Effect of Nano-Drip Irrigation and Crude Oil Application on Some Soil Physical Properties and Maize (*Zea Mays L.*) Production

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Abstract

A two factorial field experiment was conducted in loam soil as randomized complete block design with three replications during the spring season 2021, in Al-Hamidiyah research station (latitude33° 27' 11.9'N, longitude 43° 23' 025'E). To study the effect of nano-drip irrigation on soil bulk density, mean weight diameter and maize production. The first factor included crude oil application with two levels i.e., 1% and 0% while the second factor was two levels of irrigation, namely surface and sub-surface drip irrigation. The class A evaporation pan was used to determine the intervals between the irrigation events. The irrigation process was conducted when 50% of the available water is used. The soil bulk density, porosity, mean weight diameter and maize production were recorded. The obtained result showed that the lowest and highest soil bulk density were 1.37 and 1.62 Mg m^{-3} for the treatment SDI_M. While the highest porosity was resulted from the treatment $SSDI_M$ reached 47%. The highest mean weight diameter was obtained from the treatment $SSDI_M$ by giving 0.39. Regarding the maize production, the highest yield was 1.399 $kg.m^{-3}$ resulted from the treatment $SSDI_M$.

Key Words: Surface and Sub-surface Drip Irrigation, Nano-Drip Irrigation, Crude Oil Application, Soil Physical Properties.

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Introduction

The rapidly declining freshwater resources resulting from global warming simultaneously with rapid growth in population, in addition to the growth of the three main water-consuming sectors (industrial, agricultural and domestic) led to put water resources in dry areas under great pressure. Therefore, achieving sustainable food security to meet the needs of growing population, requires the sustainability of agricultural production resources (Luca, 2018). Since the agricultural sector is the largest consumer of water which represents one of the most important elements for the agricultural production sustainability. Therefore, the greatest responsibility falls on the specialists in the field of irrigation to develop irrigation systems capable to provide quantities of water that can achieve the sustainability of water. Up to the present, the drip irrigation system is the most efficient irrigation systems to cope with the problem of drought (Michael, 2022). The scientific revolution in the field of nanotechnology has been introduced to the agricultural sector in several fields such as fertilization, pesticides and nano-irrigation.

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Entering of nanotechnology in the irrigation sector, especially in developing countries, leads to an increase in the efficiency of the use of water resources by reducing the negative impact on the agricultural environment through the optimal and effective use of modern scientific developments (Mamatha et al., 2016). Recently, many studies have reported that Nano-emitters (Nano_root guard) is an efficient method for water saving (Abdul-Razzaq et al., 2017). However, a little information is available about nao-irrigation system. Therefore, comparing the nano irrigation system with efficient irrigation methods provides more information about the effectiveness and efficiency of the system. Reducing evaporation from the soil surface through mulching is one of the important means to increase the productivity of the water unit and reduce evaporation losses (Zhou et al., 2018). However, at the present time, researchers are working in the field of water conservation to add oil amendments to reduce evaporation from the soil surface, which may be an alternative to covering the soil with polyethylene films in the future. The use of oil and organic soil conditioners have a positive effect in improving the physical and hydraulic properties of soil, which is one of the design foundations of the drip irrigation system. Application of oil amendments to the soil resulted in raise the efficiency of storage, addition and distribution of water, increase soil moisture content and reduce soil salinity (Al-Bazoun, 2018).

Human food security is linked to the production of cereals such as rice, wheat and maize (Neumann et al., 2010). Maize is among the most important cereal crops that can be grown under different climatic conditions (Shahnazari et al., 2018). Maize represents a food source for humans and an important source for the production of vegetable oils, in addition to being an important part of the feed for livestock (Herbert, 2017). Thus, the objective of the current study was to investigate the effect of surface and subsurface drip irrigation with and without diluted crude oil application on some soil physical properties and yield of maize.

Material and Methods

Study Site Description and Selected Parameters

A field experiment was carried out during spring season of 2021 in Al-Hamidiyah research station (latitude33° 27' 10.8" N, longitude $43^{o}\ 41^{'}\ 52.32^{'}E$) from 17/10/2020 to 31/1/2021. In loam soil texture. The soil under study was classified according to USDA Soil Taxonomy (Soil Survey Staff, 2014a), under the subgroup as Typic Torrifluvents. Soil samples were randomly chosen from the effective root-zone depth (0-30cm), using soil auger, the collected samples were thoroughly mixed to form representative soil sample. The resulted sample was air-dried, preserved in plastic bag and transferred to the laboratory. In the laboratory, the representative soil sample crushed and passed through 2mm sieve to determine the selected soil chemical and physical properties. The pH and EC for the soil under study were determined from the 1:5 soil-water suspensions by using a pH and EC meter respectively. The total nitrogen was determined using the Kjeldahl method as described by (Mulvaney et al. 1982). Olsen method was used to determine the available P (Olsen et al. 1982). The exchangeable bases were measured by atomic absorption spectrophotometry for Ca and Mg while flame photometer was used to measure Na and K (Polemio & Rhoades 1977). The sulfates were estimated by precipitation with barium chloride and Arabic gum and measured by a color spectrophotometer, and the chlorides were estimated in the extract using the colorimetric method. The dissolved bicarbonates were estimated in the soil extract using the Autoanalyser method, described by (Richards 1954). Hydrometer method was used to determine percentages of sand, silt clay (soil texture). Core samplers (5x5 cm height and diameter) were used to collect undisturbed soil samples for bulk density determination (Black,1955). The recorded soil physical and chemical properties were presented in (Table 1). Soil bulk density was calculated according to Eq.1

$$\rho_b = \frac{m_s}{V_t} \qquad (1)$$

Where: ρ_b is the soil bulk density (Mg m^{-3}), m_s is soil dry mass (Mg m^{-3}), V_t is the total soil volume(m3). Soil porosity was calculated according to Eq.2.

$$f = \left[1 - \frac{\rho_b}{\rho_s}\right] \times 100 \qquad (2)$$

Where: f is the soil porosity (%), ρ_b is the soil bulk density (Mg m^{-3}), ρ_s is the soil particles density (Mg m^{-3}). the soil particles density was considered as 2.65 Mg m^{-3} in the calculations of soil porosity. While the mean weight diameter was determined according to Eq.3. (Youder,1956)

$$\mathrm{MWD} = \sum_{i=1}^{n} X_i W_i \ \ldots \ (3)$$

Where: MWD is the mean weight diameter(mm), Wi is the proportion of the total water-stable aggregates to the tested soil sample, *Xi* is the mean diameter of each individual size range of aggregates (mm).

Table 1. Some Chemical and Physical properties before planting

Parameter		Value	Unit
pH		7.60	-
Sodium Adsorption Ratio (SAR)		1.44	-
EC		1.48	$dS.m^{-1}$
Organic matter		1.50	$g.kg^{-1}$
Lime (CaCO3)		278.6	
Ca^{+2}		5.11	$Meq\ L^{-1}$
Mg^{+2}		4.08	
Na^{+1}		0.52	
K^{+}		4.95	
SO_4^{-2}		6.76	
HCO_3^{-}		1.82	
Cl^{-}		6.22	
Nitrogen(N)		9.75	$mg.kg^{-1}$
Phosphorous(P)		6.15	
Potassium(K)		9.342	
Cation Exchange Capacity (CEC)		17.34	$Cmolc\ kg^{-1}$
Soil Particles	Sand	42.8	%
	Silt	34	
	Clay	23.2	
Texture Soil	**loam**		
Bulk Density		1.35	$Mg\ m^{-3}$
Total porosity		47.8	%
Mean Weight Diameter		0.44	

Experimental Design and Beds Configuration

A two factorial field experiment was conducted in loam soil as randomized complete block design with three replications during the spring season 2021. The first factor included crude oil application with two levels i.e., 1% and 0% while the second factor was two levels of irrigation, namely surface and sub-surface drip irrigation. The 0% crude oil application was set as control treatment. The combinations between the study factors take the symbols of SDI_{NO} (Surface drip irrigation without crude oil application), SDI_M (Surface drip irrigation with crude oil application), $SSDI_{NO}$ (Sub-surface drip irrigation without crude oil application) and $SSDI_M$ (Sub-surface drip irrigation with crude oil application). The experimental area was 514.8 m^2 (26m*26.40m). Field preparation process such as plowing, harrowing to break the soil clods into smaller size and leveling the field were conducted before beds configuration. The field was divided into 12 treatments as raised beds with dimensions of 0.6* 10 *0.25m long, width and height respectively. The distance between the adjacent bed within the blocks is 1.5m, while the distance between the blocks are 2m. The drip lines of surface and sub-surface drip irrigation were set in the center of each bed to the depth of 0.1m. The sub-main pipes were connected to the main pipe using tee connector. Each sub-main pipe had a valve to facilitate the cleaning the drip irrigation system when needed.

Crude Oil Application and Irrigation Process

The crude oil was applied (spraying) to the soil surface as a thin layer according to the recommended i.e., 1% based on the weight of the 5 cm upper layer of the soil surface. Where 0.6 L m^{-2} was applied of the crude oil to the treated treatment which randomly chosen. The soil weight per experimental unit was calculated according to Eq.4. The crude oil application was according to E. q5. The crude oil viscosity was reduced by mixing with 20% petrol to facilitate the spraying process.

$$W_{soil} = A \times D \times \rho b \qquad (4)$$

Where:

W soil is the soil weight per experimental unit (kg), *A* is the raised bed area(m2), *D* the depth of 5 cm upper layer of the soil and ρb is the soil bulk density ($Mg\ m^{-3}$).

While the amount of the supplied crude oil was calculated according to Eq.5

$$V_{fuel-oil} = \frac{W_{soil} \times R_a \times R_d}{\rho_{fuel-oil}} \times 100 \quad (5)$$

Where:

$V_{fuel-oil}$ is the amount of the supplied crude oil, W_{soil} is the soil weight per experimental unit to the depth of 5cm.(kg), R_a is the application rate of crude oil (i.e., 1%), R_d is the percentage of crude oil in the mixture after dilution with petrol (80%), $\rho_{fuel-oil}$ is the specific weight of crude oil 0.95 (Mgm-3). Soil water retention curve was adopted for determining the field capacity and permeant wilting point limits. Water irrigation depth was calculated according to Kovda et al., 1973 as in Eq. 6

$$d = \frac{\theta_{fc} - \theta_{pwp}}{100} \times D \qquad (6)$$

Where:

d is the depth of supplied water (cm), θfc is the volumetric water content at the field capacity (%), θpwp is the volumetric water content at the permeant wilting point (%), D is the root depth(cm). The water irrigation depth when 50% of available water depleted was calculated according to Eq.7

$$d = \Theta_{0.50} \times D \qquad (7)$$

Where: d is the water irrigation depth (cm), D is the root depth at specific stage of irrigation(cm), $\Theta_{0.50}$ is the volumetric water content when 50% of available water was depleted. Since the actual water consumption represents the depth of water supplied. Therefore, $ET_a = d$

The reference evapotranspiration was calculated by substituting Eq. 8. (FAO, 1998)

$$ET_o = \frac{ET_a}{Kc} \qquad (8)$$

Where: *Eta is the* evapotranspiration(mm.day^{-1}), *ETo* is the reference evapotranspiration (mm.day^{-1}) and Kc is the crop coefficient. The irrigation intervals between the irrigation events were determined according to the class A evaporation pan. According to Eq.9 (FAO, 1998).

$$E_{pan} = \frac{ET_o}{K_P} \qquad (9)$$

Where: *ETo* is the reference evapotranspiration (mm.day^{-1}), K_p is the pan coefficient, *Epan* is the evaporated water from the pan per day (mm.day^{-1}). The adopted pan coefficient value was 0.75 according to (Al- jaberi 2021). Water productivity was calculated according to (Djaman et al., 2018 as in Eq. 10

$$WUE(kg\ m^{-3}) = \frac{Yield(kg\ ha^{-1})}{Water\ Applied(m^3\ ha^{-1})} \qquad (10)$$

Where: *WUE* is the water productivity (kg.m^{-3}).

Results and Discussion

Soil Bulk Density

The evidence shows that the soil bulk had effectively increased after compare to before cultivation for the surface and sub-surface drip irrigation (Table. 2), by giving 1.38 and 1.55 Mg m^{-3} for SSDI and SDI respectively, with increasing rate of 1.47 and 13.97 % respectively. Probably due to the role of the root development that packed the soil particles together in addition to the soil particle size, wetting-drying, freezing-thawing cycles that could entrapped the air in the soil porosity accordingly, the air bubbles bringing the soil particles close together. Consequently, results in increasing the soil bulk density. These results consented with Sabri Bahia and Hammadi (2020). Regarding the crude oil application, the obtained results show slight deference between with and without crude oil application. In this context, the soil bulk density was 1.43 and 1.50 Mg m^{-3} for the treatments with and without crude oil application with increasing rate compare to before cultivation reached 3.67 and 10.29% respectively. Due to surface runoff occurring for the treatment SDI_M as a result to the thin layer of crude oil application that cover the soil surface, consequently change the soil surface to hydrophobic media thus reduce the infiltration rate and increase the surface runoff. Therefore, the sub-surface layer exposed to pressure due to the weight of upper layer. Hence, the bulk density of sub-layer had increased the results agreed with Al-Yasiri et al., (2019) and Al-Esawi et al., (2020).

Table 2. Effect of Irrigation method and crude oil application on soil bulk density

Irrigation method	With crude oil	Without crude oil	Average of Irrigation
SDI	1.62	1.47	1.55
SSDI	1.37	1.39	1.38
Before cultivation	1.36		
LSD	**0.042**		**0.30**
Average of crude oil Application	1.50	1.43	
LSD	**0.03**		

Concerning the interaction between the irrigation treatments and crude oil application, the lowest obtained bulk density was 1.37 Mg m^{-3} for the treatment $SSDI_M$ which significantly superior to all other interaction treatment. While the highest bulk density was 1.62 Mg m^{-3} for the treatment SDI_M. The reason for this may be due to covering part or all of the surface of soil particles with hydrophobic materials, so the connection between soil particles and the oil has a large contact angle that prevents water from moving easily and thus reduced the deterioration of soil aggregates as a result of the effect of the wetting and drying cycles with redistribution porous subsurface irrigation through adequate moistening without deteriorating soil structure Mandal et al. 2013 and (Al-Daraji, 2019).

Total Soil Porosity

It is clear from Table3. that soil porosity after cultivation significantly decreased compare to before cultivation under both irrigation system (surface and sub-surface). Where the obtained porosity was 47 and 41 % for the treatment SSDI and SDI respectively. Probably due to increasing the soil bulk density resulted from root development that bring the soil particles closely together or owing to clay particles orientation that insert into soil pores, consequently clog the pores. The results agreed with Al-Muhamdi et al., (2014) and Al-Abdali et al., (2019). Regarding the crude oil application, the evidence shows significant differences. Where the porosity reached 0.45 and 0.35 % for without and with crude oil application respectively. The porosity reduction under crude oil application, probably due to the surface runoff occurring for SDI_M treatment as a result to crude oil application which change the soil to become hydrophobic (water repellant). Consequently, the coated soil aggregates with crude oil becomes less susceptible to degradation. Therefore, the obtained soil porosity under crude oil application was less. While slightly increase in soil porosity was observed in absence of crude oil. Due to soil aggregate degradation as a result to water movement in soil pores. Accordingly, increasing the soil bulk density. This result agreed with Bartha and Bossert (1984) and Kayode (2009). Regarding the interaction, the highest porosity reached 47% for $SSDI_M$ treatment which significantly superior to all other treatments. While the lowest obtained porosity was 38% for SDI_M treatment. Probably due to increasing the soil bulk density after. Consequently, Therefore, the sub-surface layer exposed to pressure due to the weight of upper layer that subjected to the weight of runoff water. The result agreed with Al-daraji (2019) and Beckwith (2005).

Table 3. Effect of irrigation method and crude oil application on soil porosity

Irrigation method	With crude oil	Without crude oil	Average of Irrigation
SDI	0.38	0.44	0.41
SSDI	0.47	0.46	0.47
Before cultivation		0.48	
LSD		**0.016**	0.012
Average of crude oil Application	0.43	0.45	
LSD		**0.012**	

Mean Weight Diameter

The result of the current study Table. 4 showed that the studied factors significantly increased mean weight diameter (MWD) after cultivation for surface and sub-surface drip irrigation. Where the highest mean weight diameter was obtained from the treatment SSDI by giving 0.37 mm compare to 0.19mm for SDI treatment. Probably due to the role of subsurface drip irrigation in slowly wetting the soil, which helped to reduce the breakdown of soil aggregates into small aggregates and individual soil particles, in addition to the water supplied for close irrigation intervals, contributed to preserved the soil moisture, consequently preventing the cracks that contribute to aggregates breakdown Hadi and Odeh (2014) and Al Jabri (2021). Also, the evidence shows significant differences in the mean weight diameter as a result to crude oil application. Where the highest mean weight diameter was resulted from without crude oil application reached 0.29 mm compare to 0.28 mm for the crude oil application treatment. Due to the role of crude oil in coating the soil aggregates as in SDI_M treatment, consequently the soil aggregates would become a water repellent aggregates. Consequently, reduce the soil aggregates breakdown Al- Nuaimi (2009) and Bahia (2008) and Shokrollah et al., (2009). The interaction between irrigation method and crude oil application had significantly decreased the mean weight diameter under surface drip irrigation. Where the highest observed mean weight diameter was 0.39 mm for $SSDI_M$ treatment which significantly superior to all other interaction treatments. While the lowest observed mean weight diameter was 0.17 mm for SDI_M treatment. The reason can be attributed to the moisture uniformity resulting from the presence of emitters near the root zone. when watering at 50% of available depleted water, consequently reduced the negative effect of rapid wetting, in addition to the role of crude oil in the volumetric redistribution of soil pores, forming more stable aggregates as a result of crude oil remaining for a longer period due to its slow decomposition, which reflects positively on the values of the mean weight diameter Al- Shami (2013) and Mesfin (2018) and Al- Draji (2019).

Table 4. Effect of drip irrigation method and crude oil application on the mean weight diameter

Irrigation method	With crude oil	Without crude oil	Average of Irrigation
SDI	0.17	0.22	0.19
SSDI	0.39	0.35	0.37
Before cultivation		0.38	
LSD		**0.031**	**0.022**
Average of crude oil Application	0.28	0.29	
LSD		**0.022**	

Maize Yield

A significant difference was observed in the average yield of maize under subsurface and surface drip irrigation Table 5. Where SSDI treatment gave the highest yield, reached 1.190 kg m^{-3}, while the average yield was 0.704 kg. M^{-3} for the treatment SDI, possibly due to the fact that subsurface drip irrigation is characterized by high irrigation uniformity, low evaporation losses, and water availability in the root zone, the result agreed with El-Hendawy et al. 2014) and Valentin et al (2020). Regarding the crude oil application, it is clear from Table 6. The oil addition led to increase the maize yield. Where the highest yield was observed from the treatment crude oil application reached 0.991 kg.m^{-3} compare to without crude oil application which gave 0.903 kg.m^{-3}. Probably due to the role of covering the soil surface with crude oil which consequently reduces the water loss through evaporation thereby increases the available water for the plant (Zhou et al., 2017). Under the interaction effect, the highest yield was 1.399 kg.m^{-3} for the treatment $SSDI_M$ while the lowest yield was obtained from the treatment SDI_{NO} reached 0.584 kg.m^{-3}. Probably due to the role of crude oil in water conserving in the root zone area as a result to preventing the evaporation from the soil surface (Sandhu et al., 2019) and Aydinsakir et al., 2021).

Table 5. Effect of drip irrigation method and crude oil application on the Maize Yield

Irrigation method	With crude oil	Without crude oil	Average of Irrigation
SDI	0.584	0.825	0.704
SSDI	1.399	0.981	1.19
LSD		**0.031**	**0.023**
Average of crude oil Application	0.991	0.903	
LSD		**0.023**	

Conclusion

A thin layer of crude oil application on the soil surface under sub-surface drip irrigation preserved the properties of the soil from deteriorating significantly, which gave the desire results, compare to the application with surface drip irrigation, due to the method of application to the soil surface i.e., spraying, which led to the formation of an water repellency layer above the soil surface, which caused runoff on the soil surface, reduce the infiltration of irrigation water to the root zone to meet the requirements of the plant. Therefore, based on the obtained results, using nano-subsurface drip irrigation with crude oil application with 1%, while under surface drip irrigation the results show that mixing the crude oil with the soil surface is recommended to avoid the runoff from the soil surface.

Competing Interests

The authors declare that they have no conflict of interest.

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