



Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 4(8) pp. 378-386, August, 2015.
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Full Length Research Paper

Effect of Organic Manure Fertigation on Sesame Yield Productivity under Drip Irrigation System

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Accepted 16 July, 2015

Application of organic manures has distinguished with improving soil characteristics, sustaining human health and ecosystems. This study concerns fertigation using organic manure as an alternative of mineral fertilizers and its effect on drip irrigation system performance and sesame yield productivity. Field experiments were conducted during two consecutive growing seasons in split plot design at the National Research Center farm, Nubaria area, Behura Governorate, Egypt. Experiments investigated the effect of two emitter types on-line emitter and built-in emitter ; three rates of irrigation 50, 75; 100% of ET_c (IR1, IR2; IR3); three levels of organic fertilizer(Poultry manure) 1, 2; 4 ton fed^{-1} (PM1, PM2; PM3) on sesame yield, water use efficiency (WUE) , fertilizer use efficiency (FUE) and emitter clogging ratio . The main results showed that, the highest and the lowest sesame yield (533and 146 kg fed^{-1} .) was obtained with treatment on line emitter x IR2 x PM3 and built in emitter x IR1 x PM1, respectively. Maximum value of WUE was 0.307 kg seeds / m^{-3} of irrigation water as recorded with the treatment on line emitter x IR2 x PM3, while the minimum value was 0.1 kg seeds / m^{-3} of irrigation water as recorded with the treatment built in emitter x IR3 x PM1. Maximum value of FUE in kg seeds kg-1 organic fertilizer was 0.39 and the minimum ones 0.074 in the following interactions between on line emitter x IR2 x PM1 and built in emitter x IR1 x PM3, respectively. Emitter clogging increased with increasing organic fertilizer application, and decreasing the irrigation treatments. The maximum and minimum values of clogging percent are (28.3 and 9.83) under the condition of (built in emitter x IR1 x PM3)and (on line emitter x IR3 x PM1), respectively.

Keywords: Sesame, fertigation, organic fertilizer, clogging, and sesame yield.

INTRODUCTION

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation

and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. The natural recycling of farm-waste organic matter through composting is aimed at minimizing nutrient loss, reducing waste accumulation and limiting greenhouse gas emission. Developing inexpensive and nutrient-rich organic media alternatives will not only eliminate environmental impacts but also reduce nursery costs and fertilization and irrigation rates (Wilson et al., 2001).

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Application of organic manures has various advantages like improving soil physical properties, water holding capacity, and organic carbon content apart from supplying good quality of nutrients. Poultry manure is rich organic manure since solid and liquid excreta are excreted together resulting in no urine loss. In fresh poultry excreta uric acid or urea is the most abundant nitrogen compound while ammonia and ammonium are present in small amounts (Krogdahl, A., and B. Dahlsgard. 1981). Poultry manure could be an excellent source of nutrients it has been extensively used for the production of other crops such as maize, Amaranth and tomato (Ayeni et al., 2010 and Makinde et al., 2010).

Many researchers have shown that poultry manure contains nutrients such as N, P, K and micronutrients that could be used to increase soil fertility (Ayeni and Adetunji, 2010).

In order to minimize cost and make the poultry manure readily soluble and effective as source of fertilizer; there is need to combine poultry manure with water for optimum vegetable production during the dry season. Composted manure that is implemented in the soil prior to planting as the sole fertilizer, resulted insignificant down-leaching of nitrate through the root zone to the groundwater. On the other hand, similar intensive agriculture that implemented liquid fertilizer through drip irrigation, as commonly practiced in conventional agriculture, resulted in much lower rates of pollution of the root zone and groundwater. Productive agriculture must inherently include the leaching of excess lower quality water below the root zone to the unsaturated zone and ultimately to the groundwater (Shani et al., 2007; Dudley et al., 2008). The reason why fertigation has become the state of art in plant nutrition particularly in arid environments is that nutrients can be applied in the correct dosage and at the required time appropriate for each specific growth stage. Fertilizers applied under conventional methods of irrigation are generally not efficiently used by the crop (Cassel et al. 2001; Hebbar et al., 2004). Proper fertigation management requires the knowledge of soil fertility status and nutrient uptake pattern of the crop. Monitoring of soil and plant nutrient status is an essential safeguard to ensure maximum crop productivity.

Drip irrigation involves the application of small frequent irrigation systems to saturate the soil and fulfill plant water requirements. There are specific problems in the management of sandy soils, including their excessive permeability and low water and nutrient holding capacities (Suganya and Sivasamy, 2006). The use of modern irrigation systems (surface and subsurface drip) in cultivating ornamental plants has improved the growth and quality of flowers (Gengoglan et al., 2006; El-Shawadfy, 2008). Therefore, managing the use of irrigation and plant nutrients is a major challenge for sandy soil amelioration efforts.

Hence, the objective of this work was to determine the effect of organic manure fertigation, types of emitters and

irrigation regimes on the yield and both water and fertilizer use efficiency of sesame in a Sandy Soil.

MATERIALS AND METHOD

Field Experiments

Field experiments were conducted in two successive growing seasons to study the effect fertigation organic manure, types of emitters and irrigation regimes on the yield and both water and phosphorous use efficiency of sesame in New Reclaimed Lands.

Irrigation water characteristics

The source of irrigation water at experimental site is well water (the total depth of wall: 45 m; water depth from ground surface: 4-5 m; and diameter of well: 6"). Screen filter (2" /2" inlet, outlet diam.; 35 m³/h discharge rate and filtration degree 120 mesh). Water sample was taken from the irrigation water to be analyzed. Table (2) shows the results of irrigation water analysis.

Experiment Layout

The experiments were carried out in split plot design with three replications combined over method of irrigation. Sesame (Shndweel 3 variety) was sown in hills, 10 cm apart. Thinning to two plants per hill was done at 14 days after planting. The normal agricultural practices for growing sesame were followed as recommended in the region. The main plots were devoted to two types of drippers for drip irrigation system; sub-main plots were devoted to three rates of irrigation treatments. On the other hand, the sub-sub-plots were devoted into three levels of organic fertilizer treatments.

Lateral line design

The lateral line (outer) diameter was 15.5 mm for both on-line and built-in emitters. The lateral length was 40 m and emitter spacing according to soil type was 0.34 m. Figure 1 show the layout of irrigation water distribution system design for experimental treatments.

Fertilization Treatments

The chemical analysis of the Poultry manure is in Table 3. The Poultry manure was prepared using water at a rate of 4.2 kg/L (Afolayan et. Al., 2014) of Poultry manure, stored for 48 hrs, and subsequently injected into the drip irrigation network and applied using a fertigation programmer at rates of 1, 2 and 4 ton fed⁻¹ (PM₁, PM₂ and PM₃). The

Table 1: Some soil physical properties of the experiment at site

Sample depth, cm	Particle Size Distribution, %				θ_w (w/w)			O.M. (%)	pH (1:2.5)	EC (dSm ⁻¹)	Texture class
	Coarse Sand	Fine Sand	Clay and Silt	CaCO ₃ (%)	F.C	W.P	S. P				
0-20	57.76	50.70	2.45	7.02	10.1	4.7	21.0	0.65	8.7	0.35	Sandy
20-40	56.99	39.56	3.75	2.34	13.5	5.6	19.0	0.40	8.8	0.32	Sandy
40-60	36.78	59.40	3.84	4.68	12.5	4.6	22.0	0.25	9.3	0.44	Sandy

Where:

F. C : Field capacity, **B.D** : Bulk density, **W.P** : Welting point, **A.W** : Available water

Table 2: Some chemical data of the irrigation water at Nubaria

pH 1:2.5	EC dS/m	Soluble ions meq/l							SAR
		Cations				Anions			
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ⁻	Cl ⁻	
7.63	0.39	1.02	0.51	2.43	0.22	0.13	1.34	2.71	2.8

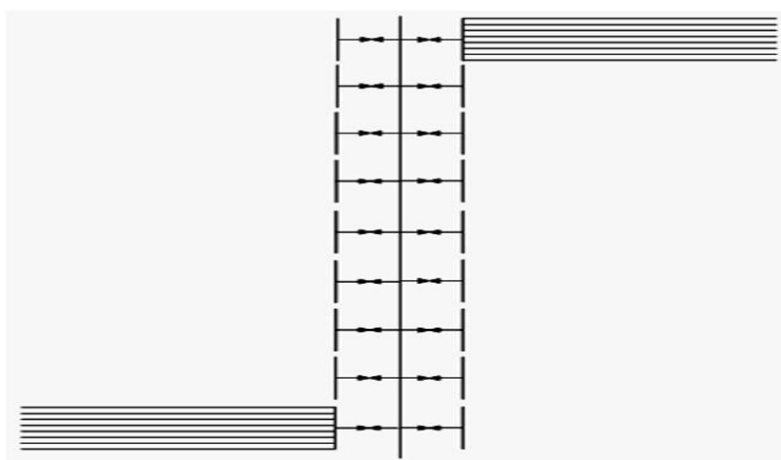


Figure 1: Distribution system design layout.

Table 3: General specifications of the experimental treatments

Crop			
Sesame (Shndweel 3 Variety)			
Emitter types			
On-Line		Built-in	
Discharge	Operating pressure	Discharge	Operating pressure
4 (l/hr)	1 (bar)	4 (l/hr)	1 (bar)
Irrigation rates			
IR1 = 50% (Etc)	IR2 = 75% (Etc)	IR3 = 100% (Etc)	
1302 (m ³ fed ⁻¹)	1736 (m ³ fed ⁻¹)	2710 (m ³ fed ⁻¹)	
Fertilization levels (Poultry manure)			
PM1	PM2	PM3	
1 (ton fed ⁻¹)	2 (ton fed ⁻¹)	4 (ton fed ⁻¹)	

Table 4: Chemical analysis of poultry manure

Particulars	Poultry manure
N content (%)	2.60
P content (%)	1.38
K content (%)	1.29
p H (1:2 soil water extract)	7.31
C: N ratio	12.2

extracted solution was injected to irrigation water using 1.5" venturi tube.

Irrigation treatments

Three irrigation rates were 100, 80, and 60 % of ET_c (2710, 1736 and 1302 m³/fed) (IR₃, IR₂ and IR₁).

Measurements

1. Emitters clogging

To estimate the emitter flow rate cans and a stopwatch were used. Nine emitters for each lateral had been chosen to be evaluated by calculating their clogging ratio at the beginning and at the end of the growing season. Three emitters at the beginning, three at middle and three at the end of the lateral were tested for flow rate.

Clogging ratio was calculated using the following equations (El-Berry et al., 2003):

$$E = q_u / q_n \times 100 \quad (1)$$

$$CR = (1 - E) \times 100 \quad (2)$$

where:

- E = the emitter discharge efficiency, (%)
 q_u = emitter discharge, at the end of the growing season (L/h)
 q_n = emitter discharge, at the beginning of the growing season (L/h)
 CR = the emitter clogging ratio, (%)

2. Total yield of plant:

The total yield of each treatment as determined using a frame 1m × 1m size. The frame was placed randomly and the sesame plants within the frame were weighted.

3. Water use efficiency (WUE):

This terminology refers to corn yield/ cubic meter of irrigation water (kg m⁻³). It was calculated according to Israelsen and Hansen (1962) as follows:

$$WUE = Y / W \quad (3)$$

Where:

$$\begin{aligned} WU &= \text{water use efficiency} && (\text{Kg m}^{-3}), \\ E & && \\ Y &= \text{total grains yield} && (\text{Kg seeds fed.}^{-1}), \\ W &= \text{total water applied} && (\text{m}^3). \end{aligned}$$

4. Fertilizer use Efficiency (FUE):

This terminology refers to the production of crop yield / kilogram of P_2O_5 . It was calculated according to Israelsen and Hansen (1962), as follows:

$$FUE = Y / PM \quad (4)$$

where:

$$\begin{aligned} FU &= \text{Fertilizers use efficiency} && (\text{Kg seeds kg}^{-1}\text{PM}), \\ E & && \\ PM &= \text{Amount of Poultry manure} && (\text{kg PM fed.}^{-1}). \\ & && \text{applied} \end{aligned}$$

5. Statistical analysis

All data collected were statistically analyzed as a split-split plot design with three replications using analysis of variance to evaluate main and interaction effects as described by Snedecor and Chocran, (1980). Means among treatments were compared using Least Significant Difference (LSD) at $P = 0.05$ probability.

RESULTS AND DISCUSSION

Figures (2, 3 and 4) indicated that all the studied parameters i.e. (seed yield) in kg fed.^{-1} and efficiency of both water ($\text{Kg seeds yield m}^{-3}$ of water) and fertilizers ($\text{Kg seeds Kg}^{-1}\text{F.}$) increased with increasing the applied organic fertilizers from 1 to 4 ton organic fertilizers fed.^{-1} . It is obvious that values of the studied parameters varied with the irrigation regimes and the dripper types used.

1. Seed yield

Data in Figure (2) showed the effect of irrigation water treatments, fertigation treatments and dripper types on seed yields of sesame crop. Results indicated that the highest grains yield value was 533 kg fed.^{-1} observed under on-line emitter using 80% of the ET_c and 4 ton Poultry manure fed.^{-1} . Meanwhile, the lowest value was 146 obtained with 60% of the irrigation water requirements and 1 ton Poultry manure fed.^{-1} under built-in emitter.

the highest value of seed yield was achieved by using fertigation technique under 4 ton Poultry manure /fed. but

the statistical analysis indicated that no significant deference was achieved between 4 and 2 ton Poultry manure /fed. PM, in the grain yield, this means saving 50% from organic fertilizer.

In general, it can be concluded that on line emitter is appropriate for sesame yield production under drought conditions. This may be attributing of the good distribution of water and nutrients through the active root zone. Also, it can be noticed that maximum sesame was observed by using the irrigation water amount equal to 80% of actual evapotranspiration. This may be due to the arid condition prevailing in the area. Therefore, lake in available water caused water stress that effect plant growth, plant physiological processes and consequently crop productivity (Rivero et al., 2007; Farouq, et al 2009 and Ali, et al. 2011).

2. Water use Efficiency

Figure (3) showed the effect of irrigation treatment on water use efficiency under dripper types. Data indicated that the highest value of water use efficiency (WUE) was $0.307 \text{ kg seeds m}^{-3}$ obtained under on-line emitter at 80% of ET_c . meanwhile, the lowest value was $0.1 \text{ kg seeds m}^{-3}$ was obtained by 100% of ET_c under built-in emitter.

Figure (3) illustrates the main effects of emitter type, irrigation treatments and organic fertilizers treatments on WUE. The three parameters have significant effect on the 5% level on WUE. According to WUE values obtained the studied parameters could be written in the following ascending orders: built-in emitter < on-line emitter, $IR_3 < IR_1 < IR_2$ and $PM_3 < PM_2 < PM_1$. Data obtained could be due to the effects of the following reasons on yield:

- Increasing fertilizers concentration increase drippers clogging and vice versa, and
- Increasing irrigation treatments to some extent increases yield and decreases drippers clogging. (Tayel et.al., 2010)

3. Fertilizers Use Efficiency:

Data on hand show the emitter type, irrigation treatments and organic fertilizer treatment all have significant effects on FUE on the 5% level. According to the values of FUE, the parameters under investigation could be put in the following ascending orders: on- line emitter < built-in emitter, $IR_3 < IR_1 < IR_2$ and $PM_3 < PM_2 < PM_1$.

Reasons for this have been previously discussed under yield and water use efficiency. Figure (4) indicated that the highest value of fertilizer use efficiency (FUE) was $0.39 \text{ kg seeds /kg F.}$ obtained under on-line emitter by using 80% of the ET_c and 1000 Kg F. fed.^{-1} . Mean while, the lowest value was $0.074 \text{ kg yield kg F}^{-1}$, obtained by using 60% of ET_c and 1000 Kg F. fed.^{-1} using built-in emitter.

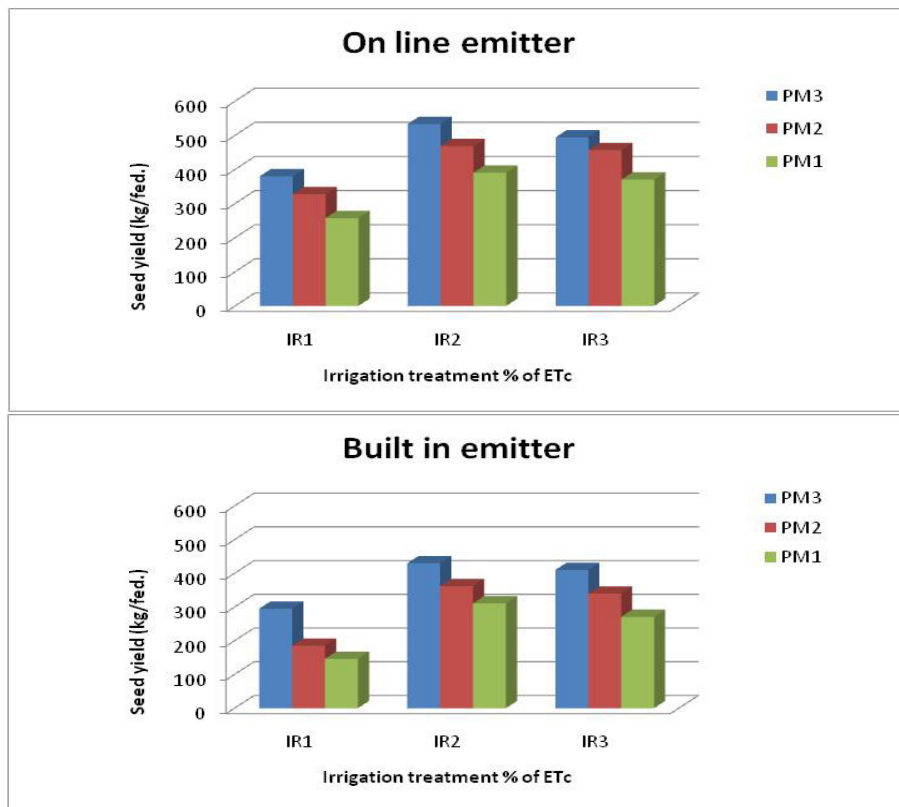


Figure 1: Effect of dripper type, Irrigation treatments and Fertilization Treatments on seed yield (kg/fed.) of sesame.

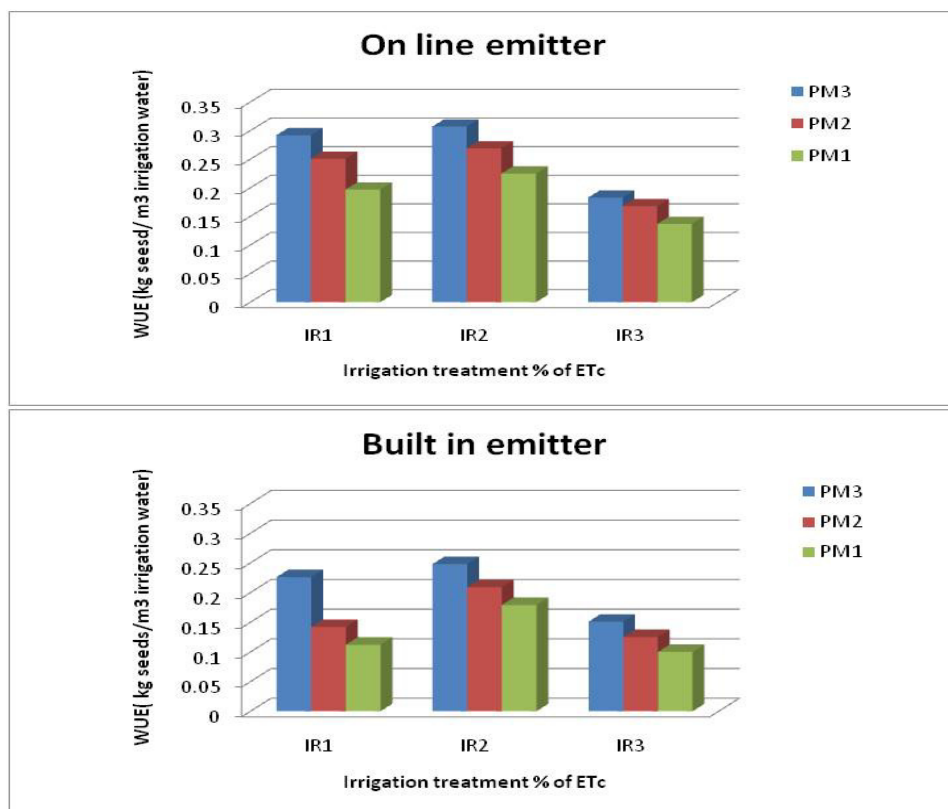


Figure 2: Effect of dripper type, Irrigation treatments and Fertilization Treatments on W U E (kg seed /m³ of irrigation water) of sesame.

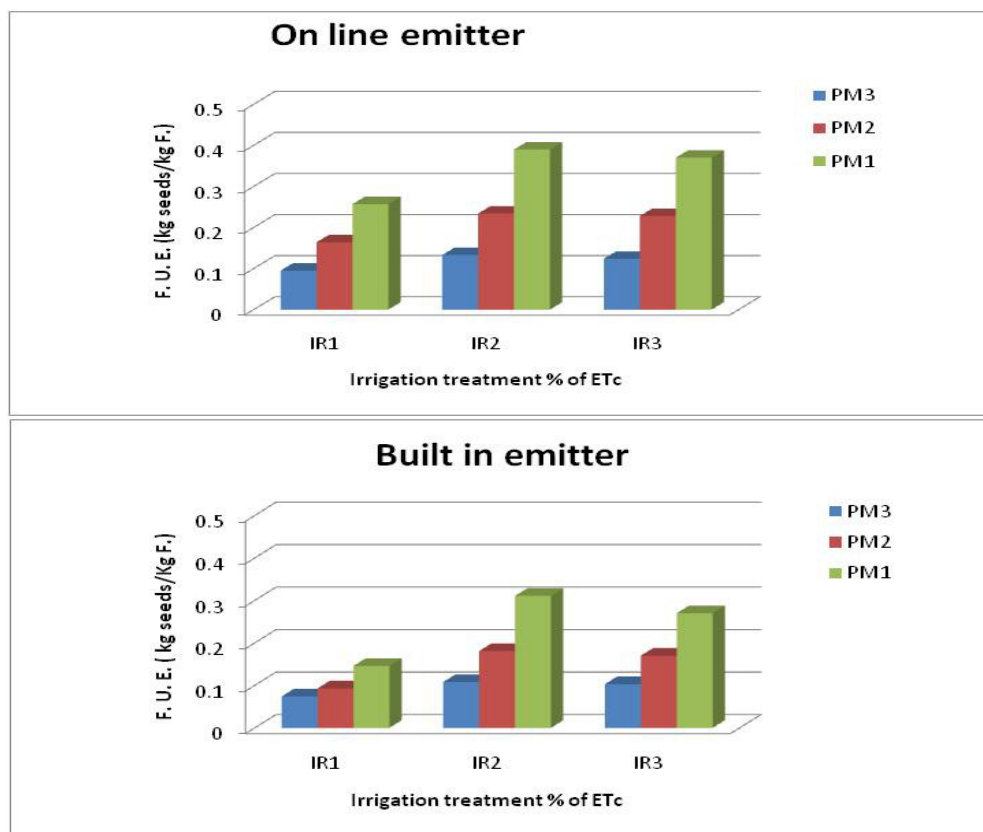


Figure 3: Effect of dripper type, Irrigation treatments and Fertilization Treatments on F U E (kg seed /kg fertilizer) of sesame

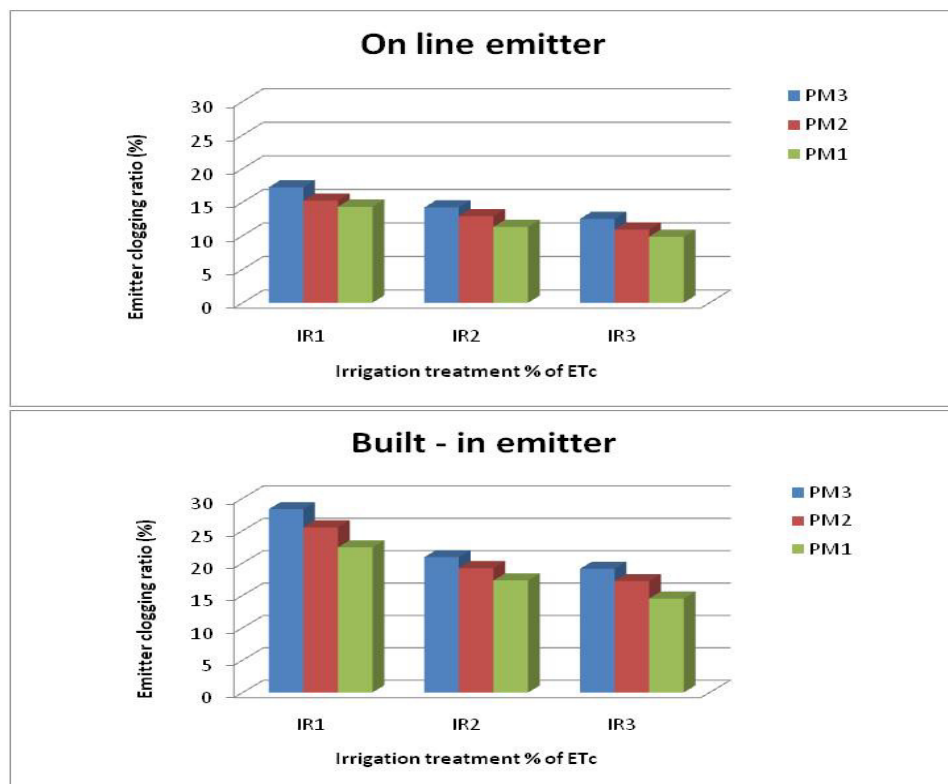


Figure 4: Effect of dripper type, Irrigation treatments and Fertilization Treatments on emitter clogging ratio (%).

4. Emitters clogging:

The results show that, Emitter clogging increased with increasing organic fertilizers application, and decreasing the irrigation rate. The maximum and minimum values of clogging percent are (28.3 %) and (9.83 %) under the condition of (built-in emitters \times IR₁ \times PM₃), (on-line emitters \times IR₃ \times PM₁), respectively. According to clogging percent emitters used could be written in the following ascending order on-line emitters < built-in emitters.

This may be due to the on-line emitters, suspending solids will deposit in the “depositing zone”, thus avoiding clogging other small-section channels. In the built-in emitter, a few suspending solids will congregate and adhere to out-edge of every channel corner, which indicates that this emitter will be clogged with the increase of particle size and concentration of suspending solids (Wei Qingsong et al., 2008).

According to clogging percent, irrigation treatments could be written in the following ascending order: IR₃ (100% of ET_c) < IR₂ (80 % of ET_c) < IR₁ (60%of ET_c). Difference in clogging percent between any two irrigation treatments is significant on the 5% level. This is due to that emitters are more flushed in the opposite of the sequence mentioned before. The obtained data show that increasing the amount of the applied organic fertilizer from 1 (PM₁) to 4ton/fed. (PM₃) increased the clogging percent under all irrigation treatments and the two emitters used. A cording to clogging percent, the following ascending order illustrates the role of nitrogen treatments: PM₁<PM₂<PM₃.

This could be explained on the basis that increasing organic fertilizers content will increase the amount of Calcium that will precipitate within the emitters and in their narrow openings after water evaporation, especially in the form of CO₃⁻ and SO₄⁻. In conclusion, it is obvious that the problem of emitter clogging increased with increasing fertilizers application, and decreasing the irrigation rate.(Mohamed Yousif Tayel et al., 2013).

CONCLUSION

The presented study concerned fertigation using organic manure as an alternative of mineral fertilizers and its effect on drip irrigation system performance and sesame yield productivity. Experiments investigated the effect of two emitter types on-line emitter and built-in emitter ; three rates of irrigation 50, 75; 100% of ET_c (IR₁, IR₂; IR₃); three levels of organic fertilizer(Poultry manure) 1, 2; 4 ton fed⁻¹ (PM₁, PM₂; PM₃) on sesame yield, water use efficiency (WUE) , fertilizer use efficiency (NUE) and emitter clogging ratio .The results showed that:

1. The highest and the lowest sesame yield (533and 146kg fed⁻¹.) was obtained with treatment on-line emitter \times IR₂ \times PM₃ and built-in emitter \times IR₁ \times PM₁, respectively.

2. The highest value of seed yield was achieved by using fertigation technique under 4 ton Poultry manure /fed. but the statistical analysis indicated that no significant deference was achieved between 4 and 2 ton Poultry manure /fed. PM₁ in the grain yield, this means saving 50% from organic fertilizer.

3. The maximum value of WUE was 0.307 kg seeds m⁻³ of irrigation water as recorded with the treatment on-line emitter \times IR₂ \times PM₃, while the minimum value was 0.1 kg seeds m⁻³ of irrigation water as recorded with the treatment built-in emitter \times IR₃ \times PM₁.

4. The maximum value of FUE in kg seeds kg⁻¹ organic fertilizer was 0.39 and the minimum ones 0.074 in the following interactions between on-line emitter \times IR₂ \times PM₁and built-in emitter \times IR₁ \times PM₃, respectively.

5. Emitter clogging increased with increasing organic fertilizer application, and decreasing the irrigation treatments. The maximum and minimum values of clogging percent are (28.3 and 9.83) under the condition of(built-in emitter \times IR₁ \times PM₃) and(on-line emitter \times IR₃ \times PM₁),respectively. According to clogging percent emitters, irrigation and fertilizers treatments used could be written in the following ascending orders on line emitter<built in emitter, IR₃< IR₂< IR₁ and PM₁<PM₂<PM₃, respectively.

REFERENCES

- Afolayan SO, Oengbe K, Lateef SA, Akintola OA, Oladele OJ (2014). Response of tomato (*Lycopersicon* ,*Lycopersiciun*,CVUC82B) to drip irrigation and planting conditions. African journal of Agriculture Research. 1543-1549.
- Ali Z, Basra SMA, Munir H, Mahmood A, Yousaf S (2011). Mitigation of drought stress in maize by natural and synthetic growth .Turk. J. Agric. For., 34(2010): 59-73.
- Ayeni LS, Adetunji (2010) Integrated application of poultry manure and mineral fertilizer on soil chemical properties, Nutrient Uptake, yield and growth components of maize, Nature and Science. 2010;8(1):60-67.
- Ayeni LS, Omole O, Adeleye EA, Ojeniyi SO (2010). Comparative effect of poultry manure and mineral fertilizer on yield and nutrient uptake of tomato in transitional Zone of Nigeria. Science and Nature. 2010;8(2):50-54.
- Cassel SF, Sharmasakar S, Miller SD, Vance GF, Zhang R (2001). Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugar beets. Agric Water Manage. 46: 241.
- Dudley LM, Ben-Gal A, Lazarovitch N (2008). Drainage water reuse: biological, physical, and technological considerations for system management, J. Environ. Qual., 37, 25–35, 2008
- Dupont M, Hurkman WJ, Vencel WH, Tanaka C, Kothori KM, Chungo K, Altenbach SB (2006). Protein accumulation and composition in wheat grains: Effect of mineral nutrients and high temperature. Europ. J. Agron., 29: 96-107.
- El-Berry AM, Bakeer GA, Al-Weshali AM (2003). Theeffect of water quality and aperture size on clogging of emitters. <http://afeld.montpellier.cemagref.fr/Mpl2003/AtelierTechno/Atelier>
- El-Shawadfy M (2008). Influence of different irrigation systems and treatments on productivity and fruit quality of some bean varieties. M. Sc. thesis, Fac. of agric., Ain Shams Univ.
- Farouq M, Wahid A, Kobayashi N, Fujita D, Basra SMA (2009). Plant drought stress, effects, mechanisms and management. Agron. Sustain. Dev., 29: 185-212.

- Gengoglan C, Altunbey H, Gengoglan S (2006). Response of green bean (*Phaseolus vulgaris* L.) to subsurface drip irrigation and partial rootzone – drying irrigation. *Agric Wat Manage.* 84: 274–280.
- Hebbar SS, Ramachandroppa BK, Nanjappa HV, Prabhakar M (2004). Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *European Journal of Agronomy.* **21(1)**: 117-127.
- Israelson OW, Hanson VE (1962). *Irrigation Principles and Practices*. 3rd ed. John Wiley and Sons, New York.
- Krogdahl A, Dahlsgard B (1981). Estimation of nitrogen digestibility in poultry. Content and distribution of major urinary nitrogen compounds in excreta. *Poultry Sci.*, 60: 2480-2485.
- Makinde EA, Ayeni LS, Ojienyi SO, Odedina JN (2010). Effect of organic, organomineral and NPK fertilizers on nutritional quality of *Armaranthus cruentus* in Lagos Nigeria. *Researcher.* 2010;2(2):91-96.
- Mohamed YT, Sabreen KP, Hani Abdel-Ghani M (2013). Effect of drip irrigation method, nitrogen source, and flushing schedule on emitter clogging. *Agricultural Sciences.* Vol.4, No.3, 131-137.
- Protein accumulation and composition in wheat grains: Effect of mineral nutrients and high temperature. *Europ. J. Agron.*, 29: 96-107.
- Rivero MR, Mikiko K, Amira G, Hitoshi S, Ron M, Shimon G, Eduardo B (2007). Delayed leaf senescence induces extreme drought tolerance in a flowering plant. *PNAS*, 104: 19631-19636.
- Shani U, Ben-Gal A, Tripler E, Dudley LM (2007). Plant response to the soil environment: an analytical model integrating yield, water, soil type, and salinity. *Water Resour. Res.*, 43, 2007.
- Snedcor GW, Cochran WG (1980). *Statistical Methods* 7th Ed. The Iowa State Univ. Press, Iowa, USA.
- Suganya S, Sivasamy R (2006). Moisture retention and cation exchange capacity of sandy soil as influenced by soil additives. *J Appl Sci Res.* 2: 949–951
- Tayel MY, El-Gindy AM, El-Bagoury KF, Sabreen Kh A (2009). Effect of injector types, irrigation and nitrogen treatments on emitters clogging. *Misr Journal of Agricultural Engineering*, **23**, 1263-1276.
- Wei Q, Lu G, Liu Jie, Shi Y, Dong W, Huang S (2008). Evaluations of emitter clogging in drip irrigation by two-phase flow simulations and laboratory experiments. *Computers and electronics in agriculture* 63 (2008) 294–303.
- Wilson SB, Stoffella PJ, Krumholz LA (2001). Containerized perennials make good use of compost. *Biocycle* 42 :59- 61.