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EFFECTS OF DIFFERENT IRRIGATION SYSTEMS AND NITROGEN FERTILIZER SOURCES ON POTATO GROWTH AND YIELD

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ABSTRACT

The effect of the applied irrigation system and nitrogen fertilizer sources are two major issues for the growth and yield of potato. A field experiment was conducted on a clay loam soil at Mansoura University Farm during the late winter planting season of 2004. This research aimed to study three different irrigation systems (subsurface& surface drip and furrow) and six different treatments of nitrogen fertilizer (control, 100% mineral, 100% organic, 100% bio-fertilizer, 50% mineral + 50% organic, 50% mineral + bio-fertilizer, 50% organic + bio-fertilizer). Results indicated that the use of surface drip irrigation system and the application of 100% mineral or a combination of mineral and bio-fertilizer gave better results. The use of subsurface drip irrigation and 100% mineral fertilizer gave the highest tuber yield (15.93-ton/feddan). Subsurface drip irrigation system proved its feasibility and applicability for irrigating potato crop.

INTRODUCTION

Potato (*Solanum tuberosum L.*) is a major food crop in many countries (Shalhevet *et al.*, 1983). It takes the fourth place among the world's various agricultural food products in production volume. It comes after wheat, rice and corn (Fabeiro *et al.*, 2001). It is a moderate crop that grows and yields well in cool and humid climates, in other words, it is grown in climatic regions from the tropics to the sub-polar. Potato is widely planted in Egypt under both furrow and drip irrigation methods.

Competition for water supplies is a worldwide phenomenon. Potato (Solanum tuberosum L.) is a relatively sensitive plant to water stress, namely, it can respond to water stress with yield reductions and loss of tuber grade. Many irrigation researches have shown that potato is relatively sensitive to soil moisture stress (Shock *et al.*, 1998; Porter *et al.*, 1999 and Fabeiro *et al.*, 2001). That is to say, the availability of soil water is one of most important factors affecting the yield and quality of potato.

Drip irrigation presumably improves the soil water regime thus leading to higher crop yields. Keshavaiah and Kumaraswamy (1993) showed that drip irrigated potato gave higher yield than furrow irrigated potato. Subsurface drip irrigation can make a real difference in increasing yield and uniformity of a crop, while simultaneously reducing water application. The extent of their potential in potato is ambiguous. Bogle *et al.* (1989) compared subsurface trickle and furrow irrigation of fresh-market tomato (*Lycopersicon esculentum Mill.*). They found that marketable tomato yield was 22% greater for plants grown with trickle irrigation than with furrow irrigation. Total water applied to furrow-irrigated plots nearly equaled pan evaporation (E_{pan})

compared to 45% of the E_{pan} for the Trickle-irrigated plots, resulting in increased water-use efficiency with drip irrigation. Sterrett *et al.* (1990) compared plant survival and yield of New Jersey 'Syn 4' asparagus (*Asparagus officinalis, L.*) that was grown on a sandy loam soil from crowns and transplants under four irrigation treatments: sprinkler, surface trickle, subsurface trickle, and no irrigation. Authors found that despite the fact that plant survival of crowns was not noticeably influenced by any irrigation treatment, survival of transplants was significantly increased by subsurface trickle. Subsurface trickle irrigation resulted in the largest increase in total yield and spear production. Authors indicated that the amount of nitrogen fertilizer for the production of potato varies with the intended market. They indicated that the potato markets are table-stock, chip-stock, fry-stock and seed-stock. For table-stock, nitrogen fertilization is applied for yield because dry matter content is not a concern. Conversely, dry matter content is critical for potato chip production. So less nitrogen application is recommended for varieties going to this market. In French frying, tuber size is most important with yield; thus for this market, more nitrogen application is usually recommended.

A comparative study was conducted on the use of surface and subsurface drip and furrow irrigation methods in potato at three different sources of fertilizer supply and one control. The objectives of this study were:

1. To determine the appropriate irrigation method and system of the three for the Potato crop.
2. To check the feasibility of using the subsurface drip irrigation system with the potato crop.
3. To determine the best combination of nitrogen fertilizer from various sources for growth and yield of potato.
4. To study the effect of different sources of nitrogen on nitrogen percent in shoot at harvest time.

MATERIALS AND METHODS

The experiment was conducted at the Farm of Mansoura University (latitude 31°05-N, longitude 31°25-E and altitude 7-m above sea level) from January to May 2004. The potato (*S. tuberosum* L. *Andasureddo*) grown was a full-season variety requiring about 130 days to reach maturity from January to June. Potato seed pieces were hand-cut to average weight about 35-g per seed piece, planted in December 23 for nursing the buds, and then transplanted to the field plots in January 3 at about 0.1-m depth below the soil surface in rows. The soil type is Clay loam. The soil physical and chemical properties are listed in table 1.

The distance between each two rows had an average value of 0.75-m and plants with 0.25-m spacing between plants in row. The density of plants was 5.3/m^2. The potatoes were planted on the raised beds that were 0.25m high. There were twenty one irrigation and fertilization treatments, which were combinations of three irrigation and seven fertilization treatments. Each treatment was replicated three times. In the experimental design, irrigation treatments were the main plots. The three irrigation treatments were subsurface drip, surface drip and furrow irrigation systems. Tap water was used for irrigation. The fertilization treatments were 100% of the mineral fertilizer (as urea), 100% of the organic fertilizer (as farmyard manure), 100% of the biological fertilizer (as Nitrogen that contained Azospirillum *sp and Azotobacter chrooccum*.), 50% of the mineral with 50% of the organic fertilizers, 50% of the mineral with the biological fertilizers, 50% of the organic with the biological fertilizers and a control treatment. The control treatment represented no fertilizer application. The fertilizer application rates were recommended by the ministry of agriculture.

Table 1: Physical and chemical properties of experimental soil

Mechanical analysis		Soluble Cations (meq/100g soil)	
Coarse Sand %	6.87	Ca^{++}	0.76
Fine Sand %	32.42	Mg^{++}	1.14
Silt %	27.59	K^{+}	0.24
Clay %	33.12	Na^{+}	0.72
Texture Class	Clay loam	**Soluble Anions (meq/100g soil)**	
Physical properties		CO_3^{-}	0.00
pH (suspension 1:2.5)	7.7	HCO_3^{--}	0.61
EC, dSm^{-1} (extract 1:5)	3.2	Cl^{-}	1.21
$CaCO_3$	4.23	SO_4^{--}	1.04
Organic Matter %	2.67	**Available nutrients (ppm)**	
SP (saturation %)	66.45	Nitrogen (N)	33.0
Bulk Density (g/cm^3)	1.21	Phosphorus (P)	18.0
Real Density (g/cm^3)	2.67	Potassium (K)	740.0

All plant seedlings were emerged in soil by January 25. Mineral N fertilizer was applied uniformly to each of the surface and subsurface drip irrigation treatment using fertigation method; however the conventional method was used with the furrow irrigation. The organic fertilizer was applied to the soil one month in advance before the planting date. However, the bio-fertilizer was mixed with the potato seed pieces at planting time.

Surface and subsurface drip systems were installed in the field January 3, 2004 to supply water to plants. The field was supplied with water through a 1-inch pipe that delivered the water to the manifold that was 3/4-in.-pipe. Twin-wall drip tapes were placed in the middle of each bed, about 0.25-m below bed surface. The tapes had an outlet spacing of 0.4-m. A flow meter was placed at the beginning of the 1-inch pipe main line to measure the amount of irrigation water. Two pressure gauges were used to make sure that the operating pressure was within the recommended range. The pressure during irrigation time ranged from 1.0 to 1.5 bars.

For the different treatments, irrigation began in January 16, weekly for the subsurface and surface drip irrigation systems and bi-weekly for the furrow irrigation system, and ended in May 4, about 10 days before maturity and harvest. The potato tubers were harvested in May 15, 2004. Total amount of irrigation water for subsurface and surface drip systems was determined using the recommended amount by Selim (1993). Author recommended an average amount of 400 mm for the whole season. The application efficiency of the surface and subsurface drip and furrow irrigation systems were considered as 93%, 93% and 80%. An extra 10% was applied for leaching purposes. To avoid loss due to application of same amount of water in all irrigations, irrigation water amounts were noticed to have similar trend as the crop coefficient values along the growing season. In other words, the growing season was divided into four terms; initial, crop development, mid and late season (Cuenca, 1989). The crop coefficient values at different stages for potato crop were sited in Cuenca (1989). A preplanting one furrow irrigation at an amount of 100-mm was applied to all the experimental plots. Then, for the subsurface, surface drip and furrow irrigation treatments, the irrigation started at a relatively low amount, 12.5-mm, in the initial period and it increased to 21.2-mm in the crop development period. Then it increased more to 26.7-mm in the mid season. Finally the irrigation amount decreased in the late season to 13-mm. The amounts of irrigation water applied by surface, subsurface drip and furrow irrigation system were listed in table 2.

Table 2: Applied amounts of irrigation water (mm) under surface, subsurface drip and furrow irrigation systems.

Date	Surface and subsurface drip	Furrow	Stage
First irrigation was applied at an amount of 100-mm			
16 January 2003	16.4	19.1	initial
23 January 2003	17.1	19.9	initial
30 January 2003	16.4	19.1	initial
6 February 2003	28.3	32.8	crop development
13 February 2003	28.9	33.6	crop development
20 February 2003	28.3	32.8	crop development
27 February 2003	28.9	33.6	crop development
6 March 2003	34.2	39.7	mid season
13 March 2003	34.2	39.7	mid season
20 March 2003	34.2	39.7	mid season
27 March 2003	34.2	39.7	mid season
3 April 2003	35.5	41.3	mid season
10 April 2003	34.2	39.7	mid season
17 April 2003	34.2	39.7	mid season
24 April 2003	17.1	19.9	Late season
4 May 2003	19.7	22.9	Late season
Total	441.6	513.3	

After harvesting soil pH was measured in the 1:2.5 soil paste extract using Beckman glass electrode pH meter (Black, 1965). Soluble carbonate and bicarbonate were determined by the titration with standard HCl solution, while soluble calcium, magnesium and sulfate (in a 1.5 soil to water extract) by the titration with a standardized versenate solution, also Cl- was determined with soluble standard silver nitrate solution. Total N and total organic carbon were estimated by Kjeldahl method and Walkley-Black procedure, respectively (Jackson, 1967). Particle size distribution was determined using Pipette method as described by Piper, 1950. Potassium was estimated using flame photometer according to Jackson, 1967. Crude protein (%) was determined as nitrogen content that was converted to its equivalent protein content by multiplying its value by a factor of 6.25 as descried by Pregl, 1945. Starch content (%) was calculated according to Burton, 1948. Water use efficiencies of the three irrigation systems were calculated using the following equation:

$$Water\ use\ efficiency\ (gram_{tuber}\ /\ Liter_{water}) = \frac{Fresh\ \ tuber\ \ yield\ (g\ /\ m^2)}{Applied\ \ irrigation\ \ water\ (L\ /\ m^2)}$$

The statistical analysis was done using Co-Stat software. The Least Significant Difference (L.S.D.) was used to determine the significance of difference among the values (Co-Stat software, 1991).

RESULTS AND DISCUSSION

Yield parameters of potato such as total chlorophyll, starch, protein, fresh and dry tuber yields and aboveground biomass were estimated and posted in Table 3. For more clearly visual analysis, figures were developed for each parameter individually of the experimental treatments.

Table 3: Yield parameters of potato as affected by different irrigation systems and nitrogen fertilizer treatments

Treatments		Total Chl.%	Starch in Tuber %	Protein in Tuber %	Fresh tuber Yield, g/plant	Dry Tuber Yield, g/plant	Above ground biomass, g/plant	Fresh tuber Yield, Ton/fed
Subsurface Drip irrigation	Control[2]	38.73	14.37	10.65	335.33	183.67	22.11	6.04
	100%MF[3]	47.37	12.35	15.73	885.00	486.24	37.06	15.93
	100%OF[4]	46.43	12.52	11.04	792.00	452.17	31.37	14.26
	Bio-fertilizer (BF)	44.67	13.01	12.75	759.00	411.48	30.14	13.66
	50%OF+50%MF	45.77	12.35	13.96	795.67	468.57	34.48	14.32
	50%OF + BF	45.00	12.73	13.21	763.33	423.57	30.62	13.74
	50% MF + BF	45.17	12.98	16.77	769.33	432.13	30.47	13.85
Surface Drip irrigation	Control	43.13	14.07	10.67	360.33	197.33	22.56	6.49
	100%MF	48.07	11.42	15.90	877.67	497.08	42.71	15.80
	OF 100%	47.73	11.69	11.15	844.33	466.48	41.95	15.20
	Bio-fertilizer (BF)	45.90	14.43	12.88	802.67	432.19	32.94	14.45
	50%OF+50%MF	46.10	11.63	14.13	845.00	478.13	42.47	15.21
	50%OF + BF	46.50	14.05	13.15	832.00	459.58	33.36	14.98
	50% MF + BF	45.63	14.41	16.67	837.67	462.88	38.08	15.08
Furrow irrigation	Control	38.50	14.10	10.00	323.00	189.77	16.89	5.81
	100%MF	48.90	12.13	14.69	742.67	626.52	31.61	13.37
	OF 100%	44.93	13.03	11.04	721.00	401.98	30.38	12.98
	Bio-fertilizer (BF)	42.20	14.10	12.10	660.67	369.26	28.29	11.89
	50%OF+50%MF	45.63	12.60	13.67	732.33	425.02	30.43	13.18
	50%OF + BF	45.23	13.47	12.94	676.00	396.12	28.82	12.17
	50% MF + BF	43.20	13.60	16.29	704.67	397.45	30.07	12.68
Statistical Analysis								
Irrigation effects	Significance	**	*	**	**	NS	**	**
	LSD 0.05	0.554	0.261	0.205	29.718	---	0.522	0.535
	LSD 0.01	0.741	0.349	0.274	39.762	---	0.699	0.716
Fertilizer effect	Significance	**	**	**	**	**	**	**
	LSD 0.05	0.846	0.398	0.313	45.395	36.196	0.798	0.817
	LSD 0.01	1.132	0.532	0.418	60.737	48.429	1.068	1.093
Inter-action effect	Significance	**	**	NS	NS	**	**	NS
	LSD 0.05	1.465	0.689	---	---	62.694	1.382	---
	LSD 0.01	1.961	0.922	---	---	83.881	1.849	---

1 Total Chlorophyll, 2 No fertilizer addition, 3 Mineral Fertilizer, 4 Organic Fertilizer, N.S.=Not significant, *=Significant at 5% level, **=Highly significant at 1% level.

Total chlorophyll content

Total chlorophyll content in percentage was illustrated in Figure 1. The highest chlorophyll contents of the subsurface, surface and furrow irrigation systems were achieved with the mineral N fertilization. The 100% mineral N fertilizer treatment had the highest chlorophyll content value compared to the rest of nitrogen fertilizer treatments (figure 1). Most probably, the high solubility of mineral fertilizer may be the rationale behind that. On the other hand, the control treatments that represent no fertilizer addition gave the lowest chlorophyll contents. The rest of the nitrogen fertilizer treatments had relatively close chlorophyll content values to each other. From the irrigation point of view, surface drip irrigation treatments were having higher chlorophyll content average values than subsurface drip and furrow irrigation treatments. The higher chlorophyll content value that was associated with the surface drip irrigation may be due to the fact that it allows keeping most of the applied water close to the root zone. In other words, plants have better chance to benefit from applied water. It can be summarized that the combination that gave the highest chlorophyll content was using the mineral fertilizer and the furrow irrigation. The difference was very significant between the surface drip and furrow for all the fertilizer treatments except for the 50% organic and 50% mineral N fertilizer treatment, Table 3. The differences between the subsurface drip and the furrow irrigation treatments were very significant except for the fertilizer treatments that were a combination of organic and both mineral and bio-fertilizers. A very significant difference was observed between the surface and subsurface drip treatments except for the treatments that involved a combination of mineral and both biological and organic fertilizers, Table 3. In summary both the surface drip and subsurface drip irrigation treatments had higher chlorophyll content values than the furrow irrigation. Also the surface drip irrigation had higher chlorophyll content than the subsurface drip irrigation; however, the difference was not significant for the nitrogen fertilizer treatments that involved combination of mineral and both biological organic fertilizers.

Tuber starch content

Tuber starch content in percentage was demonstrated in Figure 2. The highest starch contents of the subsurface, surface and furrow irrigation systems were accomplished with the application of bio-fertilizer. The lowest starch content was associated with the minerals fertilizer treatment that might be attributed to the higher leaching ability of mineral N fertilizer than the bio-fertilizer. That is to say, more bio-fertilizer was preserved for starch formation than mineral N fertilizer. From the irrigation viewpoint, the surface drip irrigation had the highest starch content. The second highest value was associated with the furrow irrigation. The furrow irrigation showed higher starch content when bio-fertilizer was used. Subsurface drip irrigation system had higher starch content values than the other two irrigation systems when 100% mineral N fertilizer was used. The difference in starch content between the surface drip and both the subsurface drip and furrow irrigation systems was very significant for almost all the fertilizer treatments, Table 3. In summary, the best combination that gave the highest starch content was the use of surface drip irrigation system and 100% bio-fertilizer.

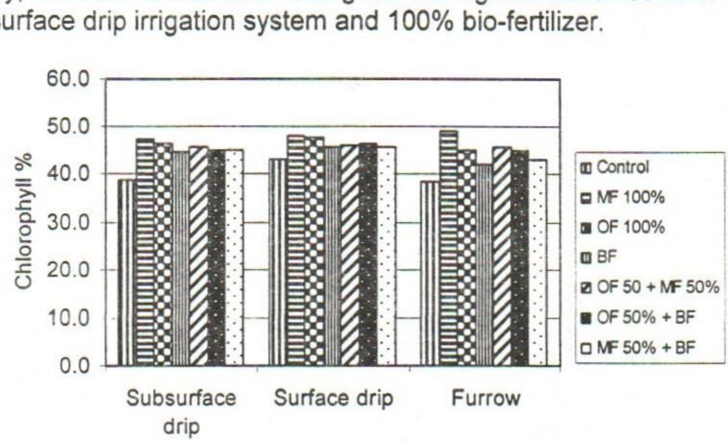

Figure 1: Percentage of Chlorophyll content in potato leaf as affected by irrigation systems and fertilization treatments.

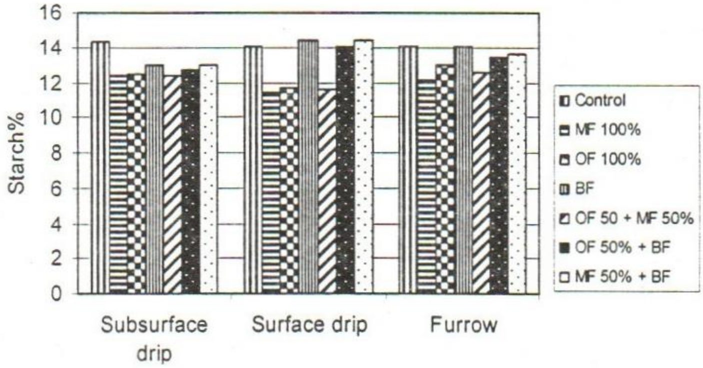

Figure 2: Percentage of Starch content in potato tuber as affected by irrigation systems and fertilization treatments.

Protein content in potato tuber

Tuber protein content was presented in Figure 3. The highest protein content of the subsurface, surface and furrow irrigation systems were attained with an application of a mixture of mineral N and bio-fertilizer. The protein content as related to irrigation and fertilization treatments was demonstrated in Figure 3. The highest two protein content values were associated with the fertilizer addition of 100% mineral N, also, with the addition of a mixture of 50% mineral N and bio-fertilizer. The lowest protein content was associated with the organic fertilizer. On the other hand, from the irrigation perspective, the subsurface drip irrigation system had higher protein contents than the furrow and surface drip irrigation systems. The difference in protein content between the subsurface drip and furrow irrigation was very significant only for the fertilization treatments that involved mineral and or bio-fertilizer. However the difference between the subsurface and surface drip irrigation systems was not significant, which may be due to the similarity of their effect in keeping the fertilizer and water close to the root zone for longer time, Table 3. In summary, the best combination that gave the highest protein content was the use of subsurface drip irrigation and 50% mineral N and 50% bio-fertilizers.

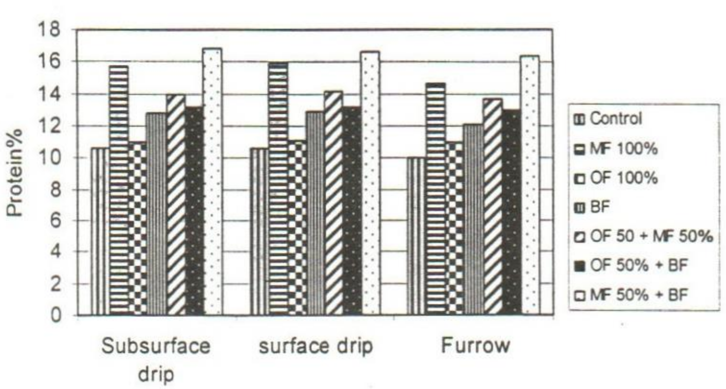

Figure 3: Percentage of protein content in potato tubers as affected by irrigation systems and fertilization treatments.

Fresh tuber yield

Fresh tuber yield was represented by Figure 4. The highest fresh tuber yields of the subsurface, surface and furrow irrigation systems were attained with the application of mineral fertilizer. It was apparent that the 100% mineral N fertilizer gave the highest fresh tuber yield. Ignoring the control treatment, the bio-fertilizer gave the lowest fresh tuber yield. From the irrigation stand point, surface drip irrigation system gave higher fresh yield average values than the other two systems; however, the highest fresh tuber yield value was associated with the subsurface drip irrigation system. The differences among the fresh tuber yield values were very significant between the surface drip and both the furrow and subsurface drip systems, Table 3. However, no significant difference was observed between surface and subsurface drip irrigation systems at the 100% mineral N fertilizer treatment. In summary, the highest fresh tuber yield was associated with the use of subsurface or surface drip irrigation systems and the 100% mineral N fertilizer. Besides what was mentioned before about the effect of subsurface and surface drip irrigation systems in keeping water close to the root zone, more frequent irrigations associated with those systems might result in better media for potato tubers to grow and reach bigger sizes, so, higher yield.

Dry tuber yield

The highest dry tuber yields of the subsurface, surface and furrow irrigation systems were attained with the application of mineral N fertilizer. Generally, the 100 percent mineral N fertilizer treatment gave the highest and the lowest dry tuber yields were associated with the mineral N and bio-fertilizer, respectively, as shown in Figure 5. The rest of the fertilization treatments gave fairly similar values for the three irrigation treatments. From the irrigation point of view, the surface drip irrigation had the highest dry tuber yield values. Comparing the dry tuber yield for the three irrigation treatments, no significant differences were observed for any of the fertilization treatments, Table 3. The best combination was using the furrow irrigation system and applying 100% mineral N fertilizer.

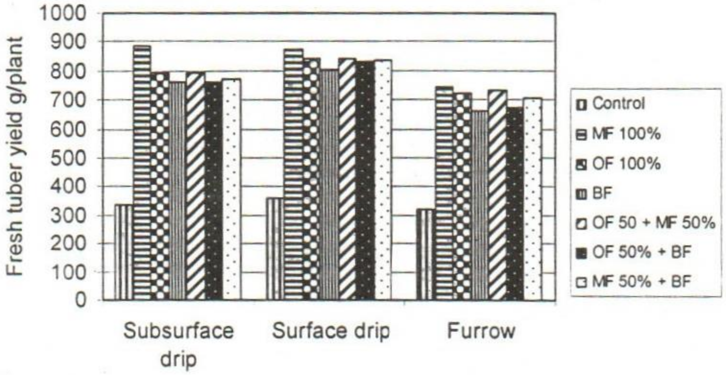

Figure 4: Fresh tuber yield as affected by irrigation systems and fertilization treatments

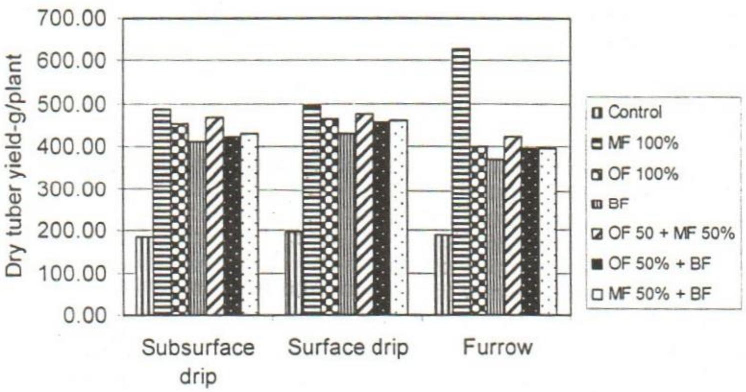

Figure 5: Dry tuber yield as affected by irrigation systems and fertilization treatments

Shoot yield

The highest shoot yield values of the subsurface, surface and furrow irrigation systems were accomplished with the application of mineral N fertilizer. The maximum shoot yield values were observed with the mineral N or organic fertilizer or the combination between the two, Figure 6. Regarding the irrigation treatments, the subsurface drip irrigation system had the highest plant shoot yield values and the lowest values were associated with the furrow irrigation system. The best combination was using subsurface drip irrigation system and the application of a mixture of mineral N and organic fertilizers, 50% each. The differences among the plant shoot yield values were significant between the surface drip and both the subsurface and furrow irrigation systems, Table 3.

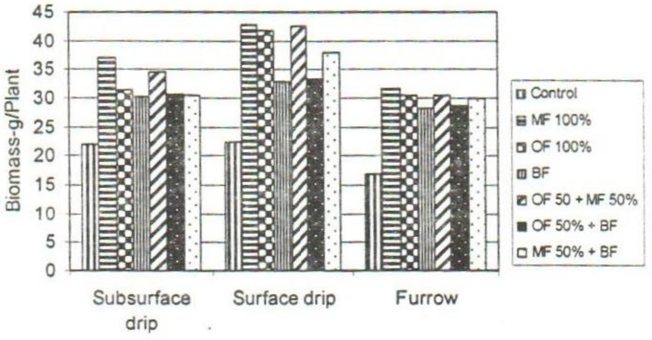

Figure 6: Dry shoot as affected by irrigation systems and fertilization treatments

Potato tuber and shoot contents of nitrogen, phosphorus and potassium give indications of how plants benefit from the applied fertilizer. Accordingly, they were measured for the different treatments and their values are listed in Table 4. The equivalent uptake values of nitrogen, phosphorus and potassium were estimated too, Table 5. Since both the content in percentage and the uptake values of nitrogen, phosphorus and the potassium have equivalent implications, only the content in percentage was extensively discussed.

Nitrogen concentration in plant shoot

The nitrogen concentration in plant shoot was estimated at harvest time and the highest value was attained when a combination of mineral N and bio-fertilizer was applied, Figure 7. The lowest nitrogen values were obtained with the application of 100% organic fertilizer. The highest nitrogen content values of the subsurface and surface irrigation systems were accomplished with the application of 100% mineral N fertilizer. However, the highest nitrogen percentage of the furrow irrigation system was attained with a mixture of the mineral and bio-fertilizer. In general the surface drip irrigation system gave the highest average nitrogen content value compared to the other two systems. The highest nitrogen percentage in shoots for the subsurface drip system was associated with mineral N fertilizer treatment. The mineral fertilizer might suit the subsurface drip irrigation system than the other fertilizer treatments, due to the fact that subsurface irrigation system keeps the root zone wet for most of the time. Consequently, the soil was not a very suitable media for biological or organic activities. The combination that gave the highest nitrogen content in shoots was using the furrow irrigation system and a mixture of mineral N and bio-fertilizer. The differences in nitrogen percentage among the three irrigation systems were not significant except for the fertilizer treatments that involved 100% mineral N or a mixture of mineral and bio-fertilizers, Table 4. It was found that the differences were very significant among the three irrigation systems for these two fertilizer treatments.

Table 4: Nitrogen, phosphorus and potassium percentage in shoots and tubers at harvest.

Treatments		NPK% in shoot			NPK% in Tubers		
		N%	P%	K%	N%	P%	K%
Subsurface Drip irrigation	Control[1]	3.13	0.2143	4.12	1.70	0.2023	2.62
	100% MF[2]	4.36	0.4103	4.66	2.52	0.3607	3.16
	100% OF[3]	3.23	0.2690	4.15	1.77	0.2270	2.63
	BF[4]	3.52	0.4303	4.38	2.04	0.3450	2.72
	50%OF+50%MF	3.99	0.3597	4.54	2.23	0.3307	2.90
	50%OF + BF	3.74	0.4387	4.53	2.11	0.3503	2.80
	50% MF + BF	4.10	0.4800	4.77	2.68	0.4487	3.24
Surface Drip irrigation	Control	3.17	0.2190	4.17	1.71	0.1847	2.61
	100% MF	4.48	0.4193	4.71	2.54	0.3683	3.12
	100% OF	3.23	0.3100	4.23	1.78	0.2630	2.71
	Bio-fertilizer	3.63	0.4287	4.35	2.06	0.3407	2.76
	50%OF+50%MF	4.02	0.3657	4.52	2.26	0.3390	2.99
	50%OF + BF	3.78	0.4283	4.47	2.10	0.3607	3.04
	50% MF + BF	4.80	0.4817	4.77	2.67	0.4427	3.31
Furrow irrigation	Control	2.96	0.1953	3.86	1.60	0.1837	2.48
	100%MF	4.17	0.4063	4.55	2.35	0.3733	3.03
	OF 100%	3.23	0.2600	4.03	1.77	0.2233	2.62
	Bio-fertilizer	3.51	0.3753	4.43	1.94	0.3197	2.73
	50%OF+50%MF	3.95	0.3520	4.59	2.19	0.2787	2.92
	50%OF + BF	3.76	0.4300	4.52	2.07	0.3553	2.79
	50% MF + BF	4.54	0.4693	4.59	2.61	0.4203	3.19
Statistical Analysis							
Irrigation effects	Significance	**	**	**	**	**	**
	LSD 0.05	0.0846	0.0066	0.0635	0.0354	0.0063	0.0383
	LSD 0.01	0.1132	0.0088	0.0849	0.0474	0.0084	0.0512
Fertilizer effect	Significance	**	**	**	**	**	**
	LSD 0.05	0.1294	0.0103	0.0972	0.0540	0.0097	0.0583
	LSD 0.01	0.1732	0.0138	0.1300	0.0723	0.0130	0.0780
Interaction effect	Significance	**	**	NS	NS	**	*
	LSD 0.05	0.2240	0.0177	---	---	0.0169	0.1012
	LSD 0.01	0.2998	0.0237	---	---	0.0226	0.1354

[1] No fertilizer addition, [2] Mineral fertilizer, [3] Organic fertilizer, [4] Bio-fertilizer, N.S.=Not significant, *=Significant at 5% level, **=Highly significant at 1% level.

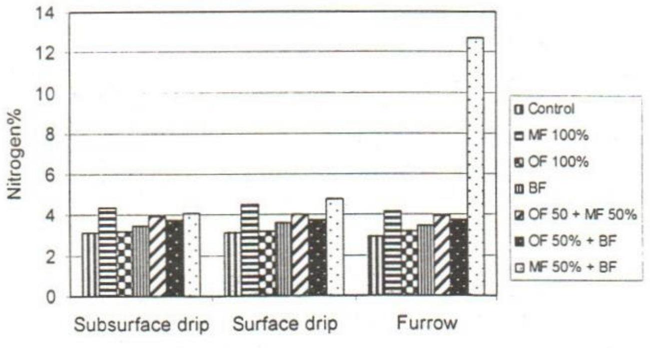

Figure 7: Nitrogen concentration in plant shoot at harvest as affected by irrigation systems and fertilization treatments.

Table 5: Nitrogen, phosphorus, and potassium uptake of shoots and tubers.

Treatments		Uptake in shoots (g/plant)			Uptake in Tubers (g/plant)		
		N	P	K	N	P	K
Subsurface Drip irrigation	Control[1]	0.69	0.0474	0.91	3.13	0.3699	4.81
	100%MF[2]	1.37	0.1288	1.46	10.88	1.5582	13.64
	100%OF[3]	1.11	0.0928	1.43	7.27	0.9329	10.83
	Bio-fertilizer (BF)	1.06	0.1297	1.32	9.56	1.6162	12.75
	50%OF+50%MF	1.48	0.1332	1.68	10.86	1.6078	14.12
	50%OF + BF	1.14	0.1337	1.38	9.55	1.5844	12.68
	50% MF + BF	1.25	0.1470	1.46	11.37	1.8994	13.75
Surface Drip irrigation	Control	0.72	0.0494	0.94	3.37	0.3634	5.14
	100%MF	1.49	0.1399	1.57	11.79	1.7067	14.45
	OF 100%	1.23	0.1181	1.61	7.68	1.1357	11.71
	Bio-fertilizer (BF)	1.52	0.1798	1.83	9.47	1.5651	12.67
	50%OF+50%MF	1.32	0.1204	1.49	10.54	1.5799	13.96
	50%OF + BF	1.61	0.1829	1.91	10.46	1.7928	15.11
	50% MF + BF	2.04	0.2046	2.03	12.75	2.1176	15.84
Furrow irrigation	Control	0.50	0.0330	0.65	3.04	0.3487	4.70
	100%MF	1.18	0.1150	1.29	9.99	1.5868	12.87
	OF 100%	0.98	0.0791	1.22	6.52	0.8247	9.66
	B	1.06	0.1127	1.33	7.71	1.2694	10.85
	50%OF+50%MF	1.25	0.1113	1.45	8.66	1.1035	11.54
	50%OF + BF	1.14	0.1310	1.38	8.32	1.4288	11.22
	50% MF + BF	1.31	0.1352	1.32	16.33	2.6310	19.97
Statistical Analysis							
Irrigation effects	Significance	**	**	**	*	**	**
	LSD 0.05	0.0334	0.0031	0.0337	0.5748	0.0889	0.7257
	LSD 0.01	0.0447	0.0042	0.0451	0.7690	0.1189	0.9709
Fertilizer effect	Significance	**	**	**	**	**	**
	LSD 0.05	0.0512	0.0049	0.0517	0.8780	0.1358	1.1084
	LSD 0.01	0.0685	0.0065	0.0692	1.1747	0.1816	1.4830
Interaction effect	Significance	**	**	**	**	**	**
	LSD 0.05	0.0889	0.0083	0.0895	1.5208	0.2352	1.9198
	LSD 0.01	0.1189	0.0111	0.1197	2.0348	0.3147	2.5686

[1] No fertilizer addition, [2] Mineral fertilizer, [3] Organic fertilizer, N.S.=Not significant, *=Significant at 5% level, **=Highly significant at 1% level.

Phosphorus concentration in plant shoot

The highest phosphorus concentration values of the subsurface, surface drip and furrow irrigation systems were accomplished with the application of bio-fertilizer. In general, phosphorus percentage in plant shoot at harvest time indicated that a combination of the mineral N and bio-fertilizers gave the highest phosphorus content values, Figure 8. On the other hand, organic fertilizers gave the lowest phosphorus values. From the irrigation standpoint, the surface drip irrigation system showed higher phosphorus content in shoot than the subsurface drip and the furrow irrigation systems. Nevertheless, the difference in phosphorus values between the surface drip and the other two irrigation systems was significant only when a combination of organic and bio-fertilizers was applied, Table 4. The best combination was using the surface drip irrigation system and applying a mixture of mineral N and bio-fertilizers, 50% each.

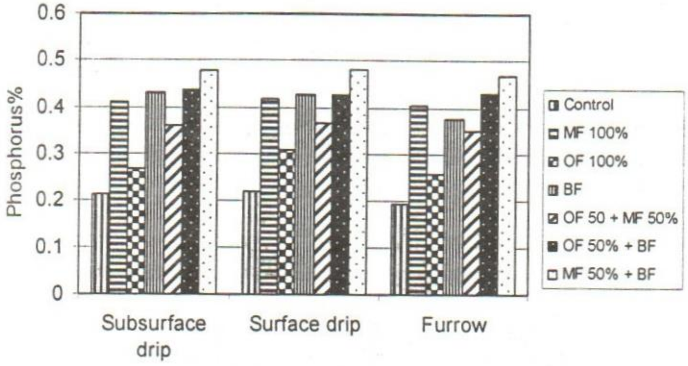

Figure 8: Phosphorus concentration in plant shoot at harvest as affected by irrigation systems and fertilization treatments.

Potassium concentration in plant shoot

The highest potassium concentration values of the subsurface, surface drip and furrow irrigation systems were attained with the application of a mixture of mineral N and bio-fertilizer. Alike phosphorus, potassium percentage values were higher with the application of a combination of mineral N and bio-fertilizers than the other fertilizer treatments, figure 9. The lowest values were associated with the organic fertilizer. Surface drip irrigation showed higher potassium content values, with significant differences, than both the subsurface drip and the furrow irrigation, Table 4. The best combination was the use of surface drip and the application of a mixture of mineral N and bio-fertilizers.

Nitrogen concentration in potato tuber

The highest nitrogen concentration values in potato tuber of the subsurface, surface drip and furrow irrigation systems were attained with the application of a mixture of mineral and bio-fertilizer. The nitrogen percentage in potato tuber had the lowest values when organic fertilizer was applied, Figure 10. Comparing the average values of the three irrigation methods, surface drip irrigation had the highest average value; however, the furrow irrigation had the lowest average value. The best combination that gave the best nitrogen content in potato tuber was using subsurface drip irrigation system and the application of a mixture of mineral N and bio-fertilizer. However, the differences among the values of the surface drip and the subsurface drip were not significant, Table 4. So, the use of surface drip irrigation system and a mixture of mineral N and bio-fertilizer may be considered as the best combination too.

Phosphorus concentration in potato tuber

The highest phosphorus concentration values in potato tuber of the subsurface, surface drip and furrow irrigation systems were attained with the application of a mixture of mineral N and bio-fertilizer. Similar to the nitrogen, the highest phosphorus content values were obtained with the application of a mixture of mineral N and bio-fertilizer, Figure 11. Nevertheless, the lowest values were associated with organic fertilizer. Surface drip irrigation had the highest average and the furrow irrigation had the lowest average. The best combination that gave the highest phosphorus content in potato tuber was using subsurface irrigation system and the application of mixture of mineral N and bio-fertilizer. The differences among the values of the surface drip and both the subsurface drip and the surface irrigation systems were significant at most of the fertilizer treatments, Table 4.

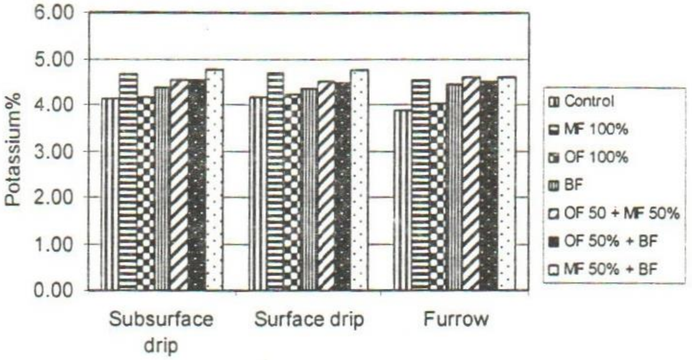

Figure 9: Potassium concentration in plant shoot at harvest as affected by irrigation systems and fertilization treatments

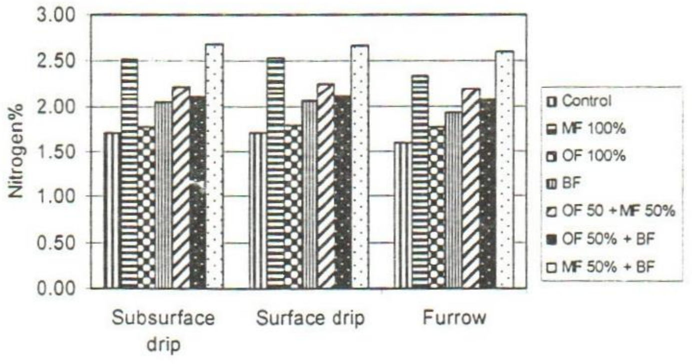

Figure 10: Nitrogen concentration in potato tuber at harvest as affected by irrigation systems and fertilization treatments

Potassium concentration in potato tuber

The highest potassium concentration values in potato tuber of the subsurface, surface drip and furrow irrigation systems were achieved with the application of a mixture of mineral N and bio-fertilizer. Generally, the potassium content in potato tuber had the highest values when the mineral fertilizer or a mixture of mineral N and bio-fertilizer were applied, Figure 12.

But, the lowest values were related to the application of organic fertilizer. Similar to the phosphorus and the potassium, surface drip irrigation had the highest average and the furrow irrigation had the lowest average. The best combination that gave the highest potassium content in potato tuber was using surface drip irrigation system and the application of a mixture of mineral N and bio-fertilizer. The differences among the values of the surface drip and both the subsurface drip and the surface irrigation were very significant, Table 4.

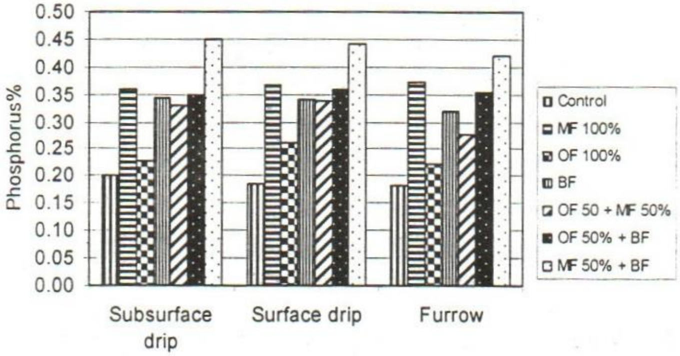

Figure 11: Phosphorus concentration in potato tuber at harvest as affected by irrigation systems and fertilization treatments

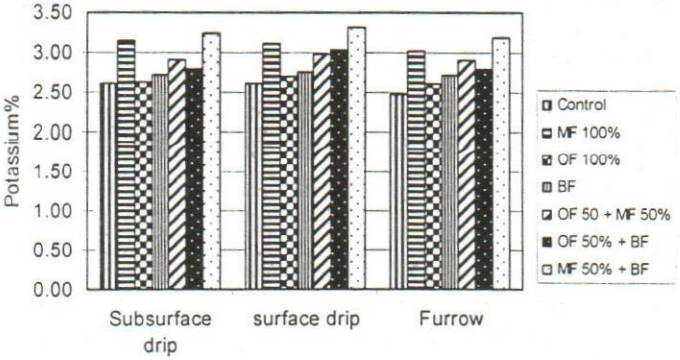

Figure 12: Potassium concentration in potato tuber at harvest as affected by irrigation systems and fertilization treatments

Water use efficiency

Water use efficiencies for different treatments were illustrated in Figure 13. It was obvious that the surface drip irrigation system had higher water use efficiencies than both the subsurface drip and furrow irrigation systems. The differences were not significant between the surface and subsurface drip irrigation systems. On the other hand, the differences were significant between furrow and both surface and subsurface drip irrigation systems. The high water use efficiency values for the surface and subsurface drip irrigation systems were expected due to their ability to keep most of the applied water close to the root zone.

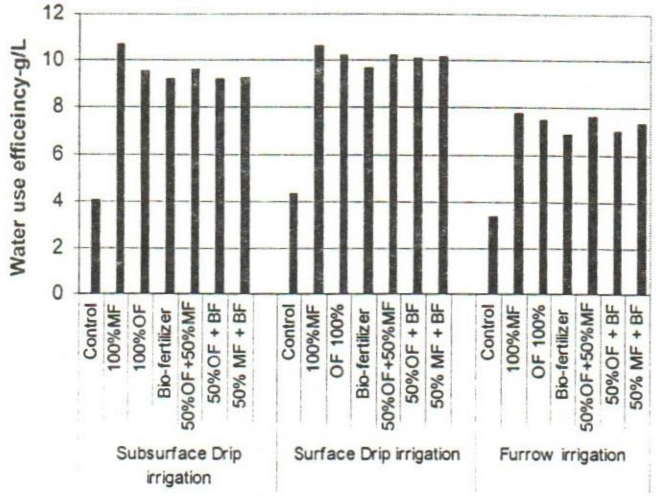

Figure 13: Water use efficiency as affected by various irrigation systems and fertilization treatments.

CONCLUSIONS

The use of furrow irrigation system and mineral fertilization gave the highest chlorophyll content. On the other hand, the second highest value was associated with use of surface drip irrigation system and organic fertilizer. Concerning the starch content in tubers, the highest value was linked to the use of surface drip irrigation and bio-fertilization. The use of subsurface drip irrigation and a mixture of 50% mineral and 50% bio-fertilizers gave the highest protein content.

The highest fresh tuber yield was related to the use of subsurface or surface drip irrigation systems and the 100% mineral fertilization. On the other hand, the maximum dry tuber yield value was obtained by using the furrow irrigation system and applying 100% mineral fertilization. Water use efficiency average values of the surface, subsurface drip and furrow irrigation systems were 9.3, 8.8 and 6.8 g/L, respectively.

The use of subsurface drip irrigation system and a mixture of mineral and organic fertilizers resulted in the highest plant shoot values.

It was noticeable that the uptake and percentage values of nitrogen phosphorus and potassium were having same trend. Nitrogen content in shoot was maximized along with the use of furrow irrigation system and a mixture of mineral and bio-fertilizers, 50% each. Nonetheless, the maximum phosphorus and potassium content values were associated with using the surface drip irrigation system and applying a mixture of mineral and bio-fertilizers.

The nitrogen or phosphorus contents in potato tubers were maximized with the use of subsurface drip irrigation system and the application of a mixture of mineral and bio-fertilizers. Finally, the best combination that gave the highest potassium content in potato tuber was using surface drip irrigation system and the application of a mixture of mineral and bio-fertilizers. It was apparent that the organic fertilizer resulted in lower nitrogen, phosphorus and potassium contents in potato tubers.

In summary, although the surface drip irrigation system gave higher values for most of the yield parameters that were measured in this experiment, subsurface drip irrigation system proved its applicability and feasibility for the potato crop production. Although mineral fertilizer yielded higher tuber and shoot yield values, a mixture of mineral and bio-fertilizers resulted in higher nitrogen, phosphorus and potassium contents in tubers and shoots.

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تأثير نظم مختلفة من الري ومصادر التسميد النيتروجيني على نمـــو ومحصـــول البطاطس

أيمن محمد الغمري[1] و ضياء الدين محمد الشيخة[2]
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يعد تأثير نظم الري ومصادر التسميد النيتروجيني المختلفة من أهم العوامل المؤثرة على نمو ومحصول البطاطس. لذلك فقد أجريت تجربة حقلية في تربة طينية بمزرعة كليـــة الزراعـــة بجامعة المنصورة، خلال موسم ٢٠٠٤. تهدف هذه التجربة إلى دراسة ثلاثة نظـــم ري مختلفـــة (التنقيط التحت سطحي، التنقيط السطحي ، الغمر) وستة معاملات مختلفة من التسميد النيتروجيني (كنترول، ١٠٠% تسميد معدني، ١٠٠% تسميد عضوي، ١٠٠% تسميد حيوي، ٥٠% معدني + ٥٠% عضوي، ٥٠% معدني + حيوي، ٥٠% عضوي + حيوي). وقـــد أوضـــحت النتـــائج أن استخدام الري بالتنقيط مع إضافة خليط من السماد المعدني والعضوي أو المعدني والحيوي أعطت أعلى محصول للدرنات (١٥,٩٣ طن/فدان). كما أشارت النتائج إلى إمكانية إستخدام نظام الـــري بالتنقيط تحت السطحي لزراعة محصول البطاطس.