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IMPACT OF SOME LOCALIZED IRRIGATION SYSTEMS ON LEMON FRUIT YIELD

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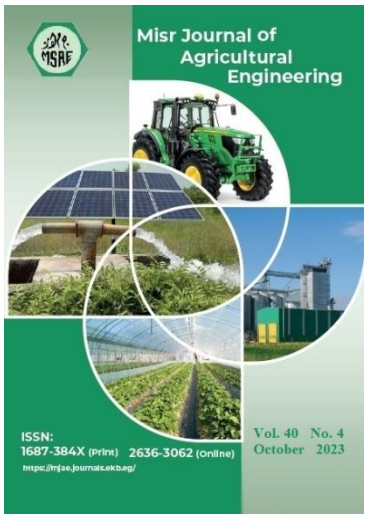


Keywords:
Limon; Micro sprinkler; Drip; Bubbler irrigation system.

ABSTRACT

The experimental field was located at Badr City, EL-Beheira Governorate, Egypt. At 30°40'49.8"N 30°33'27.3"E. It was conducted from October 2021 to March 2022. The experiment was designed using a micro sprinkler irrigation system 62 L/h, 1.25 mm. Drip irrigation system (In-line drip hoses 8 L/h, circle with flow rate 115 L/h) and pressure compensating full circle bubbler irrigation system, 110 L/h at (100 % - 80 %) water requirement. The area of experiment plots was (6×6) m², and each treatment was repeated three times. These treatments aimed to study some of the quality characteristics of Limon crop in El-Beheira Governorate using different pressurized irrigation systems used in the outlets and cultivated plants. Results indicated that at the end of the experiments flow rates for emitters (micro sprinkler, drip line, bubbler) was (42.74, 6.75 and 104.79) L/h, respectively. The values of the emission uniformity were (95.7, 93.98 and 97.53) %, respectively. The accumulative clogging ratios were ranged between (3.5, 0.8, and 0.42) %. respectively, and (33.38, 16.4, 6.92) %. respectively. The crop productivity was (10.556, 9.976, 10.208, 9.512, 11.368, 11.020, 8.352, 8.004) ton/fed/year for the variables used in the experiment ((micro sprinkler- 100% water requirement- 15cm, 30cm of the high riser), (micro sprinkler- 80% water requirement- 15cm, 30 cm of the high riser, (drip system- 100 % ,80 % water requirement), (bubbler- 100 %, 80 % water requirement)), respectively. Total structural cost/fed. were (28560, 25550, 25774) L.E. for micro sprinkler, drip and bubbler irrigation systems, respectively.

1. INTRODUCTION

Citrus fruits of all kinds are among the most important export crops in Egypt, as the production of citrus fruits in Egypt reached 4632.7 thousand tons, Egypt's production of Limon 338 thousand tons, Egypt's export of Limon 159 thousand tons for the year 2019 **(FAO 2021)**. The production of salty Limon in Egypt ranged at an average of 325 thousand tons annually, and the productivity of El-Buhaira Governorate ranged from 32.2 thousand tons annually, representing 9.9% of the republic's production. It amounted to about 24.9% of the total cultivated area in El-Buhaira Governorate for the year 2019 **(Hisham et al., 2021).**

Commercial indexes in the citrus industry are usually based on peel coloration, percentage of juice and soluble solids/acidity ratio but their relevance may differ among varieties and the specific requirements of the markets, Citrus fruit are an excellent source of many phytochemicals, including ascorbic acid, carotenoids (antioxidant and pro-vitamin A), which greatly contribute to the health-related benefits of these fruits **(Joanna Lado et al., 2018).**

Using drip irrigation system increases crop productivity, saves water, reduces food losses, increases the efficiency of using fertilizers, reduces stress on the plant, and increases the uniformity and quality of the crop **(Genius et al., 2014; Gebremeskel et al., 2018; Abou Zakhem et al., 2019)**. Despite all the advantages of drip irrigation about 60% of the total agricultural lands in Egypt use conventional irrigation, whose efficiency ranges from 40:50%. Therefore, the Egyptian government seeks to expand modern irrigation systems that will improve water efficiency from 40% to 80% **(Dhehibi et al., 2016; Jacques et al., 2018; Wahba et al., 2018).**

The micro-sprinkler irrigation system allows crop production with less water, reducing the cost of energy and the economic return was higher than the traditional irrigation systems **(Bortolini et al., 2016).**

Comparison of the traditional irrigation system and the bubbler irrigation system improved the vegetative and root growth parameters of the orange crop, and led to an increase in the fruit parameters (yield kg/tree, number of fruit/tree, fruits weight) in addition to a significant increase in chemical and physical properties of the significant change in the mineral content of the leaves. Bubbler irrigation system results in more effective roots. This increase was reflected in improved yield and quality of orange production **(Hussien, et al., 2013).**

2. MATERIALS AND METHODS

The experiment was conducted at a salty Limon farm in Badr City, El-Beheira Governorate, Egypt. Wind speed was 15 km/h and direction north-west, relative humidity was 75 % and temperature 35˚C. Laboratory experiments were carried out in the Irrigation laboratory, Agricultural Engineering Department, Faculty of Agriculture, Ain Shams University. The field experiment was conducted from October 2021 to March 2022. The total experiment area was 864 m² for all experimental treatments (micro sprinkler, 62 L/h – drip, 8 L/h – bubbler, 110 L/h) irrigation system, riser height (15 – 30) cm, water requirements (100% - 80 %) of requirements. This area was divided into twenty-four sub-main plots which it's area (6×6) m².

A. The materials

1. Soil analysis

The experimental soil was analyzed and Tables (1 and 2) represent some physical and chemical properties.

Table 1: Some physical properties of soil

Depth, cm	Texture	Bulk density, g/cm^2	Field capacity, %	Wilting point, %	Available water, %
0 - 20	Sandy	1.3	12.8	7.2	5.6
20 - 40		1.3	8.2	3.9	4.3
40 - 60		1.3	5.6	3.2	2.4

Table 2: Some chemical properties of soil

Depth, cm	EC, ds/m	TDS, ppm	pH	Cations, ppm				Anions, ppm			
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CL^{-}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$
0 - 20		211.2	8.1	1.6	0.8	0.6	0.3	2.0	0	1.0	0.3
20 - 40	0.3	198.4	8.3	1.4	0.8	0.6	0.3	1.8	0	1.0	0.3
40 - 60		230.4	8.2	1.6	1.0	0.7	0.3	2.0	0	1.4	0.2

2. Irrigation water analysis

The Nubaria canal water was used for irrigation. Table 3 points to some chemical properties of water.

Table 3: Some chemical properties for water

EC, ds/m	pH	Cations, ppm				Anions, ppm				Minor elements, ppm			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CL^{-}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Fe	Zn	Mn	Cu
0.4	7.8	0.8	2.2	1.6	0.2	2.4	0	2.0	0.4	nd	nd	nd	nd

3. Plant

Fig. 1 show Limon *(Citrus aurantifolia L.)* is a perennial tree with a lifespan of 50 to 100 years, The tree seldom grows more than 5 m (16 inches) high and if not pruned becomes shrublike. Its branches spread and are irregular, with short stiff twigs, small leaves, and many small sharp thorns. The evergreen leaves are pale green, and the small white flowers are usually borne in clusters. The fruit is usually about 3 to 4 cm (1 to 1.5 inch) in diameter, oval to nearly globular in shape, often with a small apical nipple, oval to nearly globular in shape, often with a small apical nipple, and the peel is thin and greenish yellow when the fruit is ripe. The pulp is tender, juicy, yellowish-green in color, and decidedly acidic. Most limes exceed Limon in both acid and sugar content. There are, however, some varieties so lacking in citric acid that they are known as sweet limes. These are grown to some extent in Egypt and certain tropical countries.

Fig. 1: Limon *(Citrus aurantifolia L.).*

4. Irrigation Network

- P.V.C Mainline Pipes outside diameter 110 mm – 6 bar, P.V.C sub-main pipe outside diameter 32 mm – 10 bar.
- Poly ethylene (P.E) hoses diameter 16mm, wall thickness 1.4mm.
- (P.E.) Drip line, outer diameter 16 mm, discharge 7.6 L/h, 1 bar.
- Pressure compensating full circle bubbler, Inlet 1/2" operating range flow rate: 110 L/h, Pressure: 100 kPa.
- Micro sprinkler, discharge 62 L/h and nozzle diameter 1.25 mm.
- Venturi injector ¾", motive flow through injector at 2.5 kg/cm² 1525 L/h and injection capacity 40 L/h.

B. The methods and calculations

The efficiency of any localized system depends on the characteristics of the emitters chosen. Measurements were recorded twice a month for six months of the irrigation system and were calculated once for plants and soil at the experiment (six months).

1. Measuring of discharge (Q)

Discharge was measured taken water collected in catch cans under different pressures (75 – 100 – 150 – 200) kPa for calibration.

2. Emission uniformity (EU)

To calculate emission uniformity (EU) the following formula was used (**Keller and Karmeli, 1974)**:

$$EU = 100.\ (q_{n} / q_{a}) \text{ ……..……...(1)}$$

Where:

EU = Emission uniformity, %,

q_n = Average low quarter of flow rate of the data emitter, L/h and

q_a = Average flow rate of all the data emitters, L/h.

3. Manufacturing coefficient (C.V)

The following formula was used to calculate the manufacturing coefficient (C.V) (**ASAE, 1998**):

$$CV = \frac{sd}{qa} \quad \text{……..... (2)}$$

Where:

C.V = Manufacturing coefficient,

Sd = Standard deviation, L/h and

qa = Average flow rate of all the data emitters, L/h.

$$Sd = \sqrt{\frac{q_1^2 + q_2^2 + q_3^2 + \text{.....} q_n^2 - n q_a^2}{n-1}} \quad \text{…….. (3)}$$

Where:

Sd = Standard deviation, L/h and

n = No. of emitters.

4. Clogging degree

The following formula was used to calculate a clogging ratio. (**Al-Amoud, 1997**).

$$(\frac{q_1 - q_2}{q_1}) \times 100 \quad \text{……..... (4)}$$

Where:

q1 and q2 = Average flow rate at start up and the operating, L/h respectively.

C. Experimental design

Plot area (6×6) m² for (micro sprinkler - drip – bubbler) system was selected for carrying out the experiments. Table 4 explains experimental design plots.

1- Experiments variables

a. Irrigation systems (micro sprinkler, drip, bubbler irrigation).

b. Water requirements (100 % -80 %) of water requirements.

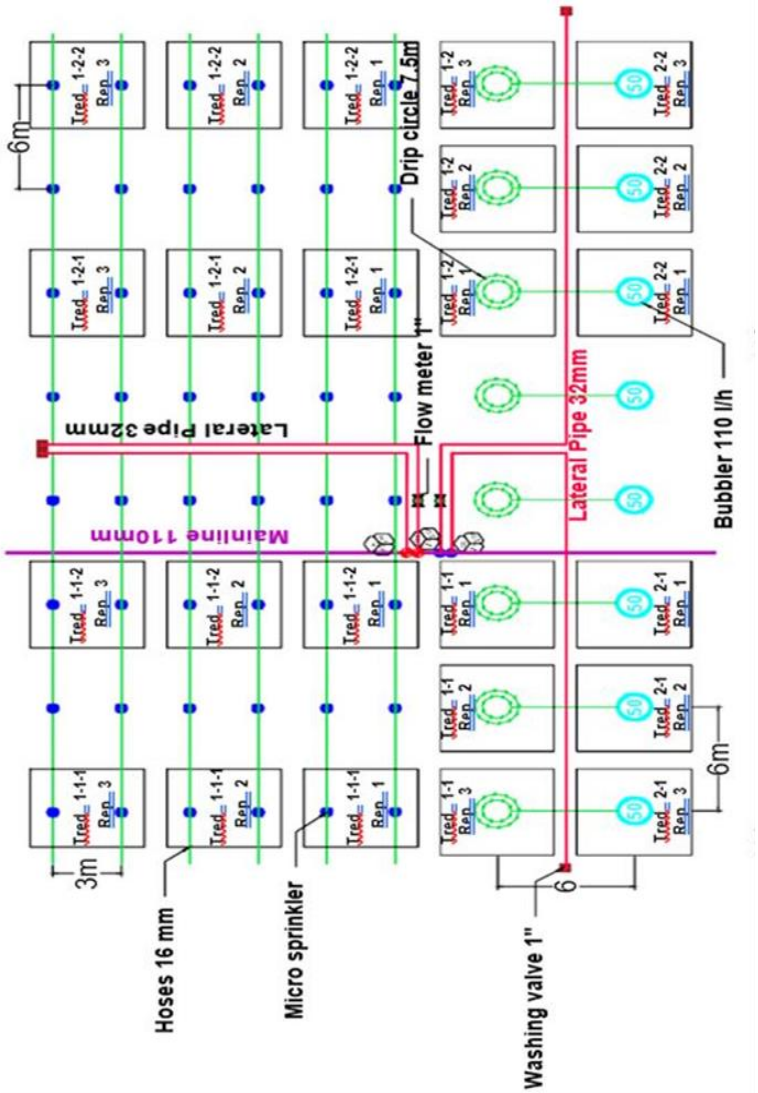
c. Height of riser for sprinkler network (15cm – 30cm).

Table 4: Specification for experimental design plots

Plot No.	Type of Network, Water requirements
1,1,1 Rep1,2,3	micro sprinkler, water requirements 100%, high 15cm.
1,1,2 Rep1,2,3	micro sprinkler, water requirements 100%, high 30cm.
1.2.1 Rep1,2,3	micro sprinkler, water requirements 800%, high 15cm.
1,2,2 Rep1,2,3	micro sprinkler, water requirements 80%, high 30cm.
2,1 Rep1,2,3	drip network, water requirements 100%
2.2 Rep1,2,3	drip network, water requirements 80%
3,1 Rep1,2,3	bubbler network, water requirements 100%
3.2 Rep1,2,3	bubbler network, water requirements 80%

2- Experimental treatments

Water was transmitted to the system through the Mainline of PVC pipes outside diameter of 110 mm to the sub-main of PVC pipes outside diameter of 32 mm to the emitters (micro sprinklers, drip lines, bubblers), Irrigation system area 864 m² was divided into twenty-four sub-main plots which it's area (6×6) m² for (micro sprinkler- drip line – bubbler) irrigation system was selected for carrying out the experiments, each treatment was repeated three times as shown in Fig. 2.



(1,1,1 Rep1,2,3) , (1,1,2 Rep1,2,3), …… etc. refer to Table 4.

Fig. 2: The prototype of design for an experiment

3. RESULTS AND DISCUSSION

1. Calibration emitters

The relationship between pressure (kPa) and flow rate (L/h) at (25-26°C) as shown in Figure (3) it's showed an increase in flow rate by increasing pressure, where at 100 kPa the values of flow rate for emitters (micro sprinkler, drippers, bubblers) were (54.04, 7.66, 109.81) L/h, respectively. And when pressure increased to 200 kPa, the flow rate increased to (67.38, 11.46, 117.82) L/h, respectively.

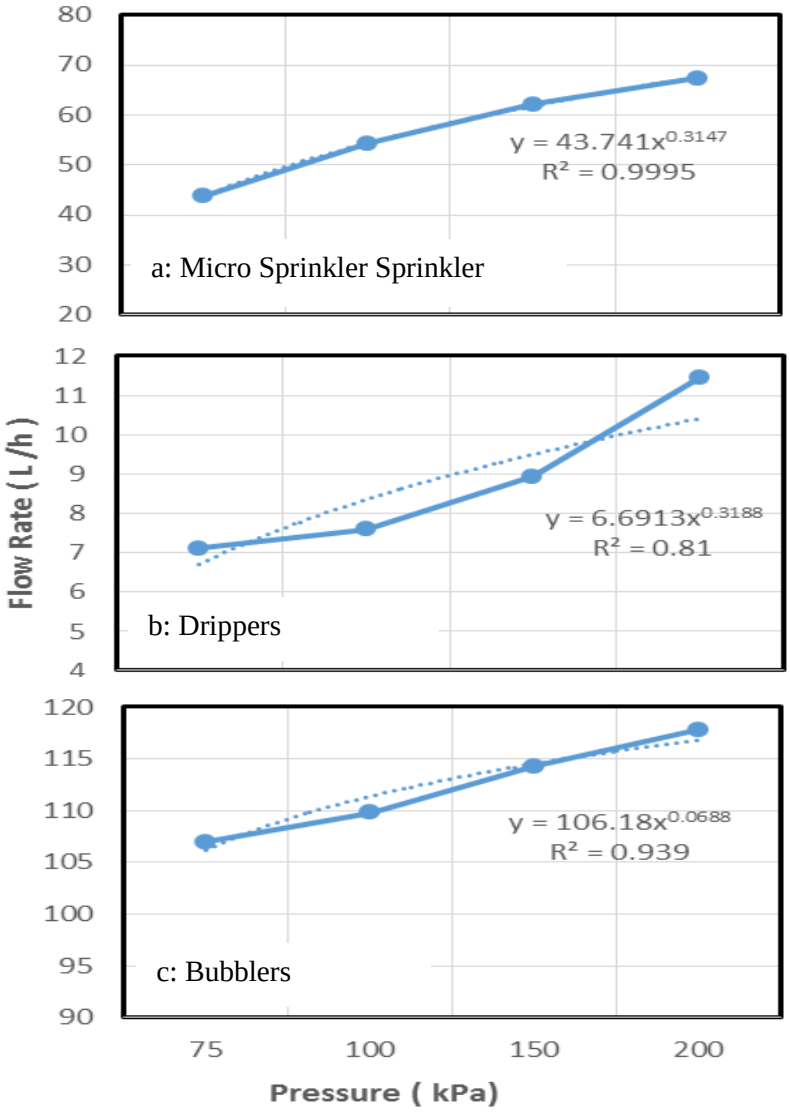


Fig. 3: Relationship between pressure and flow rate

2. Manufacturing coefficient (C.V)

Fig. 4 describes the manufacturing coefficient (C.V) which ranged between (0.014 - 0.047) for micro sprinkler, (0.028 - 0.077) for drippers and (0.015 – 0.04) for bubblers. The disparity in the value of (C.V) for self-emitters due to materials which are used in manufacturing.

For the limits of manufacturing coefficient, the result showed that the best limits for the operation of the micro sprinkler was 150 kPa, and of the dripline and bubbler was 100 kPa, which was less than 0.05.

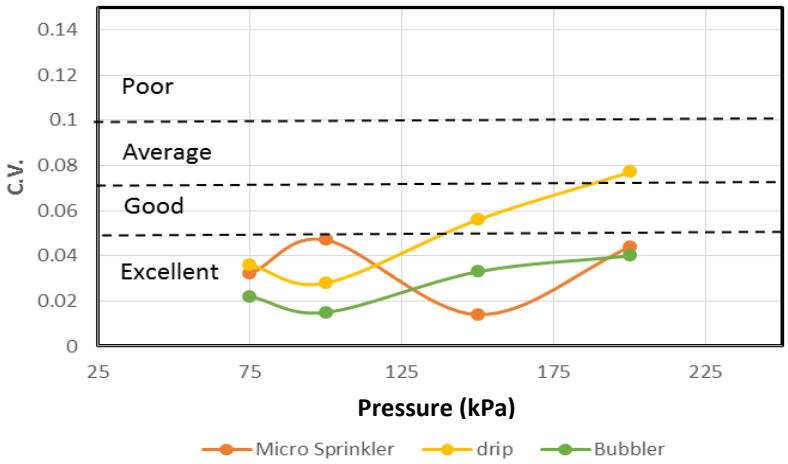


Fig. 4: Manufacturing coefficient (C.V) for all emitters

3. Performance of discharge rate

Fig. 5 it's showed a decrease in flow rate by time, where after a week the operation flow rate for micro sprinklers, drippers and bubblers was (62.2, 7.66, 109.81) L/h, respectively. After twenty-four weeks of operating, the flow rate for micro sprinkler, drippers and bubblers was (42.74, 6.75, 104.79) L/h, respectively. Thus, the reduction in flow rate for micro sprinkler, drippers and bubblers was (31.29, 12 and 4.84) %, respectively.

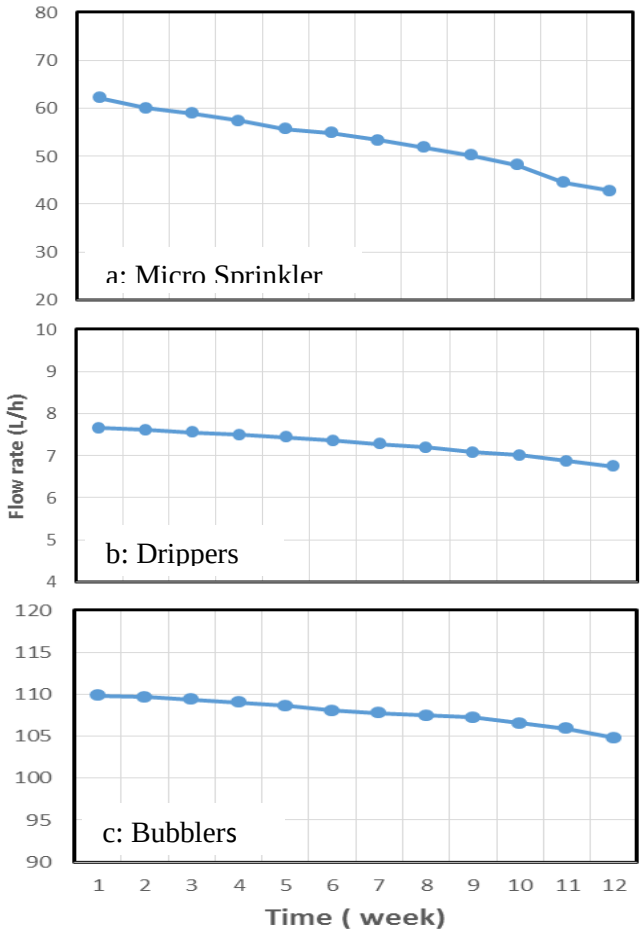


Fig. 5: Relationship between flow rate and time

4. Emission uniformity (EU).

Fig. 6 described emission uniformity (EU). After a week the operation flow rate for micro sprinkler, drippers and bubblers was (98.71, 98.97, 99.7) %. respectively. After twelve weeks of operating for micro sprinkler, drippers and bubblers was (95.7, 93.98, 97.53) %. respectively. This difference in emission uniformity (EU) is due to total suspended solids.

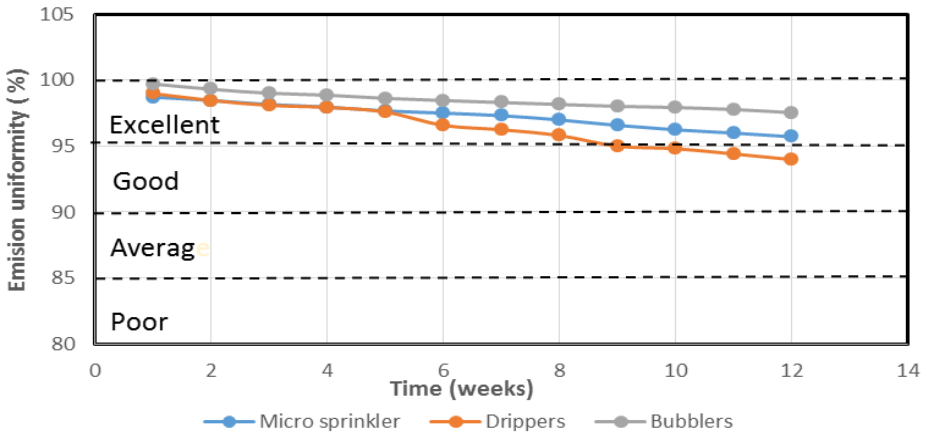


Fig. 6: Emission uniformity

5. Clogging ratio.

Discharge was measured once every two weeks for 6 months for micro sprinklers, drippers and bubblers. Fig. 7 described the accumulative clogging ratio which ranged (3.5, 0.8 and 0.42) %. respectively, and (33.38, 16.4 and 6.92) %. respectively. Hence, the accumulative clogging ratio of micro sprinklers and drippers the season was higher than bubblers.

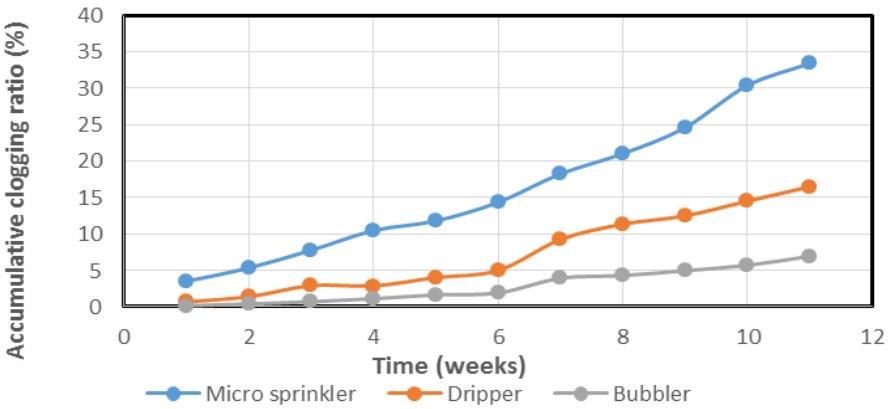


Fig. 7: Accumulative clogging ratio

6. Plant

At the end of the season, the crop productivity has measured the result was as shown in Fig. 8, (10.556, 9.976, 10.208, 9.512, 11.368, 11.020, 8.352, 8.004) ton/fed/year for the variables used in the experiment ((micro sprinkler- 100 % water requirement- 15 cm, 30 cm of the high riser), (micro sprinkler- 80 % water requirement- 15 cm, 30 cm of the high riser), (drip system- 100 %, 80 % water requirement), (bubbler- 100 %, 80 % water requirement)), respectively. Average productivity per tree is (91, 86, 88, 82, 98, 95, 72, 96) kg/Tree/Year, However, the highest productivity system was drip irrigation system with 100% water requirements and the less productivity was bubbler with 80% water requirement.

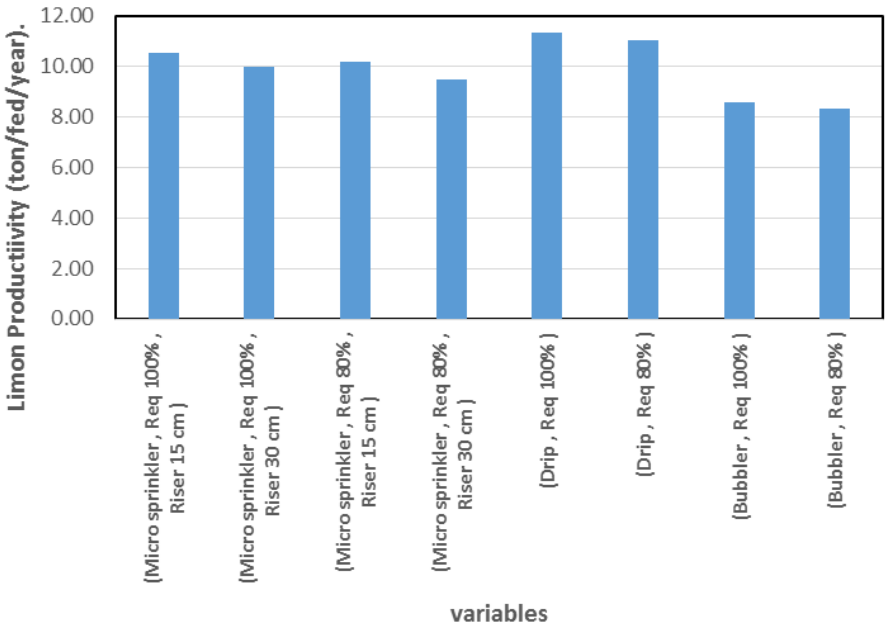


Fig. 8: Productivity of Limon

Fig. 9 describe the average weight of ten Limon fruits which was (267.67, 259.17, 241.5, 223.83, 335.83, 286, 223.67, 148) (g/10 fruits) , Fig. 10 describe the volume of ten Limon fruits was measured by Archimedes law and it was (227.33, 198.33, 218.67, 199.50, 342.50, 287.50, 150.83, 143.33) (mL/10 fruits) and the juice volume of ten Limon fruits was (120, 104.17, 132.5, 120, 216.67, 176.67, 65, 64) (mL/10 fruits) for the variables used in the experiment ((micro sprinkler – 100% water requirement -15 cm, 30 cm of the high riser, (micro sprinkler – 80% water requirement -15 cm, 30 cm of the high riser, (drip system – 100 % , 80 % water requirement (bubbler – 100 % , 80 % water requirement), respectively.

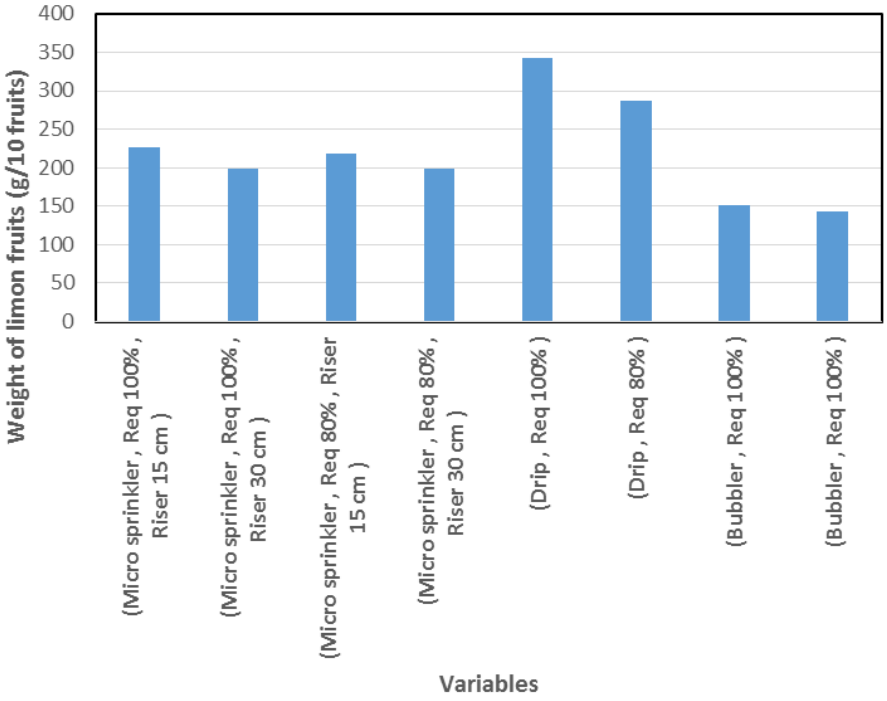


Fig. 9: weight of ten Limon fruits

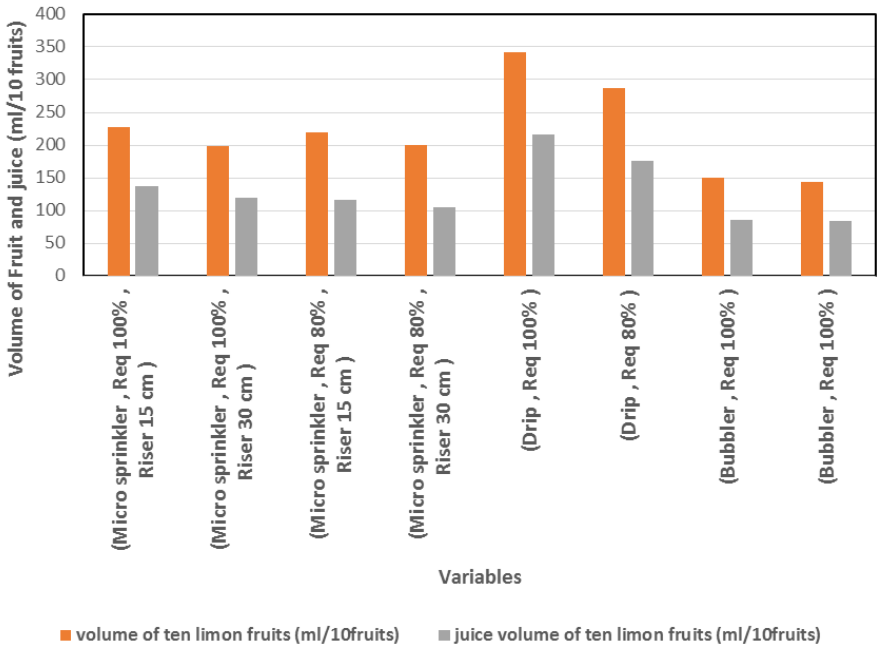


Fig. 10: Volume of Limon fruits and juice

7. Cost study

By comparing the cost of constructing an irrigation network for a sector of five fed. for each of the drip, bubbler and micro sprinkler irrigation systems, the calculation of the total construction cost for the average per fed. was as shown in Table 5, which was 28560 L.E. for micro sprinkler irrigation system, 25550 L.E. for the drip irrigation system and 25774 L.E. for the bubbler irrigation system.

4. CONCLUSION

Results indicated that:

- The operation of the emitters (in-line dripper 8 L/h, bubbler 110 L/h) were at 100 kPa and for micro sprinkler 62 L/h was 150 kPa.
- At the end of the experiment flow rate for emitters (micro sprinkler, in-line drippers, bubbler) was (42.74, 6.75 and 104.79) L/h, respectively.
- Emission uniformity was (95.7, 93.98 and 97.53) %, respectively.
- Accumulative clogging ratio (33.38, 16.4, 6.92) %. respectively.
- The crop productivity was (10.556, 9.976, 10.208, 9.512, 11.368, 11.020, 8.352, 8.004) ton/fed/year for the variables used in the experiment ((micro sprinkler- 100 % water requirement- 15 cm, 30 cm of the high riser), (micro sprinkler- 80 % water requirement- 15 cm, 30 cm of the high riser), (drip system- 100 %, 80 % water requirement), (bubbler- 100 %, 80 % water requirement)) respectively.
- The average weight of ten Limon fruits was (267.67, 259.17, 241.5, 223.83, 335.83, 286, 223.67, 148) (g/10 fruits) , the volume of ten Limon fruits was (227.33, 198.33, 218.67, 199.50, 342.50, 287.50, 150.83, 143.33) cm^3/10 fruits, and the juice volume of ten Limon fruits was (120, 104.17, 132.5, 120, 216.67, 176.67, 65, 64) mL/10 fruits for the variables used in the experiment.
- Total structural cost per fed. was 28560 L.E. for micro sprinkler irrigation system, 25550 L.E. for the drip irrigation system and 25774 L.E. for the bubbler irrigation system.

Recommendation:

From previous results drip irrigation system was better than micro sprinkler and bubbler irrigation systems. However the highest productivity system was drip irrigation system with 100 % water requirements.

Table 5: Cost study for micro sprinkler, drip and bubbler irrigation system, L.E. / 5 fed. (These prices are for the year 2023)

Type	Quantity	Price ,L.E.	Total	Quantity	Price ,L.E.	Total	Quantity	Price ,L.E.	Total
	Micro sprinkler system			Drip Irrigation system			Bubbler System		
1-U.P.V.C Pipe									
110 mm - 600 kPa,m	192.0	90.2	17318.0	192.0	90.2	17318.0	192.0	90.2	17318.0
90 mm - 600 kPa,m	6.0	62.1	372.9.0	6.0	62.1	372.9	6.0	62.1	372.9
63 mm - 600 kPa,m	78.0	31.0	2418.0	132.0	31.0	4092.0	132.0	31.0	4092.0
50 mm - 600 kPa,m	156.0	23.2	3627.0	78.0	23.2	1813.5	78.0	23.2	1813.5
32 mm - 1000 kPa,m	78.0	14.5	1132.6	1740.0	14.5	25265.0	1740.0	14.5	25265.0
U.P.V.C Fitting (15% from P.V.C. total).		3730.3			7329.2			7329.2	
2-Valves									
Butterfly valve 4"	1.0	3940.0	3940.0	1.0	3940.0	3940.0	1.0	3940.0	3940.0
Single union ball valve 2"	6.0	600.0	3600.0	6.0	600.0	3600.0	6.0	600.0	3600.0
Washing valve 2" for mainline Pipes.	1.0	255.0	255.0	1.0	255.0	255.0	1.0	255.0	255.0
Washing valve 1" for Lateral Pipes.	6.0	67.0	402.0	6.0	67.0	402.0	6.0	67.0	402.0
Flow meter 2"	6.0	3295.0	19770.0	6.0	3295.0	19770.0	6.0	3295.0	19770.0
Brass pressure gauge 400 kPa.	2.0	275.0	550.0	2.0	275.0	550.0	2.0	275.0.0	550.0
Disc filter 2" with two female adaptor.	6.0	820.0	4920.0	6.0	820.0	4920.0	6.0	820.0	4920.0
A fertilization unit that includes the Venturi injector 1".	1.0	4623.0	4623.0	1.0	4623.0	4623.0	1.0	4623.0	4623.0
3- Emitters									
Micro sprinkler HT - 206PC, with 4×7mm PE tube , spike and connector.	1152.0	43.5	50112.0	-	-	-	-	-	-
GR Hoses 16mm-50cm-8 l/h,m	-	-	-	4400.0	5.0	22000.0	-	-	-
Pressure compensating Bubbler 110 l/h	-	-	-	-	-	-	576.0	45.0	25920.0
Soled Hoses 16,mm	6800.0	3.7	25500.0	2000.0	3.7	7500.0	2000.0	3.7	7500.0
P.E. fitting		530.0			4000.0			1200.0	
Total		**142801.0**			**127751.0**			**128871.0**	

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تأثير بعض أنظمة الري الموضعية على إنتاجية محصول الليمون

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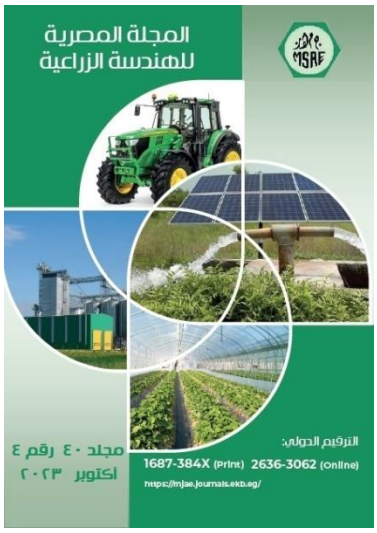

الكلمات المفتاحية:
الليمون؛ الرشاشات الصغيرة؛ نظام الري بالبابلر.

الملخص العربي

يتراوح انتاج الليمون فى محافظة البحيرة ٣٢,٢ الف طن سنويا تمثل ٩,٩% من انتاج مصر لليمون، في هذة الدراسة تم قياس بعض صفات جودة محصول الليمون تحت نظم الرى الضغطى (الرشاشات الصغيرة ، التنقيط ، البابلر)، بتصرف (٦٢ ، ٨ ، ١١٠) لتر/ساعة علي التوالي. نوع التربة رملية ومصدر المياه ترعة النوبارية، وكانت النتائج كالتالي:

بعد ٦ شهور من التشغيل كانت التصرفات (٤٢,٧٤، ٦,٧٥، ١٠٤,٧٩) لتر/ساعة، والانتظامية كانت (٩٥,٧، ٩٣,٩٨، ٩٧,٥٣) لكلا من الرشاشات الصغيرة، النقاطات، البابلر على التوالى.

كانت حدود النسبة المؤية للانسداد التراكمي (الرشاشات الصغيرة، النقاطات، البابلر) [(من ٣,٥ إلى ٣٣,٣٨)، (من ٠,٨ إلى ١٦,٤) ، (من ٠,٤٢ إلى ٦,٩٢)]% على التوالى.

فى نهاية التجربة كانت الانتاجية (١٠,٥٥٦، ٩,٩٧٦، ١٠,٢٠٨، ٩,٥١٢، ١١,٣٦٨، ١١,٠٢٠، ٨,٣٥٢، ٨,٠٠٤) طن /فدان/سنة ،و متوسط حجم العشر ثمرات (٢٦٧,٦٧، ٢٥٩,١٧، ٢٤١,٥، ٢٢٣,٨٣، ٣٣٥,٨٣، ٢٨٦، ٢٢٣,٦٧، ١٤٨) جم/١٠ثمرات ، ومتوسط حجم العصير للعشر ثمرات (١٢٠، ١٠٤,١٧، ١٣٢,٥، ١٢٠، ٢١٦,٦٧، ١٧٦,٦٧، ٦٥، ٦٤) مللى لتر/١٠ثمرات، لمتغيرات التجربة ((الرشاشت الصغيرة، احتياجات مائية ١٠٠%، ارتفاع القائم 15سم , ٣٠ سم)، (الرشاشات الصغيرة، احتياجات مائية ٨٠%، ارتفاع القائم 15سم ، ٣٠ سم)، (التنقيط ، احتياجات مائية ١٠٠% و ٨٠%)، (البابلر، احتياجات مائية ١٠٠% و ٨٠%))، على التوالى، حيث كانت افضل انتاجية عند (التنقيط ، احتياجات مائية ١٠٠%) واقل انتاجية عند (البابلر ، احتياجات مائية ٨٠%).

التكلفة الانشائية كانت (٢٨٥٦٠، ٢٥٥٥٠ و ٢٥٧٧) جنيها مصريا لشبكة الرى بالرشاشات الصغيرة ، التنقيط، و البابلر علي التوالي.