Afzal *et al.*, 2016; Hirich *et al.*, 2012; Cosi *et al.*, 2017; Kaya *et al.*, 2015; Pulvento *et al.*, 2013, Malash *et al.*, 2015; Ragab, 2015; Abdelraouf and Ragab 2018 a). The many advantages of using models to calibrate and validate predicted results are that they are cheaper, faster, and a high-accuracy alternative to difficult and costly field trials that can be easily obtained from various data simulations using this model.

The purpose of this study was for improving the yield and water productivity of tomato under arid Egyptian regions and deficit irrigation by using organic mulching and integrated N-fertilization and evaluating the performance of SALTMED model in the accurate simulation of the tomato production process under sandy soil.

2. Material and Methods

2.1. Experimental site

Field experiments were conducted during 2020 and 2021 at the research farm of National Research Center (NRC) (latitude 30° 30' 1.4" N, longitude 30° 19' 10.9" E, and 21 m+MSL (mean sea level) at Nubaryia Region, Al Buhayrah Governorate, Egypt. The experimental area has an arid climate with cool winters and hot dry summers. The data of maximum and minimum temperature, relative humidity and wind speed were obtained from the nearest local weather Station.

2.2. Physical and chemical properties of the soil and irrigation water

The physical and chemical properties of the soil and irrigation water displayed in details as shown in Tables (1, 2). The Irrigation water was obtained from an irrigation channel passing through the experimental area. The main physical and chemical properties of soil were determined in situ and in the laboratory at the beginning of the field trial.

Table 1: Main physical and chemical characteristics of the soil

Soil characteristics	Soil layer (cm)		
	0-20	20-40	40-60
Physical parameters			
Texture	Sandy	Sandy	Sandy
Course sand (%)	48.87	55.65	35.64
Fine sand (%)	48.79	40.81	60.48
Silt + clay (%)	2.14	3.64	3.88
Bulk density (t m ⁻³)	1.68	1.57	1.68
Chemical parameters			
EC (dS m ⁻¹)	0.43	0.44	0.47
pH (1:2.5)	8.15	8.75	9.21
Total CaCO ₃ (%)	7.45	2.37	4.67
Organic matter (%)	0.61	0.46	0.31

Table 2: Chemical analysis of organic fertilizer and irrigation water

Item	Compost	Irrigation water
pH	5.87	7.36
EC, (ds/m)	0.75	0.45
Anions (meq./L)	HCO ₃ ⁻ &CO ₃ ²⁻	0.12
	Cl ⁻	2.77
	SO ₄ ²⁻	1.35
Cation (meq./L)	Ca ⁺⁺	1.0
	K ⁺	0.22
	Mg ⁺	0.51
	Na ⁺	2.51
Organic Matter, (%)	96.8	-----
Moisture Content, (%)	18.7	-----
Nitrogen, (%)	0.94	< 0.02
Phosphorus, (%)	0.83	-----
Potassium, (%)	0.88	0.17

2.3. Experimental design

The experiment was established with a split plot design having three replicates. The main plots included organic mulching and without organic mulching and the sub-main plot was five cases for Integrated N-fertilization [(IN1:100% M_N + 0% O_N), (IN2:75% M_N + 25% O_N), (IN3:50% M_N + 50% O_N), (IN4:25% M_N + 75% O_N) and (IN5:0% M_N + 100% O_N)] as shown in Table (3). Where IN: Integrated N- fertilization, M_N: Mineral Nitrogen; O_N: Organic Nitrogen

Table 3: Experimental design the distribution treatments.

IN: Integrated N-fertilization	OM (Main plots)	
	Without mulching (Without M)	With organic mulching (With M)
IN1		
IN2		
IN3		
IN4		
IN5		

IN: Integrated N- fertilization, IN1: (100% M_N + 0% O_N); IN2: (75% M_N + 25% O_N); IN3: (50% M_N + 50% O_N); IN4: (25% M_N + 75% O_N); IN5: (0% M_N + 100% O_N); MN: Mineral Nitrogen; ON: Organic Nitrogen

2.4. Irrigation system components

The irrigation network consists of a centrifugal pump with a discharge of 45 m³/h with other components of the main control unit. It was the main line of PVC pipes with a diameter of 110 mm. The branch lines of PVC pipes with a diameter of 75 mm were also directly connected to the main line. Manifold lines was made from Polyethylene pipes with a diameter of 63 mm were connected to the laterals. Emitters was built in the laterals with a diameter of 16 mm and a length of 30 m and the emitter discharge was 4 liters per hour at an operating pressure of 1.0 bar and a distance of 25 cm between the emitters.

2.5. Fertilization method

The recommended doses of chemical mineral fertilizers for tomato plants were added as a fertilizer at a rate of 150 kg of phosphorous per hectare in the form of superphosphate and 250 kg of potassium was added per hectare before planting. Also, nitrogen fertilizer at a rate of 320 kg nitrogen per hectare was applied in the form of ammonium nitrate and in water soluble form at an interval of 7 days. The application of N-fertilizer started two weeks after planting on 12 equal doses, and the application stopped 50 days before the end of the growing season for tomatoes.

2.6. Estimation of irrigation requirements

The applied water was calculated and estimated using drip irrigation system, which was obtained through equation (1). Irrigation requirements for tomato for two seasons were 4570 m³ ha⁻¹/season for 2020 and 4530 m³ ha⁻¹/season for 2021. The Penman-Monteith equation was used to estimate the ET_O based on daily weather station (Allen *et al.*, 1998). The tomato crop has a duration of about 145 days and can be divided into four stages, 25 days for initial stage, 40 days for dev. stage, 45 days for mid. stage and the last 35 days for end stage. The Kc during the cropping season was 0.6, 1.15 and 0.80 in the initial, mid., and end stages, respectively. (Allen *et al.*, 1998).

$$IR = [ET_O \times Kc] / I_E - R + LR \dots\dots\dots(1)$$

Where IR is the gross irrigation requirements in mm/day, ET_O is the reference evapotranspiration in mm/day, Kc is crop factor, I_E is irrigation efficiency in %, R is rainfall in mm, and LR is the amount of water required for the leaching of salts in mm.

2.6. Evaluation parameters

I. Soil moisture content

Soil moisture content was measured regularly at frequent and constant intervals in effective roots zone of tomato plants and the field capacity and wilting points were taken as evaluation lines in consideration as an evaluation parameter for exposure range of the plants to water stress "WS". Measurements were taken at soil depths. Soil moisture content was measured by profile probe device (Abdelraouf, *et al.*, 2020 b).

II. Water application efficiency (WAE)

WAE is the actual storage of water in the root zone to the water applied to the field. WAE was calculated using equation 4:

$$AE_{IW} = D_s / D_a \dots\dots\dots(2)$$

Where WAE is the water application efficiency, %, D_a is the depth of applied water (mm), D_s is the depth of stored water in the root zone, cm by equation 5

$$D_s = (\theta_1 - \theta_2) * d * \rho \dots\dots\dots(3)$$

Where:, d is the soil layer depth (mm), θ_1 is the average of soil moisture content after irrigation (g/g) in the root zone, θ_2 is the average of soil moisture content before irrigation (g/g) in the root zone, ρ : Relative bulk density of soil (dimensionless).

III. Soil organic matter content and Electrical conductivity, EC

The organic matter content and salt concentration were measured in sandy soil before planting, during plant growth stages and after harvesting tomato crop for all treatments during the two growing seasons. The average organic matter content was the sum of the values of the estimates over the number of times and the same estimation, also, was done for the average salt concentration in the soil.

IV. Microorganism activity

Microbial biomass carbon and 0.5 M K₂SO₄ extractable organic carbon (OC) were measured at all but the harvest sampling dates in surface soil (0–20 cm) by chloroform fumigation extraction followed by UV persulphate oxidation (Wu *et al.*, 1990).

V. Yield of tomato

At the harvesting time, the yield of tomato for each plot was harvested and total yield were determined in kg m⁻² and then, converted to ton ha⁻¹.

VI. Water productivity of tomato "WP_{Tomato}": The WP_{Tomato} was calculated according to James (1988) as follows by equation 6:

$$WP_{Tomato} = Ey/Ir \dots \dots \dots (4)$$

Where WP_{Tomato} is water productivity of tomato (kg_{Tomato}/m³_{water}), Ey is the economical yield (kg_{Tomato}/ha) and Ir is the amount of applied irrigation water (m³_{water}/ha).

2.7. Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984), using Co-Stat Software Program Version 6.303 (2004) and L.S.D. at 0.05 level of significance was used for the comparison between means values.

2.8. SALTMED Model

The SALTMED model (version 3.04.25) was used in this study. A detailed description of the SALTMED model is provided in Ragab *et al.*, (2015). The model is freely available from the International Commission on Irrigation and Drainage, ICID web site:

https://www.icid.org/wg_crop.html. The SALTMED model description and the equations for the key processes of evapotranspiration, water and solute transport, the nitrogen cycle, drainage and crop growth have been provided by Ragab (2015) and Ragab *et al.*, (2005). The model is suitable for all irrigation systems. The reference evapotranspiration (ET_o) according to Allen *et al.*, (1998) was selected for this study using meteorological data obtained from the field weather station. The crop-specific input data were the Leaf Area Index (LAI), plant height, maximum and minimum root depth, and each growth stage. The soil hydraulic properties for each layer were obtained from field and laboratory measurements. *Model calibration:* The simulated soil moisture content, water application efficiency, soil organic matter content, electrical conductivity, yield and water productivity of tomato for integrated nitrogen fertilizers (100%M_N+ 0%O_N) under without organic mulching by drip irrigation were compared with the measured values during 2020 season by fine-tuning the relevant SALTMED model parameters. The main values input parameters for tomato crop used in SALTMED model are presented in Table (4). *Model validation:* The validation was carried out using the remaining treatments. Statistical and graphical methods were used to evaluate the model performance; the observed and simulated values of soil moisture were plotted as time series. The response of the model, particularly the trend over time, can therefore be visually observed. For the model calibration and validation statistical measures, the coefficient of determination R², Root Mean Square Error (RMSE) and the coefficient of residual mass (CRM) were used.

The RMSE values show how much the simulations under or overestimate the measurements.

$$RMSE = \sqrt{\frac{\sum(y_o - y_s)^2}{N}} \dots \dots \dots (5)$$

Where y_o= observed value, y_s = simulated value, N = total number of observations

Table 4: Main calibrated values of input parameters of tomato crop under without mulching and 100% M_N used in SALTMED model, 2020.

Parameter	Developmental stage	Values
Cultivation Dates		
Sowing (date)	First season	1Sep.
Harvest (day after Sowing)		145
Growth Stages		
Emergence and Initial (days)		25
Development (days)		40
Middle (days)		45
Late (days)		35
Crop Inputs		
Leaf Area Index(LAI)	Initial	0.5
	Middle	3.6
	End	3.2
Minimum root depth (m)		0.0
Maximum root depth (m)		0.6
Unstressed crop yield (t ha ⁻¹)		41.1
Harvest index		0.66
Water uptake effect	Initial	
	Middle	0.8
	End	
Soil parameters		
Lambda pore size		0.22
Root width factor		0.35
Max. depth for evaporation, mm		140
Residual water content, m2m-2		0.01
Bubbling presser, cm		15

The R² statistics demonstrate the ratio between the scatter of simulated values to the average value of measurements:

$$R^2 = \left(\frac{1}{N} \frac{\sum (y_o - \bar{y}_o)(y_s - \bar{y}_s)}{\sigma_{y_o} - \sigma_{y_s}} \right) \dots \dots \dots (6)$$

Where \bar{y}_o = averaged observed value, \bar{y}_s = averaged simulated value, σ_{y_o} = observed data standard deviation, σ_{y_s} = simulated data standard deviation.

The coefficient of residual mass (CRM) is defined by:

$$CRM = \frac{(\sum y_o - \sum y_s)}{\sum y_o} \dots \dots \dots (7)$$

The CRM is a measure of the tendency of the model to over or underestimate the measurements. Negative values for CRM indicate that the model underestimates the measurements and positive values for CRM indicate a tendency to overestimate. For a perfect fit between observed and simulated data, values of RMSE, CRM and R² should equal to 0.0, 0.0, and 1.0, respectively. All the analyses were made using Excel (Microsoft Inc.).

3. Results and Discussion

Soil moisture content, water application efficiency, soil organic matter content, activity of microorganisms, soil electrical conductivity, yield and water productivity of tomato were investigated under organic mulching by rice straw and integrated N-fertilization under arid and sandy soils in Egypt through field and modeling study.

3.1. Soil moisture content (SMC)

Soil moisture content was investigated during the growing seasons under organic mulching and without organic mulching and also, under integrated N-fertilization rates through field and modeling study for tomato production under sandy soil conditions in Egypt.

Figure (1) indicated that, the SMC values were increased under organic mulching compared with none mulching. This may be due to the high ability of the organic mulching to protect the surface of the wet soil from the speed of evaporation rate and thus the soil stay wet for the longest period without evaporation compared to the high speed of evaporation rate in the absence of mulching the soil surface above the drip hoses.

Figure (1) indicated that also, There is a significant effect due to the use of integrated nitrogen fertilization compared to relying only on mineral fertilization, as it was found from continuous measurements of soil moisture content during the tomato growing season that it increases with an increase in the percentage of adding organic fertilizers at the expense of mineral fertilizers. The foregoing is logical due to the high ability of organic materials to absorb and retain irrigation water within the root zone spread and its values are close to the moisture of the field capacity.

The highest values of soil moisture content were when using organic mulches made of rice straw in addition to 100% dependence on organic nitrogen fertilization, while the lowest values were when mulching was not used and 100% dependence on mineral nitrogen fertilization.

The model showed slightly higher values for the R^2 during 2020 and 2021 for the layer (0-40 cm). Good correlation between the simulated and observations were obtained for the 2020 and 2021 season. Figures (1, 2) indicated that, the SALTMED model proved its high sensitivity to simulate the soil moisture changes caused by irrigation events for all treatments.

3.2. Water application efficiency (WAE)

Figure (3) indicated that, the values of water application efficiency “WAE” were increased by using organic mulching. This may be due to the low rate of evaporation from the soil surface and thus the presence of irrigation water stored in the root zone in the presence of organic coverings, while the treatment of non-coverage led to the rapid loss of water by evaporation from the soil surface and because of this, the efficiency of adding irrigation water increased with the use of organic coverings compared to no coverage.

Figure (3) indicated that, the values of water application efficiency “WAE” were increased by increasing the amount of organic fertilizers applied. The lowest values were at zero adding for organic fertilizers and the highest values were at adding 100% of organic N-Fertilizers. This may be due to the high ability of the added organic materials to retain the irrigation water within the root zone and the lack of irrigation water escaping downwards by deep seepage. The highest efficiency of adding to the irrigation water was achieved when 100% of the nitrogen fertilization was added organically, not mineral and this result agreement with Ouattara, (1994) and Feller *et al.*, (2012).

Figure (3) indicated that, the highest values for WAE was under organic mulching and adding 100% of organic N-Fertilizers but the lowest values were under none mulching and adding 0% of organic N-Fertilizers.

Figures (3,4) indicated that, there are high correlation between the simulated and observations were obtained for the 2020 and 2021 season and the SALTMED model proved its high sensitivity ($R^2=0.83$) to simulate the WAE changes caused by irrigation events for all treatments.

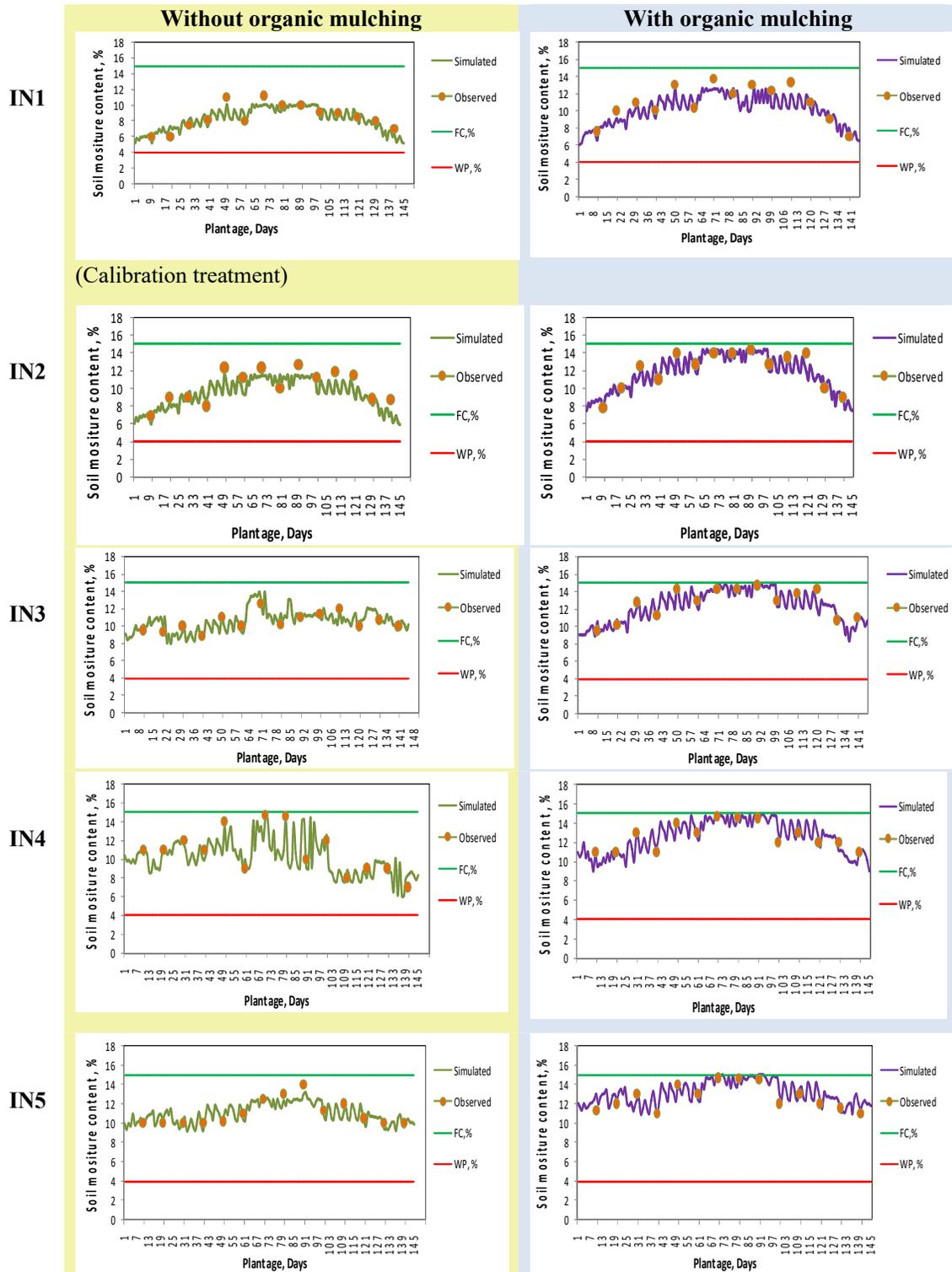


Fig. 1: Effect of organic mulching and integrated N-fertigation on the soil moisture content during the 2020 growing season compared with the simulated soil moisture content for all treatments.

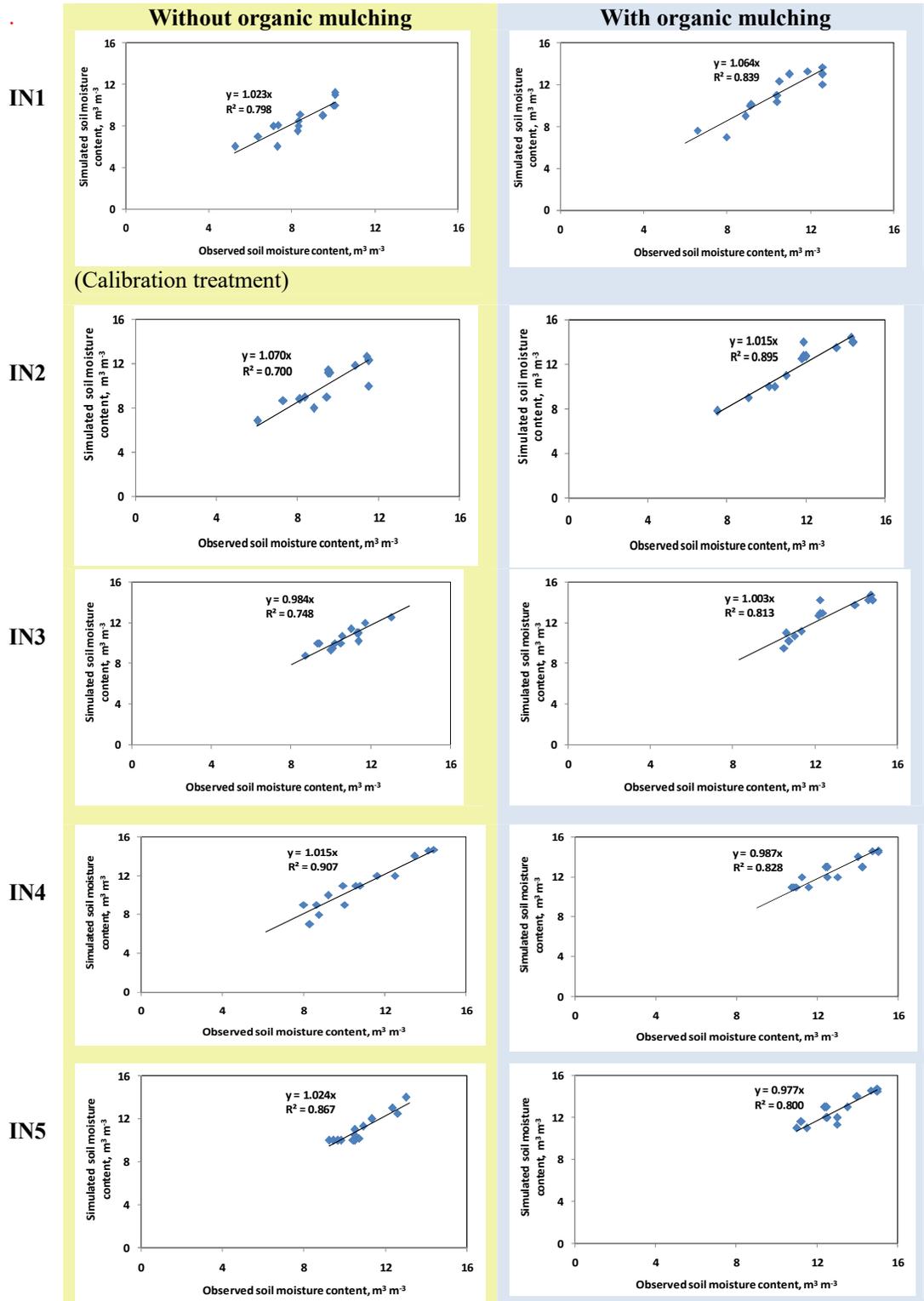


Fig. 2: Correlation between observed and simulated soil moisture content during 2020 season, and the same trend was repeated with the 2021 season

Table 5: The coefficient of determination R², RMSE and CRM for soil moisture in one layer (0- 40 cm) for all treatments during the 2020 and 2021 seasons

Correlation parameters		Treatments									
		Without mulching					With organic mulching				
		IN1 Calibr. T	IN2	IN3	IN4	IN5	IN1	IN2	IN3	IN4	IN5
2020	R ²	0.798	0.709	0.748	0.907	0.867	0.839	0.895	0.813	0.828	0.80
	RMSE	-0.016	-0.011	0.007	0.008	0.008	0.008	0.009	0.009	0.007	0.004
	RCM	-0.014	-0.025	-0.038	-0.044	0.033	-0.023	-0.015	-0.015	0.024	0.053
2021	R ²	0.916	0.924	0.931	0.952	0.954	0.96	0.94	0.95	0.97	0.911
	RMSE	-0.013	-0.016	0.007	0.008	0.009	0.009	0.009	0.009	0.008	0.005
	RCM	-0.017	-0.027	-0.036	-0.042	0.031	-0.024	-0.014	-0.015	0.025	0.062

Calibr. T: Calibration Treatment; IN: Integrated N- fertilization, IN1:100% MN + 0% ON , IN2:75% MN + 25% ON , IN3:50% MN + 50% ON , IN4:25% MN + 75% ON , IN5:0% MN + 100% ON , MN: Mineral Nitrogen; ON: Organic Nitrogen, O: Observed Value, S: Simulated Value,

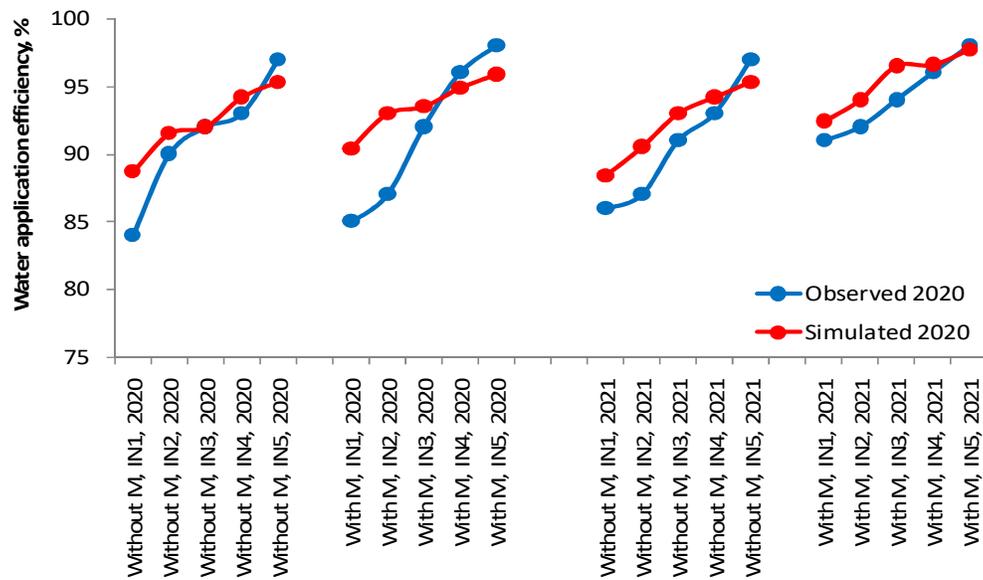


Fig. 3: Effect of organic mulching and integrated N-fertilization on the water application efficiency at peak of irrigation during growing seasons and compares it to simulated values for all treatments. IN: Integrated N- fertilization, MN: Mineral Nitrogen; ON: Organic Nitrogen).

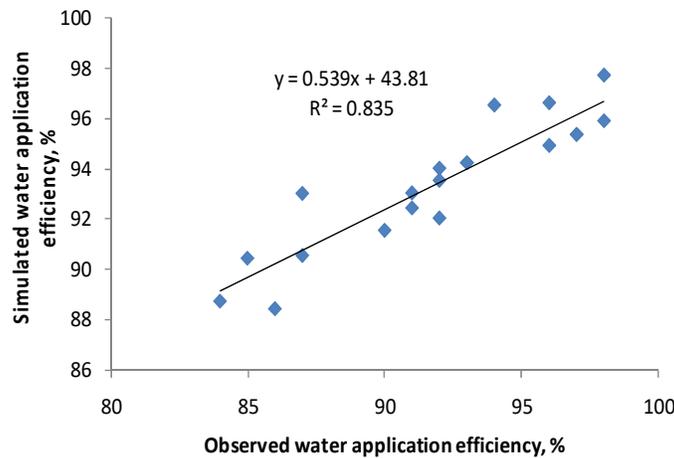


Fig. 4: Observed versus simulated water application efficiency for all treatments for seasons

3.3. Soil organic matter content (SOMC)

Table (6) indicated that, the average of soil organic matter content during growing season “SOMC” were increased by increasing organic mulching. This may be due to cutting and chopping the organic coverings made of rice straw in sandy soil after the end of the harvest time, which increases the organic matter content in the organically poor sandy soil.

Table (6) indicated that, the values of the average of soil organic matter content during growing season “SOMC” were increased by increasing the amount of organic N-fertilizers applied. This is a logical thing that does not need evidence, as the percentage of organic matter in the nitrogenous organic fertilizers added to 97.6 % it is according to the compost analysis attached above, and this increase in organic matter appears when it is added to poor sandy lands.

The lowest values of SOMC were at without using organic mulching and zero adding for organic N-fertilizers and the highest values were at using organic mulching and adding 100% of organic N-fertilizers.

Table (6) also, indicated that, there are high correlation between the simulated and observations were obtained for the 2020 and 2021 seasons and the SALTMED model proved its high sensitivity ($R^2=0.968$) to simulate the SOMC changes caused by irrigation events for all treatments.

Table 6: Effect of organic mulching and Integrated N- fertilization (IN) on the Soil organic matter content and compare it to simulated values for all treatments.

Soil mulching	IN: Integrated N- fertilization	Soil organic matter content, %			
		2020		2021	
		O	S	O	S
Without mulching (Without M)	IN1: 100%MN+0%ON	0.42	0.37	0.46	0.6
	IN2:75%MN+25%ON	0.49	0.45	0.55	0.61
	IN3: 50%MN+50%ON	0.55	0.58	0.65	0.62
	IN4: 25%MN+75%ON	0.7	0.78	0.7	0.67
	IN5: 0%MN+100%ON	0.74	0.81	0.88	0.75
With organic mulching (With M)	IN1: 100%MN+0%ON	1.1	1.2	1.23	1.2
	IN2:75%MN+25%ON	1.16	1.4	1.35	1.39
	IN3: 50%MN+50%ON	1.34	1.45	1.46	1.5
	IN4: 25%MN+75%ON	1.45	1.5	1.57	1.6
	IN5: 0%MN+100%ON	1.51	1.56	1.62	1.8
Equation and R²		Y = 1.064X - 0.018 and R ² =0.968			

IN: Integrated N- fertilization, IN1:100% MN + 0% ON , IN2:75% MN + 25% ON , IN3:50% MN + 50% ON , IN4:25% MN + 75% ON , IN5:0% MN + 100% ON , MN: Mineral Nitrogen; ON: Organic Nitrogen, O: Observed Value, S: Simulated Value,

3.4. Activity of microorganisms (AM)

Table (7) indicated that, the effect of organic mulching by rice straw and integrated N-fertilizers on some microorganisms activity in the root-zone of tomato plants such as Azotobacter, Pseudomonus and Bacillus “APB” .

Table (7) indicated that, the number and amount of APB increased by using organic mulching. This is maybe due to the availability of good environmental conditions for the growth and reproduction of these microorganisms from low temperature and appropriate moisture content of the surface layer and depth of root spread under organic mulching systems. .

Table (7) indicated that, increasing the amount on organic N- fertilizers through integrated N-fertilizers led to a positive effect on the increasing growth of APB within the root spread area of tomato crop that was cultivated. This seems logical to a large degree, as the added organic matter is the appropriate and required environment for the growth and reproduction of microorganisms within the root spreading area of any cultivated plant, especially tomatoes.

Finally, with the increase in the organic mulching of rice straw and increasing the amount on organic N- fertilizers through integrated N-fertilizers, the highest values of the APB in the roots of the

cultivated crops were achieved where the lowest values were at without mulching treatment and relying on 100% mineral nitrogen fertilization and the absence of any organic additives.

In this biometric assessment criterion for microorganisms within the area of root spread, the field study was conducted only as there is no simulation of microorganism data using the SALTMED model, as it did not include the biological simulation of microorganisms inside the soil.

Table 7: Effect of organic mulching and integrated N-fertilization on some of microorganism activity in the effective root zone of tomato plant

Organic mulching	Integrated N-fertilization	Azotobacter, No./gm _{soil}		Pseudomonas, No./gm _{soil}		Bacillus, No./gm _{soil}	
		2020	2021	2020	2021	2020	2021
Without mulching (Without M)	IN1: 100%MN+0%ON	105	120	11000	12500	360	420
	IN2: 75%MN+25%ON	112	175	21600	22400	440	500
	IN3: 50%MN+50%ON	214	240	34000	36000	590	650
	IN4: 25%MN+75%ON	413	505	51000	50900	1100	1600
	IN5: 0%MN+100%ON	610	650	71000	83000	1650	2000
With organic mulching (With M)	IN1: 100%MN+0%ON	128	160	12800	14300	430	470
	IN2: 75%MN+25%ON	145	260	30100	23500	490	565
	IN3: 50%MN+50%ON	268	290	40000	50000	680	770
	IN4: 25%MN+75%ON	520	580	63000	75200	1280	1830
	IN5: 0%MN+100%ON	699	770	82500	91000	1790	2250

IN: Integrated N- fertilization, IN1:100% MN + 0% ON , IN2:75% MN + 25% ON , IN3:50% MN + 50% ON , IN4:25% MN + 75% ON , IN5:0% MN + 100% ON , MN: Mineral Nitrogen; ON: Organic Nitrogen, O: Observed Value, S: Simulated Value,

3.5. Soil electrical conductivity (SEC)

Figure (5) indicated that, the values of SEC were decreased by using organic mulching. This is due to the very low evaporation rate from the wet soil surface compared to the lack of mulching.

Figure (5) indicated that, the values of the average of SEC during growing season were decreased by applying integrated N-fertilizers and therefore increasing the amount of organic fertilizers applied. The lowest values were at 100% of organic N-Fertilizers and the highest values were at no adding. This may be due to increasing water holding capacity. This led to a decrease in the rate of evaporation from the soil surface, and thus a decrease in the concentration and accumulation of salts in the soil.

Through the positive effect of using organic coverings and integrated nitrogen fertilization, which means an increase in the organic component over the mineral, where the lowest values of salt accumulation within the sandy soil were when organic covered with rice straw to the surface of the soil and over the drip hoses with the addition of 100% of the organic nitrogen fertilization.

Figures (5, 6) indicated that, there are high correlation between the simulated and observations were obtained for the 2020 and 2021 season and the SALTMED model proved its high sensitivity ($R^2=0.903$) to simulate the SEC changes caused by irrigation events for all treatments.

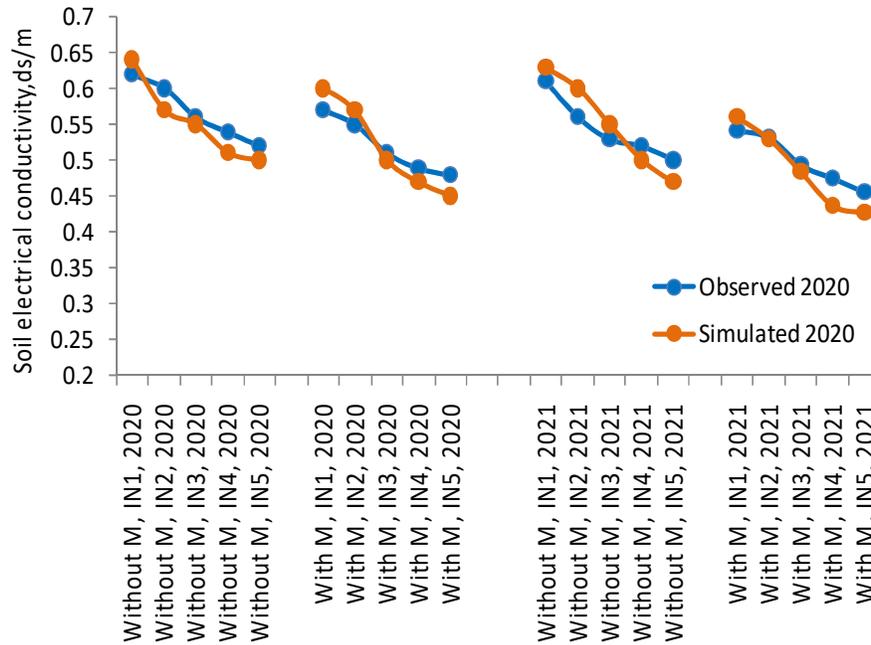


Fig. 5: Effect of organic mulching and Integrated N- fertilization (IN) on the soil electrical conductivity and compare it to simulated values for all treatments. (M_N: Mineral Nitrogen; O_N: Organic Nitrogen).

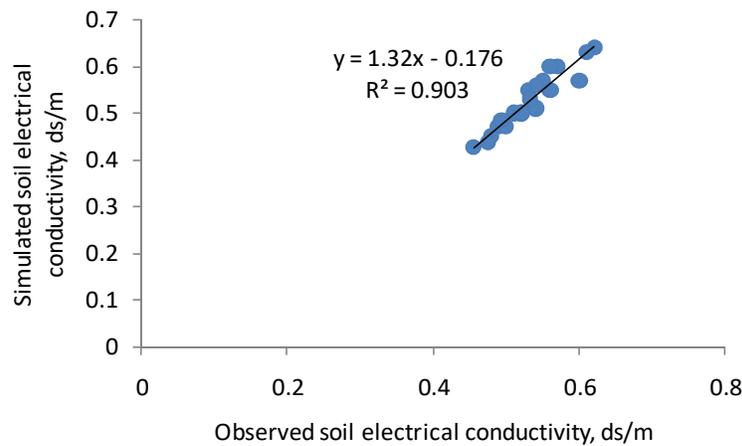


Fig. 6: Observed versus simulated soil electrical conductivity for all treatments for seasons 2020 and 2021.

3.6. Yield of tomato (Y_{Tomato})

Figure (7) and Table (8) indicated that, the values of Y_{Tomato} were increased by using organic mulching compared to not covering the soil surface. This is due to the sandy soil retaining the moisture content for the longest possible period with the use of organic coverings, which limit and prevent the speed of evaporation from the soil surface, which reduces the moisture stress to which the roots of the cultivated plants are exposed, in addition to the decrease in the accumulation of salts in the soil, as well as creating the appropriate conditions for the growth and reproduction of microorganisms. The previous benefits had a positive effect on increasing and improving productivity with the use of organic covers produced from rice straw and this result agreement with Liu *et al.*, 2002; Hu,*et al.*, 995; Kar and Singh 2004 and Haitham *et al.*, 2014.

Figure (7) and Table (8) indicated that, the values of the yield of tomato “ Y_{Tomato} ” were increased by applying integrated N-fertilizers management which means, increasing the amount of organic N-

fertilizers applied up to 50% and it decreased with the continued increase in organic N-fertilizers addition. The lowest values of Y_{Tomato} were at adding 100% organic N-fertilizers with zero mineral N-fertilizers and the highest values of Y_{Tomato} were at adding 50% organic N-fertilizers with 50% mineral N-fertilizers. This is due to the presence of two types of stress in the case of interaction dynamics, with an increase in one of them, the other decreases, namely the moisture stress and the stress of N-fertilization. Reliance on 100% of mineral nitrogen fertilization led to no fertilization stress and the presence of maximum water stress, while reliance on 100% of organic nitrogen fertilization led to the least water stress, while the maximum stress of nitrogen fertilization was achieved and the availability of very limited access to fertilize tomato plants. The highest values of tomato productivity were achieved when using the integrated nitrogen fertilization (50% mineral fertilization and 50% organic fertilization, where a balance occurred between the fertilizing stress of nitrogen and water stress, which led to an increase in the absorption of water and available fertilizing elements, including nitrogen and this result agreement with Vliegen- Verschure, 2013; Gasparatos *et al.*, 2011; Yih-Chi *et al.*, 2009; Lal, 1997; Tadesse *et al.*, 2013; Bodruzzaman *et al.*, 2010; Naeem *et al.*, 2009 and Akhtar *et al.*, 2011.

Figure (7) and Table (8) indicated that, the interaction between organic mulching and integrated N- fertilization on the Y_{Tomato} . The highest value of Y_{Tomato} was under using organic mulching and adding 50% organic N-fertilizers with 50% mineral N-fertilizers. It combines with the application of these techniques all the encouraging benefits of sustaining, increasing and improving the productivity of tomatoes and any other crop in dry sandy soils with limited irrigation water and drought.

Figures (7, 8) and Table (8) indicated that, there are high correlation between the simulated and observations were obtained for the 2020 and 2021 season and the SALTMED model proved its high sensitivity ($R^2=0.903$) to simulate the Y_{Tomato} changes caused by irrigation events for all treatments.

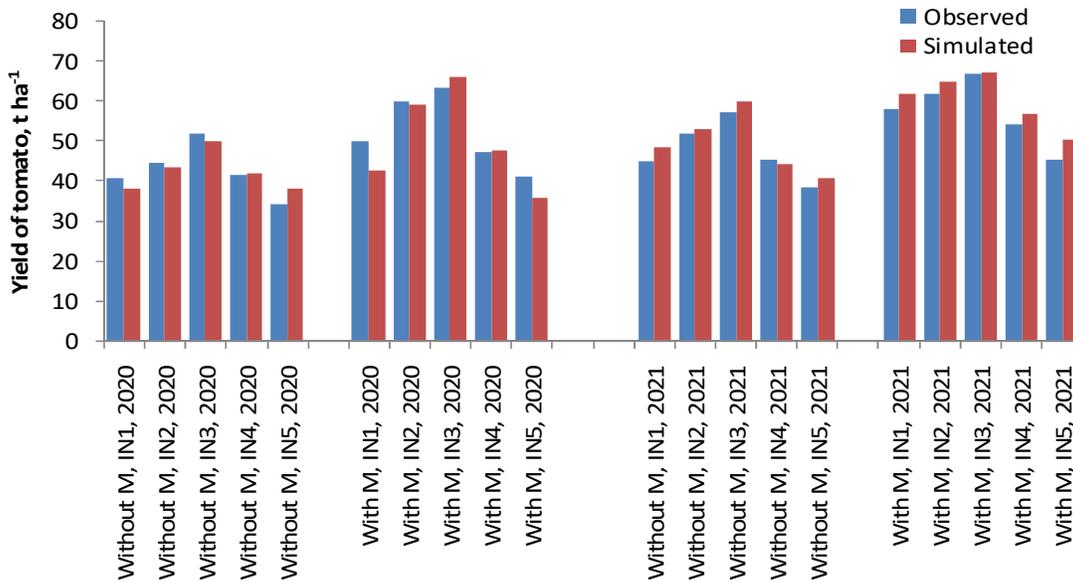


Fig. 7: Effect of organic mulching and Integrated N- fertilization (IN) on the yield of tomato and compare it to simulated yield for all treatments. (M_N: Mineral Nitrogen; O_N: Organic Nitrogen)

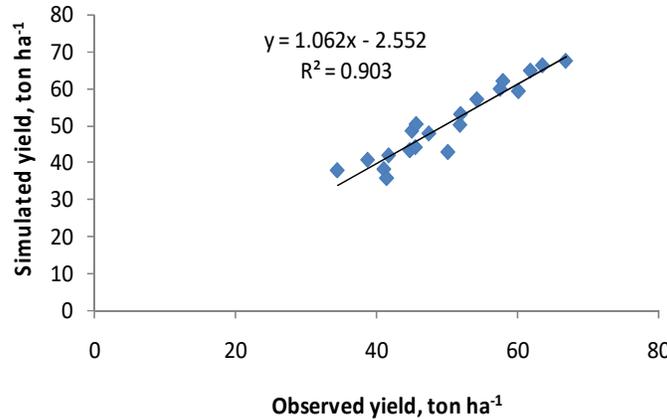


Fig. 8: Observed versus simulated yield of tomato for all treatments for seasons 2020 and 2021.

3.7. Water productivity of tomato (WP_{Tomato})

Figure (9) and Table (8) indicated that, the effect of deficit irrigation and integrated N-fertilization on the WP_{Tomato} where, the highest values of WP_{Tomato} were occurred under using organic mulching with adding 50% organic N-fertilizers with 50% mineral N-fertilizers. The lowest values of WP_{Tomato} were none mulching with 100% organic N-fertilizers and zero mineral N-fertilizers.

An increase in crop productivity with a constant volume of irrigation water added is an increase in the water productivity of the crop and a saver of irrigation water.

Figures (9, 10) and Table (8) indicated that, there are high correlation between the simulated and observations were obtained for the 2020 and 2021 season and the SALTMED model proved its high sensitivity ($R^2=0.906$) to simulate the WP_{Tomato} changes caused by irrigation events for all treatments.

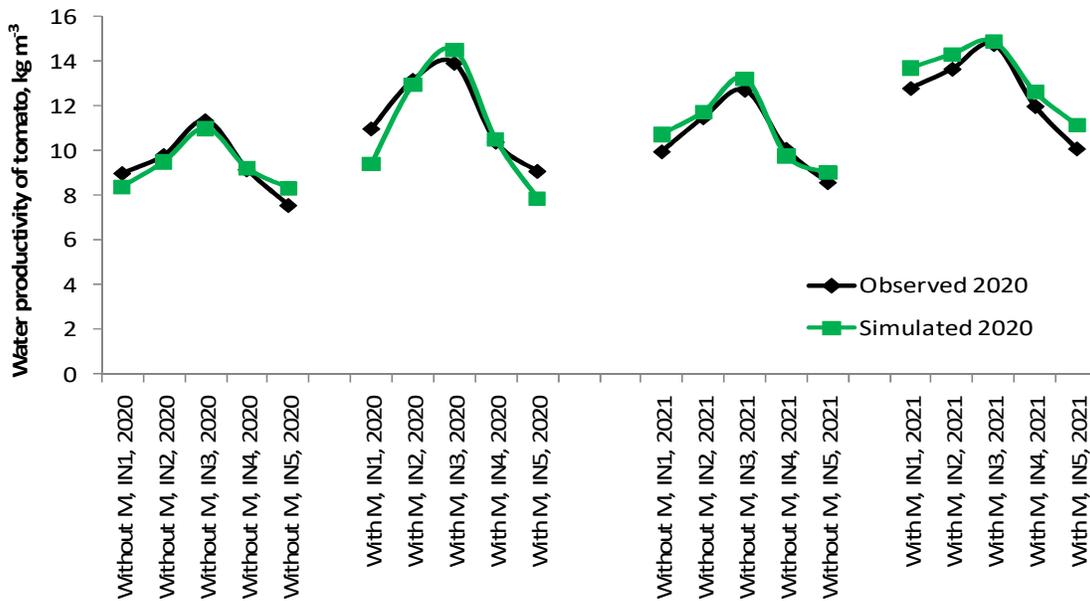


Fig. 9: Effect of organic mulching and Integrated N- fertilization (IN) on the yield of tomato and compare it to simulated water productivity for all treatments. (M_N: Mineral Nitrogen; O_N: Organic Nitrogen)

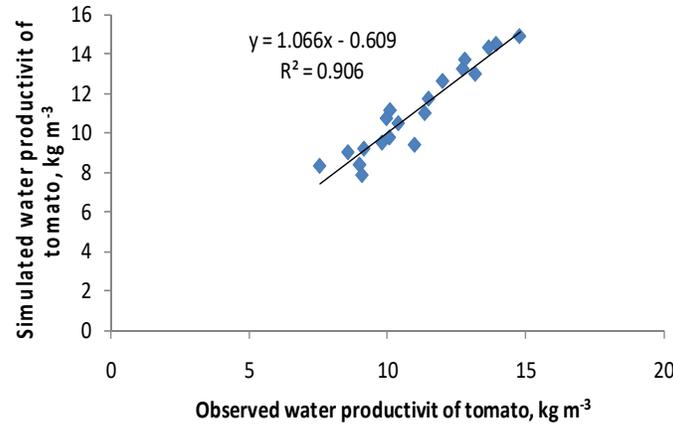


Fig. 10: Observed versus simulated water productivity of tomato for all treatments for seasons 2020 and 2021

Table 8: Effect of organic mulching and Integrated N- fertilization (IN) on the yield and water productivity of tomato and compare it to simulated treatments.

Soil mulching	IN: Integrated N-fertilization	Yield, ton ha ⁻¹				Water productivity, kg/m ³			
		2020		2021		2020		2021	
		O	S	O	S	O	S	O	S
Without mulching (Without M)	IN1: 100%MN+0%ON	41.1	38.4	45.1	48.7	8.99	8.4	10.0	10.8
	IN2: 75%MN+25%ON	44.8	43.5	52.0	53.2	9.80	9.5	11.5	11.7
	IN3: 50%MN+50%ON	51.9	50.3	57.6	60.0	11.35	11.0	12.7	13.3
	IN4: 25%MN+75%ON	41.8	42.1	45.6	44.3	9.15	9.2	10.1	9.8
	IN5: 0%MN+100%ON	34.5	38.1	38.8	40.9	7.55	8.3	8.6	9.0
With organic mulching (With M)	IN1: 100%MN+0%ON	50.2	43.0	58.0	62.1	10.98	9.4	12.8	13.7
	IN2: 75%MN+25%ON	60.2	59.4	61.9	64.9	13.17	13.0	13.7	14.3
	IN3: 50%MN+50%ON	63.6	66.3	66.9	67.5	13.92	14.5	14.8	14.9
	IN4: 25%MN+75%ON	47.5	48.0	54.3	57.2	10.39	10.5	12.0	12.6
	IN5: 0%MN+100%ON	41.5	36.0	45.7	50.5	9.08	7.9	10.1	11.2
L.S.D._{.5%}		3.1		2.6					

IN: Integrated N- fertilization, IN1:100% MN + 0% ON , IN2:75% MN + 25% ON , IN3:50% MN + 50% ON , IN4:25% MN + 75% ON , IN5:0% MN + 100% ON , MN: Mineral Nitrogen; ON: Organic Nitrogen, O: Observed Value, S: Simulated Value.

4. Conclusion

The results indicated that, using of organic mulching compared to no soil coverage or as a sustainable alternative to plastic mulching led to a decrease in the evaporation rate thus, the soil surface remains moist for as long as possible, and increase in biological activity and decrease the soil salt accumulation in sandy soils which mean, protecting the soil surface and the root zone from increasing water and salt stress and creating the optimal environment conditions for the growth and reproduction of microorganisms. The results also showed the importance of the integrated nitrogen fertilization, which increases the proportion of adding the organic component. Using of organic mulching and integrated nitrogen fertilization led to an increase in the SMC, WAE, SOMC and an increase in biological activity, as well as a decrease in the accumulation of salts in the soil. It combines with the application of these techniques all the encouraging benefits of sustaining, increasing and improving the productivity of tomatoes and any other crop in dry sandy soils with limited irrigation water and drought. The study concluded that relying on organic mulching and integrated nitrogen fertilization increased the productivity and water productivity of tomatoes. The results also showed the accuracy of the SALTMED simulation model in simulating the evaluation criteria that were studied using drip irrigation system under sandy soils in Egypt.

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