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FERTIGATION UNDER MODERN IRRIGATION SYSTEM

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Abstract

Four irrigation systems, (surface drip, subsurface drip, sprinkler, and leaky pipe) and two methods of fertilizers application (fertigation and broadcasting) were selected in order to determine the proper irrigation and fertilization systems for irrigating vegetable crop in new reclaimed land. Crop growth, water use efficiency, and N use efficiency were considered for systems comparisons. Pea was cultivated as an indicator plant.

Applying N fertilizer through the selected irrigation systems (surface and subsurface drip, sprinkler and leaky pipe) was more efficient than fertilizer broadcasting. Highly significant increase in stem length, branches and pods number per plant, crop yield, and both water and N use efficiency were obtained by fertigated Pea plants.

There was a slight increase (statistically not significant) in stem length, branches number per plant, crop yield and both water and N use efficiency under surface drip more than in both sub-surface drip, sprinklers and leaky pipe.

INTRODUCTION

Irrigation can play a role in producing food for the expanding population of Egypt. Enhancement of crop productivity is inseparable from resource base (land, water, energy). The goal of agriculture should be to increase and maintain crop yield at high levels per unit area and at high return per unit of water, while maintaining a high quality environment. Control the soil water content in the root zone provides both adequate water and nutrients as an aim of total water management. A continuous improvement in irrigation technology and efficient use of irrigation water and fertilizers are essential to keep food supply in balance with the increasing demand on environmentally sound grounds (Papadopoulos, 1993). In Egypt fertigation is being practiced on field trials and green house crops with both sprinkler and drip irrigation (El-Gindy, 1984).

As indicated in the literature, substantial progress has been made in understanding the relationship between water application in irrigation and crop response. Surface irrigation is suitable for applying agrochemical to the soil. However, trickle/micro irrigation has been successuflly used for applying plant nutrients and other chemicals since 1950. The cost of chemigation is generally less than when applying chemicals through conventional irrigation methods. Farmers can save up to 35% on their chemicals bills if appropriately used (Nimah, 1995). El-Gindy, (1988) reported that the yield of tomato under drip irrigation increased by 33% and 35% over the furrows and sprinkler irrigation systems and by 54.5% and 154.4% over furrows and sprinkler irrigation of cucumber. In Egypt, fertigation is introduced in newly reclaimed sandy soils, it is reported that water and fertilizer efficiency use have increased' and yields of 200 ton/ha of cucumber have been achieved compared to 50 ton/ha with traditional techniques. Under sandy conditions, fertigation is an appropriate technique for effecient use of water and fertilizers. Accordingly, fertigation prospects in Egypt are very promising (Papadopoulos,1989). El-Berry, (1989) found that the water use efficiency was the highest in case of subsurface drip system (5.93 kg/mm) which was approximately twice and seven times that of sprinkler and basin systems, respectively, in case of Alfa-Alfa production under desert conditions. Bacon and Davey (1982) explained that under micro irrigation, depending on the rate of application, the concentration of ammonium ions in the vicinity of the emitter can be very high. Hamdy, (1991) reported that fertigation at each irrigation resulted in a notable increase in tomato production which is nearly 70% greater than that obtained with conventional methods of N applications. With further irrigation, ammonium ion will move into the root zone where it will be converted to nitrate by soil organisms and will move as do applied nitrates, and Steduto (1983) reported that as compared to the traditional fertilization, yield increased by about 30% with twice or four times fertigation and that yield increased by 70% when fertigation was evenly applied during the whole irrigation season. Abdel-Maksoud *et al* (1992) studied three different irrigation systems namely, drip, sprinkler, and furrow irrigation under tomato field in new lands. The results showed that, the yield obtained under drip irrigation (20.000 kg/fed) increased by 19.36% than the yield obtained under sprinkler (16, 800 kg/fed) and by 13.60% than the yield obtained under furrow (17, 600 kg/fed) while value of water use efficiency under drip where 14.6 kg/m^3 of water increasing by 14.34% and 14.14% than the sprinkler and furrow systems respectively.

Several investigations were carried out during the last few years to compare conventional methods of chemical application and chemigation and reported that N fertigation received the greatest attention and has probably the largest application, (Abo-Khaled, 1991). Nitrate nitrogen (N) is a very mobil nutrient which is used extensively in crop production. Concentrations of N at levels in excess of accepted levels for human health are found at an increasing frequency in surface water and ground water resources. Hubbard *et al.* (1984) suggested that when N was applied to the root zone of growing corn with a center pivot irrigation system, it did not leach from the root zone during the growth season. They suggested that N be managed during the growing season by adjusting the N rates to the yield goal so that no N would remain in the soil at the end of the growing season. Smajstrla (1994) stated that the long-term hydraulic performance of linesource pipe micro irrigation laterals installed in turf grass plots in Florida, USA, were studied.

MATERIALS AND METHODS

The field experiments were conducted in sandy soil through chemigation project at Bustan area for two growing seasons 1995 and 1996. Soil mechanical and chemical analysis are presented in table 1 and table 2 and irrigation water analysis is presented in Table 3.

Table 1. Soil mechanical analysis.

Soil depth	Soil mechanical analysis %					
	Coarse sand	Fine sand	Silt	Clay	F.C	W.P
0-25	53.9	40.36	4.25	1.74	9.47	4.29

Table 2. Soil chemical analysis.

Soil depth	Chemical analysis						
	Coarse sand				Soluble anions (mg/L)		
	Q^{2+}	Mg^{2+}	N^{+}	K^{+}	HCO_3^-	SO_4^{2-}	CL^-
0-20	3.01	2.82	4.72	0.74	4.104	0.642	6.77
20-40	2.91	2.73	5.42	0.57	3.10	3.42	5.60

Table 3. Irrigation water analysis.

Cations dm/cm						Anions dm/cm			
EC	PH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CL^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-
0.56	7.84	1.04	0.75	8.02	0.43	3.75	4.54	-	1.96

The soil of Bustan experimental site is a coarse sandy texture with deep soil profile and very low field capacity. The available water for plant is extremely low.

Irrigation systems

Four irrigation systems were tested in this study namely: surface drip, sub-surface drip, sprinkler and leaky pipe.

Surface and sub-surface irrigation :

Surface and sub-surface systems (20-cm - deep were installed). The area of each system was of 270 square meter (3 m x 90 m). There are four laterals with 0.75 m spacing. Lateral length and spacing, distance, and emitters spacing, emitters discharge, water application rate, irrigation intervals and fertilization were kept in simulation.

Components of drip irrigation system :

1. Control head:

The control head is located at source of the water supply. It consists of centrifugal pump, back flow prevention device, pressure regulator, pressure gauges, flow meter, sand media filter, and screen filter.

2. Main and sub-main lines :

110 mm diameter p.v.c pipe is used for the main and 63 mm p.v.c for sub-main.

3. Manifold:

32 mm p.v.c pipes were used to supply water to the constructed laterals on one side.

4. Laterals :

Three types of drip lines namely: GR, Bi wall and leaky pipe were used. GR was of 16 mm P.E tube, built in drip line with flow rate of 4 Lph/0.5 m. Bi-wall was of 16 mm P.E tube, built in drip line with flow rate of Lph/0.5 m. Leaky pipe porous, flexible rubber hose 11 mm diameter with flow rate of 4 Lph/1 m and 10 cm deep.

Components of sprinklers irrigation system :

1. Control head:

The control head is located at source of the water supply. It consists of centrifugal pump, back flow prevention device, pressure regulator, pressure gauge, flowmeter, sand media filter, and screen filter.

2- 331 m length with 110 mm in diameter main line.

3- 90 m length with 63 mm in diameter sprinkler line.

4- The sprinkler lines were connected with the main pipe through a valve (2 inch in diameter).

5- The sprinkler line riser was 95 cm high (70 cm burried under ground and 25 cm above soil surface).

6- The sprinklers spacing on lateral was 15 m

7- Laterals spacing was of 18 m.

8- Two nozzles sprinkler (Regan) of 1 inch (6.5/4.2 mm) was used with discharge rate of $4m^3$/hr.

Experimental layout under drip irrigation :

The experimental area of (0.75 feddan) was divided into two sections (fertigation and broadcasting). Each includes six experimental plots (15.75 m X 14.5 m) per each. Each plot included contains 21 laterals of 14.5 m length with 0.75 m spacing, and the space between laterals was 75m. Three kinds of laterals namely pipe, GR, 4 surface Bi-wall and 4 subsurface Bi-wall.

Pea seeds were planted in November 7th, 1995. Date of harvest was April 20th, 1996. The same experiment was repeated in growing season of 1996 using same pea variety, irrigation systems and schedule and at the same time of the year. Data stated in Tables 4,5 and 6 are the average of the two growing seasons.

Methods of fertilizers application were evaluated using the following :

1. Some growth parameters that include, stem length, number of both branches, and pods per plant were measured. Five random plants from each experimental plot were selected for the above mentioned measurements.
2. Crop water use efficiency expressed as Kg of the crop yield produced by each cubic meter of irrigation water.
3. Crop fertilizer use efficiency expressed as Kg of the crop yield produced by each unit of fertilizer used.
4. Optioned yield as total seed yield Kg/fed.

Data of growth parameters and optioned yield were collected under surface drip (GR drip lines), sub-surface drip (GR drip line), surface Bi-wall, subsurface Bi-wall, buried leaky pipe and sprinkler.

Experimental area was divided into three equal plots as follows :

- Fertigation treatment: treatment 1 was for fertigation, treatments 2 and 3 were for broadcasting treatments. Each plot includes six experimental plots (15 m X 18 m).
- Fertilizers: Fertilizers quantities were supplied in two stages;

1. Before planting 100 kg ammonia sulfate, 150kg superphosphate, and 50 kg potassium sulfate/fed were broadcasted and mixed with soil.
2. After a period of 34 days from seeding quantity of 250 kg/fed, of ammonia sulfate divided into 3 doses were broadcasted under the drippers on Decmber, January, and February. The same quantity divided into 20 doses (10 times for each month of fertigation from December to February), were introduced to the plants through irrigation water. The total amount applied of N fertilizer was 70 unit/fed.

RESULTS AND DISCUSSION

Effect of irrigation system on crop growth, yield, water use efficiency, and N use efficiency :

1. Growth parameters :

The effect of irrigation system (surface, sub-surface drip, sprinkler, and leaky pipe) on growth, parameters yield, and its attributes is presented in Table 4. The obtained data show that no significant difference in stem length, and pods number/plant under the four irrigation systems. On the other hand there were significant differencecs in branches number.

Table 4. Effect of irrigation system on growth, yield, water use efficiency and its attributes of pea.

Irrigation system	Stem length, cm	Branches number/ plant	Pods number/ plant	Total yield, kg/fed	Water applied, m^3/fed Broad.	Water applied, m^3/fed Fert.	Water use effi., m^3/kg
Surface drip (GR)	70.23	3.133	77.00	1162.4	883.5	873.2	1.33
Sub-surface drip (GR)	73.63	3.100	71.40	1037.62	979.2	898.5	1.15
Sprinkler	76.037	3.480	54.629	1010.20	1088.0	1086.0	0.93
Leaky pipe	78.041	3.650	52.062	998.28	1121.6	1120.0	0.89

2. Crop yield:

Table 4 shows that, the crop yield under surface drip system reaches 1162.40 kg/fed compared to 1010.20, 1037.62 and 998.28 kg/fed under sprinkler, subsurface drip and leaky pipe respectively. In other words, the surface drip recorded crop yield increases of 11%, 13%, 14% compared to the above mentioned treatments respectively.

3. Water use efficiency:

Values of water use efficiency by plants were 1.33, 1.15, 0.93, and 0.89 kg/ m^3 under surface trickle, subsurface trickle, sprinkler system and leaky pipe.

4. N use efficiency:

Values of N use efficiency by peas plants under the four irrigation system were 17.2, 16.00, 14.2 and 12.1 kg/unit of N for the surface trickle, subsurface trickle, sprinkler and leaky pipe respectively.

From the previous results, it is clear that both surface and subsurface drip irrigation systems produced the higher vegetative growth, yield, water and N use efficiencies compared to sprinkler irrigation and leaky pipe system. This may be due to high amount of irrigation water in the root zone, more water penetration, less evaporation and less salinity.

Effect of methods of fertilizer application on crop growth, yield, water use efficiency, and N use efficiency :

1. Growth parameters :

The effect of different methods of fertilizer application on growth parameters and yield, under surface and subsurface drip irrigation was tabulated in Table 5. Table 5 shows that the stem length of plants fertigated under surface (GR) drip system (70.23 cm) was longer than that obtained under the broadcasting, (58.2 cm) by 20.60% and the stem length of plant fertigated under surface Bi-wall irrigation (66.9 cm) was longer than that obtained under the broadcasting (62.60 cm) by 6.8%. Under leaky pipe system the stem length of plants fertigated (69.4 cm) was longer than that obtained under the broadcasting (64.70 cm) by (7.20%). The stem length of plants fertigated under subsurface (GR) drip irrigation (73.6 cm) was higher than that under broadcasting (63.32 cm) by (16.3%). The stem length of plants fertigated under subsurface Bi-wall irrigation (65.4 cm) was higher than the obtained under the broadcasting (61.5 cm) by (6.3%). Regarding to number of branches/plant, no significant increase was recorded under fertigation comparing to broadcasting in respect to surface and subsurface drip systems.

Pods number/plant was also higher under fertigation with surface (GR) drip than under broadcasting by (24.80%). This increase was statistically significant and higher under fertigation with surface Bi-wall irrigation than that under broadcasting by (31.882%) and higher under fertigation with leaky pipe irrigation than that under broadcasting by (4.91 %). Moreover pods number/plant where fertigated through sub-surface (GR) drip and subsurface Bi-wall were higher than that under the broadcasting. This increase was statistically highly significant.

Table 5. Effect of the fertlizer application methods on growth parameters, yield, and water use efficiency under surface drip (GR), sub-surface (GR), surface Bi-wall, sub-surface Bi-wall and leaky pipe irrigation system.

Irrigation system	Methods of fertilizer application	Stem length, (cm)	Branches number/ plant	Pods number/ plant	Total yield, Kg/fed	Water use effic., Kg/m^3	N.use effic., Kg/unit
Surface drip (GR)	Fertigation	70.23	4.260	77.00	1135.22	1.3	16.22
	Broadcast	58.22	4.302	61.72	839.346	0.95	12.00
Sub-surface drip (GR)	Fertigation	73.63	4.01	71.4	1069.23	1.19	15.27
	Broadcast	63.22	3.976	54.11	783.343	0.8	11.91
Surface Bi-wall	Fertigation	66.888	3.88	57.58	920.34	1.05	13.15
	Broadcast	62.61	3.414	43.66	780.224	0.88	11.15
Sub-surface Bi-wall	Fertigation	65.388	3.911	64.38	997.46	1.11	14.25
	Broadcast	61.55	4.000	49.66	787.65	0.8	11.25
Leaky pipe	Fertigation	69.366	3.233	52.10	820.42	0.73	11.72
	Broadcast	64.72	3.880	49.66	710.302	0.63	10.15

2. Crop yield :

The obtained results emphasized that crop yield of peas plants fertigated under surface (GR) drip irrigation reached up to 1135.20 kg/fed, compared with 839.30 kg/fed under the broadcasting, recording an increase of 35.25%. Under the subsurface (GR) system, the obtained yield was (1069.30 kg/fed) and (783.34 kg/fed) under fertigation and broadcasting, respectively. The crop yield increased by 36.5%.

However, when using the surface Bi-wall system, the obtained yield was (920.30 kg/fed) and (780.224 kg/fed) under fertigation and broadcasting, respectively. The yield increased by 17.95%. Yield of peas plants fertigated under subsurface Bi-wall reached 997.497 kg/fed, compared with 787.65 kg /fed under the broadcasting, with an increase of 26.60%. With leaky pipe system, the obtained yield was (820.40 kg/fed) and (710.3 kg/fed) under fertigation and broadcasting respectively, with 15.5% increase of crop yield.

3. Water use efficiency:

Water use efficiency was the highest (1.30 kg/m^3) when fertigating the plant through surface drip (GR). The lowest water use efficiency was recorded under fertilizer broadcosting 0.95 kg/m^3.

4. N use efficiency:

Data shown in Table 5 shows that the value of N use efficiency under fertigation through surface (GR) drip was 16.22 kg/unit compared to 12.00 kg/unit obtained under broadcasting. Also it is clear that N use efficiency under fertigation through sub-surface (GR) was 15.3 kg/unit compared with 11.9 kg/unit under broadcasting.

Fertigation versus broadcasting fertilizer application under sprinkler irrigation system :

1. Growth parameters:

The tabulated results in Table 6 show that stem length under the fertigation (76.04 cm) was longer than that under the broadcasting (65.14 cm) by (17.0 %).

Regarding to the number of pods/plant, indicates that an increase of 29.2% was recorded under fertigation compared to broadcasting method. Also the number of the branches/plant was higher under fertigation method than when broadcasting the fertilizer by 17.0%.

2. crop yield:

Data in Table 6 show that the crop yield of peas under the two fertilization methods. The data released that the higher yield was obtained under fertigation (989.24 kg/fed) was higher that obtained under broadcasting (760.25 kg/fed) by 28.3%.

3. N use efficiency:

The effect of fertilizer method was remarkably noticed when the N use efficiency increased by 29.40% under fertigation compared to broadcasting.

4. Water use efficiency:

Values of water use efficiency by peas plants for both methods of fertilizer applications are shown in Table 6. In-spite of the delivered amount of water was the same (1088 m^3/fed) under the two methods of fertilizer application. Water use efficiency recorded an increase of 28% under fertigation compared to broadcasting method. These findings are in agreemnt with those obtained by El-Gindy (1984 and 1988) and Abdel-Maksoud *et al.* (1992).

Table 6. Effect of method of fertilizer application on growth, yield, and its attributes under sprinkler irrigation system .

Method of fertilizer application	Stem length, (cm)	Branches number/ plant	Pods number / plant	Total yield, kg/fed	Water use efficiency, Kg/m^3	N use effi., kg/unit
Fertigation	76.037	3.98	64.029	989.24	0.98	14.1
Broadcast	65.148	3.42	50.11	760.245	0.70	10.9

CONCLUSION

Application of plant nutrients through irrigation systems (fertigation) is desirable for labor and energy savings, because of flexibility in timing of application, placement of nutrients in wet soil volumes and easy and precise control of application rate and nutrient concentration in the water.

From the previous results, it is clear that fertigation method produced the higher vegetative growth, yield, water and N use efficiencies compared to broadcasting methods. Fertigation is an application method which facilitates incremental applications of N used efficiencies compared to broadcasting methods. Fertigation also facilitates incremental applications of N close to or right before time periods of maximum N uptake, a managment scheme which can improve N utilization efficiency. Any fertigation requiring incorporation and water for activation can be applied with an appropriate amount of water to incorporate the fertigation to the desired depth and activate it immediately. Irrigation distribution was better in fetigation treatment and consequently soil moisture distribution and water availability for plant was more suitable. In addition to fertilizer concentration and its distribution, root performance therefore improved and enhanced both vegetative growth and yield.

Also, it is clear that fertigation through surface drip is more efficient than fertigation through sprinker. This may be due to limited wetted area affected by drip compared to sprinkler and the fertilizer reaches only where the irrigation water is applied.

REFERENCES

1. Abdel-Maksoud S.E. Hassan, M. M.S. El-Shal and E.E. Abdel-Aal. 1992. Study on selecting the proper system of tomato irrigation in new land, Misr. J. Agric. Eng 9 (7) : 347-358.

2. Abou-Khaled, A. 1991. Fertigation and chemigation an over view with emphasis on the Near East. Proc. Of Expert Consultation on Fertigation/Chemigation. FAO, Cairo, Egypt. Sept., 8-11.

3. Bacon, P.E., and B.G. Davey. 1982. Nutrient availability under tricle irrigation. 2: Mineral nitrogen. Soil Soc. Am. J. 44 : 987-990.

4. El-Berry, A.M. 1989. Effect of irrigation system on moisture pattern, productivity and harvesting of fodder in arid lands. Misr J. Agric. Eng. Vol. 6: 359-371.

5. El-Gindy. A.M. 1984. Study chemicals application through mechanized irrigation system. Agricultural mechanization project report no 1. Egypt Ministry of Agriculture-USAID .

6. El-Gindy, A.M. 1988. Modern chemigation techniques for vegetable crops under Egyptian conditions, Misr J. Agric. Eng., (1: 99-110).

7. Hamdy, A. (1991). Fertigation prospects and problems in Italy. Proc. Of Expert consulation on Ferigation/chemigation FAO, Cairo, Egypt. Sept, 8-11.

8. Hubbard, R.K., L.E. Asmussen and H.E. Allison. 1984. Shallow ground water quality beneath an intensive multiplecropping system using center pivot irrigation. S. Environ. Qual. 13 : 156-161.

9. Nimah, M.N. 1995. Technological development and new concepts for the efficient distribution and use of irrigation water and fertilizer. Advanced short course on fertigation. Faculty of agriculture Lebanon university.

10. Papadopoulos, I., 1989. Use of fertigation and chemigation to increase plant productivity, 10th, session of the Regional Commission on land and water use in the Near East, FAO, Jordan 10-14 December 1989.

11. Papadopoulos, I. 1993. Regional Middle East and Europe project on Nitrogen Fixation and water balance studies. Amman, JORDAN, 18-27 October, 1993. Assignment Report : 1-65.

12. Smajstrla, A.G. 1994. Field studies of porous pipe microirrigation laterals. ASAE.

13. Steduto, P. 1983. Fertigation preliminary studies on tomato in Southern Italy. MAI-Bari, Italy pp 101.

الرى الكيماوى تحت أنظمة الرى الحديثة

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قد تم تنفيذ التجربة بقطاع النوبارية منطقة البستان وذلك على محصول البسلة تحت ظروف الحقل المكشوف فى موسمى ١٩٩٥ ، ١٩٩٦ وتهدف الدراسة الى :–

١ . تقييم إضافة السماد النيتروجينى خلال بعض أنظمة الرى المختلفة (الرى بالتنقيط السطحى وتحت السطحى والرى بالرش الثابت).

٢ . مقارنة نظم الرى محل الدراسة لتحديد أفضلها لإضافة السماد النيتروجينى لرى البسلة.

٣ . دراسة إمكانية تقليل معدل إضافة الكيماويات.

وقد دلت النتائج المتحصل عليها فى التجربة على زيادة النمو الخضرى للمحصول وكفاءة عالية لاستخدام المياه والنيتروجين فى حالة الرى الكيماوى وذلك مقارنة بإضافة السماد نثرا مع طرق الرى العادية. كما وجد ايضا ان الرى الكيماوى من خلال طرق الرى بالتنقيط أكثر كفاءة عنه فى حالة الرى بالرش.

وكانت هذه النتيجة ترجع الى صغر المساحة المبتلة وكذلك تقين كمية السماد فى المنطقة المبتلة تحت نظام الرى بالتنقيط مقارنة بالرى بالرش.