IMPROVING WATER USE EFFICIENCY USING DRIP AND SPRINKLER IRRIGATION TO GROW POTATOES AT TWO LOCATIONS IN THE NEW VALLEY.

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ABSTRACT

These experiments were conducted at El- Kharga and El-Dakhla Oases (latitude 25.45 and 25.48 °N respectively) at the governrate of New Valley during the fall/winter seasons of 1996/1997 and 1997/1998. Two potato cultivars (Draga and Diamant) were planted and irrigated using the trickle irrigation system at two irrigation regimes (30 and 60 min daily = 840 and 1680 m^3/ season). The sprinkler irrigation system was tested at 30 min daily level (1680 m^3/ season) vs the drip irrigation regimes at Dakhla location only. The strong winds resulted in an irregular distribution of the sprinkled water. That lead to an even potato plant growth and a low total and marketable yield. Some physical and chemical characteristics of the soils and water of the two locations were conducted. The combined analysis of variance over the two seasons indicated that the use of the trickle irrigation system at 60 min. resulted in improving the yield of the tow potato cultivars. Sowing Diamant cv. resulted in more yields, than Draga cv. at the two locations. However, the water use efficiency was higher in the 30-min irrigation regime and it is advisable to be used there to increase the cultivated land and total yield. Finally the Dakhla location was superior to the Kharga location which may be due to differences in soil fertility and water quality.

INTRODUCTION

The New Valley area, with a large cultivable land but a precious little by way of fresh water supplies, needs to maximize its food output per unit of land while minimizing water use. As part of its drive to cut down on water use, the government chose to promote drip irrigation, which is more expensive than most other irrigation methods. However drip irrigation in terms of water use efficiency is a desirable irrigation method in an area like the New Valley, where the only source of water is the under ground water. Drip irrigation is the slow drop-by-drop, localized application of water at a grid just above the soil surface. Drip irrigation saves water by reducing the size of the wet soil surface, thus decreasing the amount of direct evaporation and excess percolation through the root zone. Unlike sprinklers, drip irrigation is practically unaffected by wind conditions, nor is it affected by soil surface conditions. Soil is maintained in a continuously moist condition. Nutrients can be applied through the drip systems, thus reducing use of fertilizers and improving the quality of returned water. Increases in water use efficiency in drip irrigation, compared with conventional basin/furrow irrigation, are attributed to both water savings and the increase in yields resulting from favorable soil moisture and nutrient regimes. The reduction of water use was 60% when the drip irrigation was used to grow potato (Xie et. Al, 1993).

Saggu and Kaushal (1993) stated that drip irrigation is better than furrow irrigation for potato crop. In a field trial at Akola, Maharashtra in 1993/94, potatoes cv. Kufri Lavakar were drip irrigated to 100% of crop evapotranspiration, basin irrigated, or given different furrow irrigation treatments. Growth, leaf area, tuber yield and water use efficiency were highest with drip irrigation (: Awari and Hiwase, 1994). It is a well known fact that potato is one of the most sensitive crops to soil water stress. Water stress is recognized as a major constraint on potato production worldwide (Schapendonk, *et al.*, 1989). Drip irrigation is one of the most effective methods to supply water to crops (Hartz, 1993). It is well known that drip irrigation can result in water saving if the correct management procedures are applied. It can be attributed to the fact that the evaporation component of evapotranspiration is much lower than is the case with conventional sprinkler irrigation. Direct evaporation from the soil surface is low because of the irrigation of a smaller portion of the soil volume, and therefore water savings of 20% to 40% can be achieved (Hillel and Rawitz 1987; Du Plessis, *et al.*, 1998). According to Hillel and Rawitz (1987) the wetted portion of the soil is maintained in a continuously moist state and never allowed to be depleted or to approach the so-called wilting point. This creates an uniquely favorable soil moisture regime and gives drip irrigation a distinct advantage over sprinkler and surface irrigation. One of the most common problems encountered with drip irrigation amongst producers is that irrigation is applied in excess of crop requirements. The advantage of water savings by drip is forfeited if crops are over irrigated. According to Bravdo & Proebsting (1993) the water distribution under each dripper forms a bulb-shaped zone where most of the irrigated soil is under the soil surface. Hillel and Rawitz (1987) stated that If over irrigation occurs the bulb-shaped or onion-shaped wetted zone gradually becomes carrot-shaped and eventually may form a leading excess water downward towards the water table. Irrigation scheduling with the Soil Water Balance computer model produced the highest total tuber yield, as well as acceptable water use efficiencies (Du Plessis et al., 1999). Irrigation requires a relatively high investment in equipment, fuel, maintenance and labor, but offers a significant potential for increasing net farm in- come. Frequency and timing of water application have a major impact on yields and operating costs. To schedule irrigation for most efficient use of water and to optimize production, it is desirable to frequently determine the soil water conditions throughout the root zone of the crop being grown. (Harrison and Tyson, 1993).

Shock (2000) stated that water requirements for irrigation are reduced because water can be applied vastly more efficiently with a drip irrigation system. Depending on the year and the soil, 14 to 28 ac-in/ac of water has been needed to raise onions under drip irrigation in the Treasure Valley. With furrow irrigation systems, typically 4 ac-ft/ac or more of water is applied. Drip irrigation with more water than a plant's requirement will result in the loss of most of the drip irrigation benefits. The soil will be excessively wet promoting disease, weed growth, and nitrate leaching.

A potato (Solanum tuberosum L. cv. Russet Burbank) experiment was initiated to examine the effect of water and N on potato yield and quality, tuber N concentrations, petiole NO_3 concentrations, and N distribution in the soil (Roland and Marcum, 1998). The field trial consisted of a line-source irrigation system with six water rates (0.33, 0.66, 1.00, 1.10, 1.20, and 1.30 times crop evapotranspiration ET_c) each having six planting-time N rates (0, 56, 112, 168, 224, and 448 kg ha^{-1}) replicated four times with treatments applied to the same plots in two successive years on a Pittville sandy loam (fine-loamy, mixed, mesic Typic Argixerolls). Yields were significantly increased with water, averaging 14.1 to 54.4 Mg ha^{-1} in 1992 and 20.8 to 46.5 in 1993. Nitrogen rate significantly increased yield in 1993, averaging 28.7 to 44.1 Mg ha^{-1}, but not in 1992. Near-maximum yields were obtained with 1.10 to 1.20 ET_c applied water and 0 to 56 kg N ha^{-1} in 1992 and with 1.10 to 1.30 ET_c applied water and 168 to 224 kg N ha^{-1} in 1993.

This study is one of several studies has been done under the New Valley conditions (Gameh et al, 1999 and Gameh 1999). The aim of this study was to test the efficiency of modern irrigation systems to grow potatoes in the Western desert soil under two locations at the New Valley.

MATERIALS AND METHODS

These experiments were carried out at two out of four drip and sprinkler irrigation experimental farms (see map Fig, 1), of Assiut University at the New Valley Governorate. The two locations were at El-Kharga Oasis (The capitol of the New Valley) and El-Dakhla Oasis (Mout-1; 200 km to the west of El-Kharga). The latitude of El-Kharga and El-Dakhla Oases are 25.45 and 25.48 ^{o}N respectively. Soil and water samples were collected from the two locations. Soil samples received the necessary pretreatment and were analyzed according to Jackson (1958). Micro-nutrients in soil were extracted by DTPA puffered solution and measured using Atomic absorption Spectrum (AAS) according to Lndsay and Norvell (1978). Some physical and chemical characteristics of the soils and water of the two locations are given in table (1 and 2). The ground water of the New Valley contains a high level of iron. The iron can be easily participated when exposed to air and can clogging the drippers and damage the system. Gameh (1999) proposed a solution for this problem by using setting basins and filtration systems. The regular practices for field preparation were carried out. Ridges of 1.2 m width and 0.25 m height were prepared. Two drip lateral lines of GR polyethylene tube of 0.016 m diameter with built-in dripper of 0.5 m apart which give 0.002 m3/h discharge per dripper were spreaded on each ridge at 1m distance between them. The length of each lateral line was 30 m. Two ridges of 30 m length were used for each treatment (total of 60 m^2 = 1/70 fed.). The irrigation treatments were applied daily at a rate of 16.8 m^3 (60 min) and 8.4 m^3 (30 min) and started immediately after planting and continued until ten days before harvesting. The sprinkler irrigation system were fixed irrigation sprayers installed at 9X9 m apart from each other to get 100% over lapping. The sprinkler treatment was applied at El-Dakhla location only. The rate of sprinkling irrigation was 16.8 m^3 (30 min daily). Two potato cultivars were used in these experiments namely Diamant and Draga. The potatoes were planted at 0.25 m apart during the fall/winter seasons of 1996/1997 and 1997/1998. The planting dates for the two seasons were September 29th and

September 27th of 1996 and 1997 respectively. The harvesting was done after 110 days from planting. Organic matter was buried 0.3 m under the soil beds 15 before planting. Daily irrigation through dripping or sprinkling irrigation was continued for ten days prior to planting. A compound fertilizer (19 + 19 + 19 + micro-nutrients) was injected at rate of 4 kg/fed. every day after three weeks from planting; when 90-95% of the plant emergence. This fertilizer was extended for six weeks then was shifted for potassium rich fertilizer (12 + 4 + 42) for other three weeks.

Table (1): Physical and chemical characterization of the soils at El-Kharga and El-Dakhla locations.

Properties	**El-Kharga**		**El-Dakhla**	
Mechanical analysis	Surface	Subsurface	Surface	Subsurface
Sand %	70.70	70.66	16.94	13.40
Silt %	19.16	21.11	35.23	40.00
Clay %	10.14	8.23	47.83	46.60
Texture	Silt-Loam	Silt-Loam	Clay	Clay
Saturation capacity %	27.60	25.35	67.44	63.83
Field Capacity %	18.32	16.35	42.68	40.69
$CaCO_3$	8.93	8.12	4.45	3.93
pH	8.21	8.23	7.87	7.85
EC_{1-1}	2.13	2.30	3.45	2.69
Available P (ppm)	7.10	5.50	18.50	14.70
Available K (ppm)	64.00	51.90	145.60	129.00
Available N (ppm)	0.004	0.002	0.030	0.013
DTPA extractable Fe (ppm)	6.20	5.30	23.40	13.60
DTPA extractable Mn(ppm)	2.40	2.30	4.80	3.10
DTPA extractable Zn (ppm)	0.70	0.80	1.70	1.00
DTPA extractable Cu (ppm)	0.10	0.10	0.50	0.50

The experiment was designed as a completely randomized blocks with four replications. The data were subjected to statistical analysis. A combined analysis of variance over the two seasons and the two locations was conducted and the means were compared using Duncin Multiple Range Test (DMRT) at 5% level according to Gomez and Gomez (1984). The goal of these experiments was achieved through choosing twenty plants from each treatment and studying the following characteristics:

1- stem number per plant
2- tuber number per plant
3- average tuber weight (g)
4- total yield (ton/feddan)
5- marketable yield (ton/feddan)
6- foliage weight (g) per plant
7- The water use efficiency kg/m^3 (WUE) was estimated as:
   total yield (kg) / the amount of water used for the treatment (F.A.O., 1982)

RESULTS AND DISCUSSION

I- Effect of location (Soil & water) and irrigation regime using drip irrigation.

Stem number:

The effect of the two irrigation regimes on the stem number of draga and diamant cvs. grown under Dakhla and Kharga conditions is presented in Table, 3. No significant differences were found between the two cvs. and the two irrigation regimes within each location. However, there was a significant difference between the two locations (Fig. 2). Caesar et al.(1981) revealed that number of stems depends less upon the variety and more upon the location. Soil analysis of the two locations, (Table, 1), show higher soil fertility of Dakhla soils than Kharga soils. That may be reflected in better growth in Dakhla site. The higher stem number will give better yield as reported by Claypool and Morris (1931) who found that two stem hills gave twice yield as of one stem; three–stem yield was somewhat greater than two-stem while four-stem yield was slightly greater than three-stem.

Foliage weight, (g) per plant

The data for this character are shown in Table, 3. Diamant at both locations gave the highest foliage weight when irrigated for 60 min every day. In contrast, Draga recorded the lowest foliage weight in both locations when irrigated with water for 30-min level every day.

In general the Diamant cv. had more foliage weight than Draga cv. (Fig., 3). Further, the Dakhla location exceeded the Kharga location regarding this character. Finally, The use of 60 min water regime every day overcame the 30 min regime.

Tuber number per plant:

Table (4) presents the data of this character. The highest number of tubers per plant was obtained when Draga cv. was irrigated for 30-min. daily under Dakhla location. However, Diamant cv. gave the highest tuber number when irrigated for 60 min a daily. Fig 4 presents the effect of the location, cultivar and irrigation level on the number of tuber per plant. Dakhla location, Draga cv. and the 60-min irrigation produced more tubers number as compared with the other treatments.

Average tuber weight (g):

There was no obvious effect of the two water regimes on the average tuber weight of the two tested cultivars (Table, 4). However, Dakhla location was superior to the Kharga concerning this character (Fig. 5). Also the Diamant cv. produced a heavier average tuber weight than Draga cv.

Total yield (ton per fed):

The total yield of any crop is almost the most important character that most researchers and producers are looking at beside quality. Under the Dakhla conditions Diamant cv. produced the highest total yield when irrigated for 60 minutes a day (Table, 5). The same trend was also found, under the Kharga location where, Draga cv. produced the highest total yield when watered for 60 minutes (12.097 ton/fed).

Figure 6, illustrate the effect of the three factors on the total yield. The Dakhla location was superior as compared with the Kharga (62% more yield). Diamant cultivar was better than Draga and gave almost 15% more yield. Finally, irrigated for 60 min. per day produced more yield than the 30 min. treatment. The water distribution pattern under the dripper of Dakhla (Fig, 8a and b) show the water content in 34.5 and 31.1 % at 50 cm depth at early and end of the season (Gameh, et al., 1999). As for, Kharga pattern (fig 8 c and d) the respective value were 10.2 – 9.5 %. This may add an explanation to the better growth of the potato plants and the more total yield gained under El-Dakhla location.

Marketable yield (ton/fed):

The marketable yield showed the same trend as the total yield (Table, 5). The highest marketable yield was obtained as the Diamant cv. was grown under the Dakhla conditions and irrigated for 60 min every day (15.006 ton /fed). This treatment exceeded the lowest value obtained from the Kharga location when cultivated with the Draga cv. and irrigated 30 min per day by almost 92% (7.812 ton/fed). Fig (7) illustrates the effect of the three factors on the marketable yield. The marketable yield trend almost was the same as the total yield.

Comparing the sprinkler and drip irrigation systems experiment:

The sprinkling irrigation system was used only at EL-Dakhla location in comparison with drip system. Table 6 presents a comparison between the effect of two systems and the amount of water that was used under the two irrigation systems on the average tuber weight (g), the tuber no. per plant, the marketable and total yield and the water use efficiency. The sprinkler system had produced lower average tuber weight (g), marketable and total yield than drip irrigation. In contrast, the number of tubers per plant was higher under sprinkler than drip. Moreover, It was found that most of the tubers produced under the sprinkler irrigation system were unmarketable (almost 45.29 and

55.69 % of the total yield of Draga and Diamant respectively). That may be related to the effect of the water distribution of sprinkler irrigation which is known to make most of the roots and stolen grow close to the soil surface. These factors made the tubers exposed to the sun. Thus made most of the tubers greenish in color and rich in solanine, and therefore unmarketable. Also, the strong winds in this area (wind speed is 5-9 nodes for about 300 days) resulted in an irregular distribution of the sprinkled water (axcentral oval shape instead of regular circles). That lead to an even growth of the potato plants in the field and a low total yield.

Water use efficiency

A widely applicable expression of efficiency is the water use efficiency, which has been discussed by several workers (Vites (1962), Vites, (1966), Hillel and Rawitz (1972) and Ahmed (1998)). The water use efficiency of potato that was grown under the sprinkling irrigation was very low in comparison with the drip irrigation system (almost less than 50% of the 60-min level of drip irrigation). However, the use of 30-min (840 m^3) of irrigation with the drip irrigation gave the highest water use efficiency. So, if there was limitation in land, the 60-min drip irrigation would be better practice to produce more total yield. But if limitation was in water resources and there was large cultivable agricultural land (as in the case of the New Valley), using of 30 min irrigation regime could be recommended. That is because when 30 min drip irrigation level will be used the cultivated land will be doubled and the yield of Diamant will increase from 5.723 (sprinkler) and 13.261 (60 min drip) to 23.570 ton / fed.

CONCLUSION

In conclusion the soil texture of El-Dakhla is at the boarder of silt-clay to clay soil. This makes it having a high water holding capacity; almost two folds of El-Kharga soils (Table, 1). Further, the soil fertility, such as, N,P,K levels of El-Dakhla was almost three folds as El-Kharga soils (Table, 1). Further, Rates of applied N required for 95 and 100% of maximum yield ranged from 87 –261 kg/ha across sites. Sensitivity of nitrate-N levels to variations in N supply depended on site and petiole sampling time (Williams and Maier (1990).

Phosphorus application significantly ($P< 0.05$) increased total tuber yield at 16 sites. The mean relative yield for these responsive sites was 69.7% compared with 97.5% for the non-responsive sites. Tuber size distributions were determined at 13 sites and, depending on site and cultivar, the yield of 80-450 g tubers for the highest yielding treatments represented from 64.2 to 93.7% of the total yield of tubers for those treatments (Maier et al., 1989). Sánchez et al. (1999) Potato (Solanum tuberosum) generally requires high amounts of phosphate fertilizer to reach economically acceptable yields, particularly in soils originating from volcanic ash. This is a consequence of the potato plants low root density and the slow soil diffusion rate of phosphorus (P) in these soils. Our objective was to evaluate the effect of P rates on tuber yield, biomass production, and distribution, biomass P accumulation and concentration, and P distribution in potato cv. Mexiquense. The experiment was carried out in an Andisol (7.8 µg g-1 Olsen-P) located at the east of Valle de México. Fertilization rates were 0, 18, 41, 46, 69, 78, 90, 106, 113, 135, 150, 163, and 207 kg ha-1 P, from ordinary superphosphate. Top growth and root biomass, tuber yield, P percentage and P accumulation in different plant parts were measured at harvest. Minimum and maximum average tuber yields were 8.4 and 18.0 Mg ha-1; the plants absorbed 5.8 and 11.8 kg ha-1P, corresponding to 0 (control) and 207 kg ha-1 P, respectively. Phosphorus fertilization had little influence on plant P concentration, where average concentrations in tuber and top growth were 0.20 and 0.24% P, respectively. in contrast, P accumulation increased with increasing P rates, but P distribution between tuber and top growth was dependent on the amount of P applied. The control treatment showed approximately 1:1 distribution of P between top growth and tuber, but as P rate increased, top growth P decreased and tuber P increased. When applying the highest P rate, 36% of P accumulated in the top growth and 64% in the tuber. These two facts led to a higher total, marketable yield and better foliage growth in El-Dakhla oasis than El-Kharga.

Also, El-Dakhla irrigation water (Table, 2) may have played a role in enhancing the growth of the plants at this site, since it was rich in micro-nutrients such as Mn, Zn, Cu and specially Fe. Therefore, the plants of El-Dakhla location grew better. That could be reflected on a higher net assimilation rate and a higher food storage into the tubers. This will ended as higher total yield.

The Diamant cultivar seems to be more suitable for this area than the Draga cultivar. Further, under the New Valley conditions it s more profitable to grow potatoes using 840 m^3 of water using the drip irrigation system and doubling the cultivated area since the soil in The New Valley is relatively unlimited natural resource.

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تحسين كفاءة استخدام الماء باستعمال الري بالتنقيط و الري بالرش لزراعة البطاطس فى موقعين بالوادي الجديد

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تم أجراء هذه التجارب فى واحتى الخارجة والداخلة بالوادى الجديد (خط عرض ٤٥و٢٥ و ٤٨و٢٥ شمالا على التوالي) خلال خريف وشتاء ٩٦ / ٩٧ ، ٩٧ / ٩٨ حيث تم زراعة صنفي بطاطس (دراجا و دايمونت) وتم ريهما بالتنقيط باستخدام مستويين من ماء الرى (٣٠ و ٦٠ دقيقة يوميا = ٨٤٠ م^{٣} و ١٦٨٠م^{٣} للموسم) ذلك بالإضافة الى مقارنة نظام الرى بالرش والتنقيط تحت ظروف واحة الداخلة بمعدل ١٦٨٠م^{٣} للموسم للرى بالرش ونفس معدلى الرى بالتنقيط السابق ذكرهما. وقد تم أجرا تحليلات طبيعية وكيميائية للتربة بالموقعين التى أظهرت خصوبة موقع الداخلة بالمقارنة بموقع الخارجة. كذلك فقد تم اجرا ء التباين المشترك للموسمين وتم مقارنة النتائج احصائيا. وقد أشارت النتائج ان الرياح الشديدة قد أدت الى توزيع غير منتظم لماء الرش مما أدى الى نمو غير متجانس للنباتات النامية مما قلل من المحصول الكلى والتسويقى. كذلك أظهرت النتائج أن استعمال الرى بالتنقيط عند ٦٠ دقيقة ادى الى زيادة المحصول بغض النظر عن الصنف المستخدم الا ان الصنف دايمونت أعطى محصولا كليا وتسويقيا أعلى مقارنة بالصنف دراجا فى كلا الموقعين. وعلى الرغم من ذلك فأن كفاءة استعمال الماء كانت أفضل فى معاملة الرى بالتنقيط ٣٠ دقيقة يوميا ولذا فأنه يمكن أن ننصح باستخدام هذه المعاملة تحت ظروف الوادي الجديد المعروف بسعة أراضيه القابلة للزراعة مع ندرة المياه.