Response of Potato to Irrigation Water Levels and Organic Manure Fertilization Under Drip Irrigation System

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ABSTRACT: This study was carried out at the Experimental Farm of Faculty Agriculture (Saba- Basha), Alexandria University, Egypt, during 2016 and 2017 growing seasons to investigate the response of potato cv. Herms to water stress and organic manure fertilization under drip irrigation system. The experiments were carried out in a split plot design with three replicates. Four irrigation levels (100, 75, 50 and 25% of ET_0) were arranged in main plots and the four organic manures (control, cows, sheep, and chicken) were arranged in sub plots. The results indicated that, all vegetative growth parameters (plant height, shoot fresh and dry weights, leaf area index, and total chlorophyll) significantly affected by irrigation level and organic manure fertilization in which 100% of ET_0 and chicken manure gave the highest values. Also, the yield and its components gradually increased with increasing water supply up to 100% compared with other treatments during 2016 and 2017 seasons, such as, (tuber length, tuber diameter, average of the tuber weight, specific gravity, tuber dry weight, total tubers yield, % of marketable tubers/plant and weight of unmarketable tubers/plant, respectively). Also, increasing soil moisture contents from 75% to 100% caused a significant increase in the concentrations of N, P, K, reducing sugars, non-reducing sugars and total sugars in tubers, in both seasons. Also, a significant increase of tubers starch percentage, compared to the other treatment was observed during both seasons. On the other hand, that application of chicken manure produced the highest values of all yield and its components and chemical composition of potato plants during both seasons compared with the other organic treatments. As general, irrigation of potato at 100% of ET_0 and fertilizing with chicken manure lead to the highest values of vegetative growth and yield, thus it is recommended to use these treatments as agricultural practices in similar areas for potato production. The findings in this study strongly recommend that irrigation at 100% of reference evapotranspiration would be advantage if the farmer's target is to maximize tuber yield. But if the target is to put more area into production under limited water supply, irrigation at 75% of reference evapotranspiration in potato may be feasible.
Keywords: potato, drip irrigation, organic fertilizer, tuber yield, chemical composition

INTRODUCTION

The potato (*Solanum tuburasum L.*) is one of the staple foods of modern western civilization and is getting more important in developing countries. The potato is the fourth most important food crop in the world ranking at 365.8 million tons per year (FAOSTAT, 2014).

In Egypt, potato is cultivated in the summer, fall and winter seasons. The tremendous use of chemical fertilizers in agricultural production may deposited toxic chemicals in foods, especially in fresh vegetables. As a result, there is a demand for chemical free-food products. Many farmers and scientists in the world are becoming increasingly aware of the organic production. Challenges for organic production are management of nutrients, diseases and insects) Finckh *et al.,* 2006).

Likewise, as reported by Monirul *et al*. (2013) variation in the rate of organic manure application and inorganic fertilizers could influence the yield of potato. Organic manures and their extracts have been used to improve soil fertility and in combating pests and diseases (Barker and Bryson, 2006; Khadem *et al*., 2010).

Organic fertilizers are indispensable for vegetable cultivation in the densely populated lends due to the often low organic matter content of the arable land. This production system is an important priority area globally in view of the growing demand for safe and healthy foods and long term sustainability in addition to concerns on environmental pollution. In this system, production is based on synergism with nature which accounts for its sustainability (Sheraz *et al.,* 2010).

Drought is a severe environmental stress limiting agricultural production in many countries. However, in Egypt water availability for agriculture production is being reduced as a consequence of global climate change, and growing demand for other uses. Therefore, great emphasis is placed on water management for dry conditions based on plant physiology, with the aim of increasing water use efficiency. Maximizing irrigation water use efficiency is a common concept used by irrigation project managers; also, the visual quality of the crop yield is the primary criteria on used to assess irrigation systems effectiveness. In recent years, however, growing competition for scarce water resources has led to applying modified techniques for maximizing water use efficiency and improving crop yields and quality, particularly in arid and semi-arid regions as like Egypt (Abdelraouf *et al.,* 2013).

The expected outcome is reasonably good yields with considerable water savings and higher water use efficiency (WUE), which is very importance in areas like Egypt where water resources are limited. Subsequently, solving this scientific problem via providing the appropriate balance between both independent variables, will enhance the productivity of potato crop, and brought about the highly profits for all involved in potato crop qualitatively and quantitatively.

Thus, the present work aimed to study the effect of four irrigation levels and four organic manures fertilization on the productivity of the potato crop and quality of the potato tubers.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of the Faculty of Agriculture (Saba- Basha) at Abees region, Alexandria, Egypt, during the summer growing seasons, of 2016 and 2017 to study the response of potato plants cv. Herms to water stress and organic manure applications under drip irrigation system.

A surface soil sample (0-30cm) was collected before planting to identify some physical and chemical properties of the experimental soil (Jackson, 1973; Carter and Gregorich, 2008) and the collected data are listed in Table (1).

The used seed tubers were exported from Scotland planted on 17th and 12th of February in both seasons as a whole at 0.30 m apart in the row, 10 m long and 0.6 m width. All experimental units were (18 m^2) consisted of three rows. The organic manure were cows, sheep and chicken manures in addition to the control treatment (without organic manure application) and the irrigation treatments were 25, 50, 75 and 100% of reference evapotranspiration (ET_0).

Organic manure requirements of potato crop were added at the rate of 10 kg/plot at soil preparation. The chemical analysis of the organic manures is illustrated in Table (2) according to Peters *et al.* (2003) and Pal (2013).

Table (1). Some physical and chemical properties of the experimental soil in 2016 and 2017 seasons

Soil parameters	0-30 cm depth	30-60 cm depth	Unit
Particle size distribution			
Sand	29.7	29.7	**%**
Silt	15.0	17.5	**%**
Clay	55.3	52.8	**%**
Textural class	Clay	Clay	**-**
Organic matter content (%)	2.87	2.87	%
Total calcium carbonate	18.12	18.12	%
Electrical Conductivity (EC_{sw}), (1:1, soil: water extract) dS/m	2.98	2.29	dS/m
pH (1:1, soil : water suspension)	8.05	8.15	-
Soluble Cations:			
Ca^{2+}	1.00	0.78	meq/l
Mg^{2+}	3.29	2.15	meq/l
Na^{+}	24.45	19.48	meq/l
K^{+}	0.56	0.42	meq/l
Soluble Anions:			
$CO^{=}_{3+}$ HCO^{-3}	0.58	3.57	meq/l
Cl^{-}	21.70	15.95	meq/l
$SO^{=}_{4}$	6.80	2.70	meq/l
Available nutrients			
Nitrogen (N)	98.23	101.12	**%**
Phosphorus (P)	18.00	15.69	**%**
Potassium (K)	850	750	**%**

Table (2). Chemical analysis of the applied organic manures

Parameters	Chicken manure	Shape manure	Cow manure	unit
pH (1: 10 water suspension)	8.0	8.5	8.6	-
EC (1:10 water extract)	5.7	9.7	8.0	dS/m
Organic matter	11.7	16.4	10.5	%
Organic carbon	6.7	8.33	6.24	%
C/N ratio	8.0	8.0	4.59	
N	2.34	1.20	1.10	%
P	0.42	0.62	0.52	%
K	3.00	2.20	2.50	%

The sulphur powder was added at rate of 100 kg/fed at soil preparation. The plants were fertilized with 75 kg P_2O_5/fed in the form of mono calcium phosphate (15.5%P_2O_5), potassium sulfate (48% K_2O) at rate of 96 kg K_2O/fed was added throughout the drip irrigation system and ammonium nitrate (33.5% N) throughout the drip irrigation system at rate of 100 kg/fed. All other agricultural practices for potato production were followed as recommended in the area. Harvest was done at 28th of May in both seasons.

Vegetative growth

Ten whole plant samples per plot were randomly selected, 90 days after planting, for the determination of the following vegetative growth parameters:

- **Plant height (cm)** measured from soil surface to the terminal bud.
- **Plant fresh weight** determined by weighing the fresh material.
- **Plant dry weight** determined by drying the fresh material at 70 °C for 48 h, then weighing the dried material.
- **Leaf area index** determined using area-weight of potato leaves, and then related to surface area occupied by one plant **(**Moursi *et al.*, 1968).
- **Total chlorophyll content:** leaf sample was taken from five plants in each plot and transported to the laboratory and taken all leaves 1cm^{2} about 6-10 disks then place in the test tube and added 15ml Acetone. Leaf samples are dissolved in a chemical solution to extract the chlorophyll (a, b) and absorbance is measured using a spectrophotometer at wavelengths 663 and 645 μm (Metzner *et al.*, 1965).

Yield and yield component parameters

- **Number of tubers per plant** counted as the average number of tubers per plot area.
- **Average tuber weight (g)** calculated by dividing tuber yield of each plot by its tuber's number.
- **Tuber yield of plant (g/plant)** measured as the weight of tuber for one plant.
- **Gross tuber yield (ton/fed)** calculated and attributed to the feddan where feddan = 4000 m^2.
- **Percentage of marketable tubers (%):** all tubers characterized by its width 2 cm or more free from injuries, wounds, cracks or cuts, decays, insect infestations, secondary growth tubers are considered acceptable for marketing.

Random samples of 20 tubers per treatment were randomly used to measure the tuber specific gravity of the potato tubers which calculated by weighting a certain weight of tubers for each treatment, then the specific gravity was computed according to the following equation cited after Dinesh *et al.* (2005) as follows:

$$\text{Tuber specific gravity} = \frac{\text{Tuber weight in air}}{\text{(tuber weight in air- Tuber weight in water)}}$$

Also, **r**andom samples of 10 potato tubers were used to determine the following tuber quality characters:

- **Tuber dry matter (%)** by taking a certain weight of fresh tubers and dried at 70 °C for 48 h, then tuber dry matter was calculated as follows:
  Dry matter (%) = (Dry weight/ Fresh weight) X 100

- **Reducing and non-reducing sugars percentages (%):** known mass (5 g) of fresh tuber was taken to determine the reducing and non-reducing sugars, using sulphuric acid, phenol (5%) and Nelson arsenate –molybadate; then they were colorimetrically determined according to the method of Malik and Singh (1980).
- **Starch:** starch percentage (%) was determined using a sample of 0.1 g of the residue by hydrolysis with concentrated HCl for 3h under reflux condenser (AOAC, 1985).The total sugars was determined according to the method of Malick and Singh (1980) and the factor 0.9 was used to calculate the starch (Woodman, 1941).

Chemical composition

The N, P, and K percentages were determined in the dry tubers were determined according to Tandon (1995). The dried plant samples were milled and stored for analysis. However, 0.5g of the tubers powder was wet-digested with H_2SO_4–H_2O_2 mixture according (Lowther, 1980) and the following determinations were carried out in the digested solution:

- **Nitrogen content:** was determined colorimetrically by Nessler`s method (Chapman and Pratt, 1978).
- **Phosphorus content:** was determined by the Vanadomolyate yellow method as given by Jackson (1973) and the intensity of color developed was read in spectrophotometer at 405nm.
- **Potassium content:** was determined according to the method described by Jackson (1973) using Beckman Flame photometer.
- **Total soluble solids of tuber (TSS %)** was determined in the tuber juice as percentage by hand refractometer according to Chen and Mellenthin (1981).
- **Protein (%):** was determined by estimating the total nitrogen in the tubers and multiplied by 6.25 to obtain the protein percentage according to AOAC (1990).

Experimental design and statistical analysis

The experimental layout was presented as a split plot in a randomized complete blocks design (RCBD), with three replicates. Four irrigation levels (100, 75, 50 and 25% of reference evapotranspiration, ET_0) were assigned in the main plots and four organic manures (control, cows, sheep and chick manures) were randomly, distributed in the sub- plots. Collected data of the experiments were statistically, analyzed using the analysis of variance method. Comparisons among the means of the different treatments were done, using least significant differences (L.S.D) test procedure at p = 0.05 level of probability, as illustrated by Snedecor and Cochran (1991).

RESULTS AND DISCUSSION

Vegetative growth

Data in Tables (3 and 4) showed the effect of water stress on vegetative growth characteristics (plant height (cm), plant fresh weight (g), plant dry weight (g), leaf area index (LAI) and total chlorophyll content of potato leaves). It is clear an increased trend for these growth parameters in response to increased amounts of irrigation water. Increasing water levels up to 100 % of ET_0 produced the tallest plants (60.32 and 63.27cm), plant fresh weight (229.98 and

298.40 g), plant dry weight (45.88 and 59.61 g), leaf area index (3.52 and 3.69) and total chlorophyll content (38.45 and 39.91) during both seasons, respectively. Reducing irrigation quantity to 25% of ET_0 reduced all studied characters in descending order (44.91 and 46.97 cm) in plant height, (168.15 and 234.10 g) in plant fresh weight, (33.61 and 46.81 g) in plant dry weight, (1.68 and 1.78) in leaf area index and (32.58 and 33.92) in total chlorophyll index during both seasons, respectively. The trend of results is logic because water stress causes reduction of vegetative growth of plant through reducing of crop canopy and biomass. Also, increasing irrigation water to 1539.3 and 1681.9 m^3/fed in both seasons is necessary for maintaining of optimal soil moisture in root zone during the growing period of potato (Marutani and Cruz., 1989). Opena and porter (1999) stated that potato is relatively sensitive to moisture stress because it has a sparse root system and approximately 85% of the root length is concentrated in the upper 0.3 m soil layer.

Maintenance of photosynthetic activity under water stress is a key element of plant drought tolerance. Under water stress, photosynthesis per leaf area is mainly restricted by stomatal and mesophyll limitations, i.e., in how far CO_2 remains available for the photosynthetic apparatus, when stomatal and mesophyll conductance is kept low to avoid excessive transpiration. Only at high stress levels non-stomatal metabolically limitations, such as reduced ribulose bisphosphate carboxylase regeneration and ATP synthesis inflict carbon assimilation under drought (Parry *et al.,* 2007). The lowest values of soil moisture (25% of the ET_0) decreased all vegetative growth characters, in the two growing seasons (Tables 3 and 4). These results are in agreement with those obtained by Fabeiro *et al.* (2001), Lahlou *et al.* (2003), Rashidi and Gholani (2008) on potato.

The adverse effect of drought on plant growth may be due to the stomatal closure, which lower or prevent water loss, and reduce CO_2 availability for the chloroplast (Flexas *et al.,* 2004). Erice *et al.* (2007) showed that total dry weights of plants were significantly reduced in high field capacity soils. The growth reduction that followed drought stress may be due to a massive and irreversible expansion of small daughter cells produced by less meristematic divisions, inhibition of cell expansion. Water stress resulted in less water content in tissues, which reduce the turgor pressure of the cell, and the enlargement of the cell, causing a reduction in plant growth (Shao *et al.,* 2007).

Data in Table (1) showed the effect of deficit irrigation (DI) techniques on leaf area index and total chlorophyll. There were significant differences between values of leaf area index during two seasons 2016 and 2017. The highest values for leaf area index were under 100% ET_0 treatments and this mainly due to that contrary root signals caused by PRD would make a slight reduction of the stomatal opening that would decrease the water loss substantially with only a small effect on the photosynthesis rate, provided plant turgor is maintained by the watered fraction of the root system.

On the other side, the data illustrated in Tables (3 and 4) clearly showed that application of organic manures significantly increased all studied characteristics as compared with untreated plants. The most effective treatment in this concern was chicken manure. The highest values for plant height (60.54 and 63.29cm), plant fresh weight (239.06 and 315.28 g), plant dry weight (47.80 and 63.02 g) leaf area index (3.01 and 3.16) and total chlorophyll content (41.33 and 42.86 mg/g) were attained during 2016 and 2017 seasons, respectively.

However, vegetative growth of potato increased as the application of farmyard manure increased and this may be due to the nutrient composition of the farmyard manure. These findings are supported by the earlier work by Najm *et al.* (2013) who reported that the maximum amount of plant height was obtained using 20 ton ha^{-1} cattle manure.

The use of irrigation in organic potato production can, however, lead to negative consequences. Irrigation of plantation increases the threat of late blight and could cause the leaching of nutrients from the rhizosphere to the deeper layers of the soil. As in our research drip irrigation seems to be the ideal solution (Mazurczyk *et al.,* 2007 and Nowacki, 2013). Abou-Hussein (2005) used the organic fertilizer in the form of compost at a rate of 35.7 Mt/ha under similar conditions but with higher mineral NPK. The increase may be attributed to improved soil characters and increased organic matter and nutrients at 5 years after the start of the experiment. Abou-Zeid and Bakry (2011) found that chicken manure at 35.7 Mt/ha (216 kg/ha), in sandy soil, increased plant height, leaf number/plant, branches number/plant and shoot dry matter compared to mineral NPK fertilizers alone, which may be attributed to low rates of mineral fertilizers used (215-85-215 NPK kg/ha). Warren (2004) showed that organic manure such as cow dung improved the soil pH which facilitated nutrient uptake by the plant. Such *et al.* (2015) demonstrated that the highest values of plant height, stem diameter and leaf size were detected with plants fertilized with cow dung at the rate of 20 t/ha.

The interaction between irrigation levels and organic manure was significant with shoot fresh weight, leaf area index and total chlorophyll content in both seasons, and non- significant with plant height and shoot dry weight in first season. Also, it was not significant during both seasons on plant dry weight as shown in Table (3).

Yield and yield components

It is clear from data in Tables (5 and 6) that the yield and its components gradually increased with increasing water supply up to 100% of ET_0 during 2016 and 2017 growing seasons. In this respect, irrigation of potato plants with 100% of the reference evapotranspiration has the highest values of all studied characters. Treatment of 100% of ET_0 had superiority in all characters such as, (average of the tuber weight (75.71 and 78.57 g), tuber length (5.97 and 5.96 cm), tuber diameter (6.45 and 6.70 cm), specific gravity (1.072and 1.074, Tuber dry weight (19.86 and 20.28 g), total tubers yield (16.827and 17.25 tons/ha), weight of marketable tubers/plant (715.35 and 736.81 g) and weight of unmarketable tubers/ plant (56.98 and 55.56g), respectively, during both seasons compared with other treatments. These results are similar with those obtained by Fabeiro *et al.* (2001), Lahlou *et al*. (2003), Rashidi and Gholani (2008) and Kandil *et al.* (2011) on potato.

Table (3). Average values of the potato vegetative growth parameters of potato as affected by irrigation levels and organic manure fertilization and their interaction during 2016 growing season

		Plant height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf area index	Total chlorophyll (mg /g FW)
Main effect of irrigation level (A), % of ET_0						
100		60.32	229.98	45.88	3.52	38.45
75		54.26	218.26	43.65	2.88	36.12
50		47.96	204.42	39.75	2.26	34.93
25		44.91	168.15	33.61	1.68	32.58
LSD (0.05)		**2.05****	**4.22****	**2.23****	**0.25****	**1.52****
Main effect of organic manure (B)						
Control		43.93	174.04	34.80	2.18	30.12
Cows manure		48.82	193.49	38.71	2.43	33.46
Sheep manure		54.25	214.21	41.59	2.72	37.18
Chicken manure		60.54	239.06	47.80	3.01	41.33
LSD (0.05)		**0.11****	**1.95****	**1.8****	**0.06****	**0.08****
Interaction effect (AXB)						
Irrigation level, % of ET_0	**Organic manure**	**Plant height (cm)**	**Shoot fresh weight (g)**	**Shoot dry weight (g)**	**Leaf area index**	**Total chlorophyll (mg /g FW)**
100	Control	51.15	194.63	38.9	2.99	32.59
	Cows manure	56.83	217.66	43.13	3.32	36.22
	Sheep manure	63.15	240.3	48.05	3.69	40.24
	Chicken manure	70.17	267.15	53.43	4.10	44.76
75	Control	46.00	186.49	37.30	2.44	30.62
	Cows manure	51.12	205.16	41.03	2.71	34.03
	Sheep manure	56.80	229.06	45.83	3.01	37.81
	Chicken manure	63.11	252.31	50.46	3.35	42.02
50	Control	40.67	172.58	34.51	1.91	29.63
	Cows manure	45.18	192.45	38.99	2.12	32.91
	Sheep manure	50.21	213.99	37.80	2.4	36.57
	Chicken manure	55.78	238.65	47.69	2.62	40.64
25	Control	37.91	142.48	28.49	1.40	27.62
	Cows manure	42.15	158.49	31.69	1.56	30.69
	Sheep manure	46.83	173.49	34.68	1.78	34.1
	Chicken manure	51.51	198.12	39.6	1.97	37.89
LSD (0.05)		**n.s.**	**3.90****	**n.s.**	**0.13****	**0.16****

Table (4). Average values of the potato vegetative growth parameters of potato as affected by irrigation levels and organic manure fertilization and their interaction during 2017 growing season

		Plant height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Leaf area index	Total chlorophyll (mg/g FW)
Main effect of irrigation level (A), % of ET_0						
100		63.27	298.4	59.61	3.69	39.91
75		56.97	283.24	56.59	3.03	37.52
50		50.35	270.81	53.74	2.38	36.14
25		46.97	234.1	46.81	1.78	33.92
LSD (0.05)		**2.3****	**8.83****	**1.33****	**0.28****	**1.7****
Main effect of organic manure (B)						
Control		46.13	233.53	48.28	2.30	31.12
Cows manure		51.19	254.40	50.84	2.56	34.82
Sheep manure		56.95	283.35	56.61	2.85	38.68
Chicken manure		63.29	315.28	63.02	3.16	42.86
LSD (0.05)		**0.14****	**5.28***	**n.s.**	**0.03****	**0.30***
Interaction effect (AXB)						
irrigation level,% of ET_0	**organic manure**					
100	Control	53.7	252.45	50.44	3.12	33.89
	Cows manure	59.38	281.16	56.22	3.48	37.66
	Sheep manure	66.3	312.27	62.35	3.87	41.85
	Chicken manure	73.67	347.74	69.45	4.30	46.23
75	Control	48.3	240.53	48.00	2.61	31.85
	Cows manure	53.68	265.13	53.00	2.84	35.39
	Sheep manure	59.64	296.47	69.28	3.17	39.33
	Chicken manure	66.26	330.83	66.08	3.51	43.53
50	Control	42.69	242.7	46.97	2.01	30.03
	Cows manure	47.44	251.16	50.21	2.23	34.23
	Sheep manure	52.71	379.38	55.78	2.52	38.03
	Chicken manure	58.57	310.2	62.00	2.75	42.26
25	Control	39.83	198.43	39.7	1.47	28.73
	Cows manure	44.25	220.17	43.95	1.69	32.02
	Sheep manure	49.17	245.29	49.05	1.86	35.53
	Chicken manure	54.64	272.52	54.55	2.1	39.4
LSD (0.05)		**0.001****	**10.57***	**n.s.**	**0.07****	**0.61***

The positive effect of 100% or 75% of the reference evapotranspiration on tubers yield and its components may be attributed to the moderate soil moisture content, which led to increase in nutrient availability and its uptake, as well as a reduction in soil salinity compared to low irrigation level. Higher irrigation level increased growth parameters, which reflected as higher rates of photosynthetic processes and carbohydrates production that increased final tubers yield. Whereas, the reduction in total yield due to water deficit may be attributed to the reduction in leaf area due to fewer and small leaves, and the increase in stomatal resistance and gas exchange, as well as the reduction in transpiration rate, which all resulted in a reduction in photosynthesis (Ghosh *et al.,* 2000).

Also the exposure of plants to the water stress negatively influenced the growth of stolons, which decrease tubers number of the plant (Struik *et al.* 1990). As mentioned by Belanger *et al.* (2002), there is a reduction in tubers bulking rate by 40% in the water stress treatment than normal irrigation treatment, which causing a decline in tuber average weight. Such reduction in the rate of photosynthesis, number of tubers and average weight of tubers caused a decrease in the tuber yield, total and marketable yield of tubers. The present results agrees with (Gawish, 1992; Hegazi and Awad, 2002; Belanger *et al.*, 2002 and Al-Aubiady, 2005) who reported that exposing potato plants to water stress at tubers formation stage caused a reduction in the number of tubers, tuber average weight, tuber yield and total and marketable tuber yields.

In this respect, data in Tables (5 and 6) showed that application of chicken manure produced the highest values of all yield and its components of potato during 2016 and 2017 seasons compared with control (untreated). The increases in tuber yield may be due to the availability of N, P and K in soil through the application of organic manures (Kumar *et al.* 2008, Baishya 2009, Zaman *et al.* 2011). With observation of Al-Balikh (2008) chicken manure resulted in highest values for number of tubers/plant, total tuber yield/ha and marketable tuber yield/ha.

Enhancement of tubers yield of potato plants as a results of using the farmyard manure at different levels may be attributed to the positive effects of farmyard manure application on the vegetative growth characters of potato plants which consequently increased photosynthesis efficiency and synthesis of carbohydrates such as starch content which reflected in increasing of tubers yield of plants (Mauromicale *et al.,* 2006 and Ahmed and Quadri, 2009). Similar results were obtained by Al- Zehawi (2007) and Al-Hisnawy (2011) who used organic manure which inducing most of yield components. This was possibly due to the fact that organic manure increased soil organic matter, water holding capacity, nutrient availability, soil aggregation, root system and microbial activity (Carter *et al.,* 2001 and John *et al.,* 2002).

Table (5). Average values of potato yield and yield components as affected by irrigation levels and organic manure fertilization and their interaction during 2016 growing season

Treatments		2016 growing season									
		Average tuber weight (g)	Tuber length (cm)	Tuber diameter (cm)	Gross yield (ton/fed)	Tuber yield g/plant	Weight of unmarketable tuber g/plant	Weight of marketable tuber g/plant	marketable Tuber (%)	Specific gravity	Tuber dry matter (%)
Main effect of irrigation level (A), % of ET_0											
100		75.71	5.97	6.45	16.83	757.94	40.89	715.35	94.76	1.072	19.86
75		71.94	5.63	5.97	15.97	718.38	47.63	673.00	93.643	1.074	19.62
50		66.34	5.08	5.56	14.57	655.40	52.24	603.41	92.92	1.069	19.37
25		63.20	4.70	4.80	13.97	628.46	56.98	571.22	91.19	1.070	19.00
LSD (0.05)		**1.83****	**0.21****	**0.29****	**0.17****	**5.9****	**2.12****	**8.32****	**1.8****	**0.0017****	**n.s.**
Main effect of organic manure (B)											
Control		58.45	4.53	4.96	13.36	602.60	57.60	543.30	90.8	1.068	19.34
Cows manure		65.40	5.04	5.40	14.57	655.48	51.36	603.67	92.45	1.073	19.45
Sheep manure		72.63	5.60	6.05	15.95	717.19	46.63	670.74	93.753	1.074	19.47
Chicken manure		80.72	6.22	6.37	17.44	784.99	42.15	745.27	9.88	1.071	19.59
LSD (0.05)		**0.58****	**0.01****	**0.26****	**0.07****	**4.4****	**0.81****	**0.51****	**1.2***	**0.0035****	**n.s.**
Interaction effect (AXB)											
Irrigation level, % of ET_0	**Organic manure**										
100	Control	64.18	5.06	5.48	14.58	660.87	47.56	606.56	93.2	1.072	19.27
	Cows manure	71.31	5.63	6.09	15.93	716.77	42.80	673.96	94.35	1.072	19.50
	Sheep manure	79.23	6.25	6.77	17.54	787.38	38.53	748.85	95.38	1.072	20.47
	Chicken manure	88.11	6.95	7.47	19.26	866.72	34.67	832.05	96.22	1.073	19.22
75	Control	60.97	4.77	5.06	13.91	626.06	55.40	570.65	91.16	1.070	19.00
	Cows manure	67.88	5.30	5.63	15.20	683.93	49.86	634.05	93.26	1.08	19.00
	Sheep manure	75.28	5.89	6.25	16.66	749.38	44.88	704.51	94.34	1.076	18.90
	Chicken manure	83.65	6.55	6.95	18.09	814.17	40.39	782.79	95.36	1.072	19.12
50	Control	55.07	4.31	4.78	12.72	572.52	60.87	511.64	89.92	1.063	19.65
	Cows manure	62.86	4.79	5.40	13.85	623.14	54.64	568.50	91.69	1.070	19.50
	Sheep manure	69.84	5.32	6.01	15.11	680.1	49.18	631.66	93.162	1.072	18.85
	Chicken manure	77.60	5.92	5.98	16.58	746.12	44.26	701.85	94.39	1.072	19.47
25	Control	53.59	3.99	4.45	12.24	550.94	66.57	484.34	88.53	1.068	19.97
	Cows manure	59.54	4.43	4.49	13.29	598.07	58.15	538.16	90.5	1.08	20.37
	Sheep manure	66.16	4.92	5.19	14.49	651.88	53.92	597.96	92.16	1.070	19.57
	Chicken manure	73.51	5.47	5.10	15.84	712.93	48.53	664.40	93.56	1.067	19.52
Interaction LSD (0.05)		**	*	*	**	n.s.	**	**	**	n.s.	n.s.

* Significant at 0.05 level of probability, ** Significant at 0.01 level of probability and ns not significant

Table (6). Averages values of potato yield and yield components as affected by irrigation levels and organic manure fertilization and their interaction during 2017 growing season

Treatments		2017 growing season									
		Average tuber weight (g)	Tuber length (cm)	Tuber diameter (cm)	Gross yield (ton/fed)	Yield weight g/plant	Weight of unmarketable tuber g/plant	Weight of marketable tuber g/plant	marketable Tuber (%)	Specific gravity	Tuber dry matter (%)
Main effect of irrigation level (A), % of ET_0											
100		78.57	5.96	6.70	17.25	757.94	39.69	736.81	94.23	1.074	20.28
75		74.65	5.82	6.21	16.44	718.38	46.25	693.19	93.5	1.013	20.07
50		69.26	5.21	5.81	14.94	655.47	50.68	621.51	91.85	1.070	19.84
25		65.76	4.84	5.45	14.31	628.455	55.56	583.85	90.7	1.074	19.30
LSD (0.05)		**1.48****	**0.45****	**0.24****	**0.20****	**1.2****	**1.84****	**9.19****	**1.6****	**n.s**	**0.60***
Main effect of organic manure (B)											
Control		62.20	4.67	5.14	13.68	602.6	55.89	559.60	90.05	1.010	19.57
Cows manure		68.99	5.19	5.68	14.93	655.48	50.29	621.77	91.98	1.073	19.72
Sheep manure		76.65	5.58	6.32	16.36	717.19	45.27	690.83	93.41	1.074	19.82
Chicken manure		80.40	6.40	7.03	17.97	784.99	40.47	763.13	94.85	1.073	20.36
LSD (0.05)		**4.65****	**0.27****	**0.04****	**0.02****	**4.3****	**0.13****	**6.32****	**1.6****	**n.s.**	**0.54***
Interaction effect (AXB)											
Irrigation level, % of ET_0	**Organic manure**										
100	Control	69.61	5.21	5.70	14.91	670.935	46.17	624.76	91.78	1.074	19.87
	Cows manure	76.27	5.79	6.25	16.35	735.727	41.55	694.17	94.03	1.073	20.00
	Sheep manure	84.75	5.69	7.04	17.97	808.71	37.40	771.31	95.107	1.075	19.25
	Chicken manure	83.66	7.16	7.82	19.79	890.673	33.66	857.01	95.99	1.074	20.25
75	Control	65.14	4.91	5.26	14.26	641.565	53.79	587.77	91.15	1.080	19.32
	Cows manure	72.38	5.55	5.85	15.56	700.237	48.41	653.07	92.71	1.076	18.62
	Sheep manure	80.42	6.07	6.50	17.12	769.212	43.57	725.64	94.01	1.075	19.00
	Chicken manure	80..65	6.74	7.22	18.83	845.485	39.21	806.27	96.14	1.076	20.25
50	Control	58.32	4.44	4.93	12.53	585.95	58.96	528.99	89.37	1.069	19.37
	Cows manure	65.37	4.85	5.49	14.19	638.605	53.06	585.55	91.23	1.069	20.40
	Sheep manure	72.63	5.48	6.07	15.52	698.365	47.75	650.61	92.76	1.072	20.05
	Chicken manure	80.71	6.09	6.75	17.02	765.883	42.97	722.90	94.06	1.072	20.45
25	Control	55.73	4.11	4.66	12.53	563.50	64.63	498.87	87.91	1.074	20.70
	Cows manure	61.92	4.56	5.12	13.62	612.47	58.16	554.30	89.98	1.075	19.87
	Sheep manure	68.80	5.07	5.69	14.85	668.247	52.53	615.90	91.73	1.075	19.97
	Chicken manure	76.57	5.63`	6.33	16.26	731.445	47.11	666.33	93.19	1.071	20.50
Interaction LSD (0.05)		**n.s.**	**n.s.**	**	**	**	**	**	**n.s**	**n.s.**	**n.s.**

* Significant at 0.05 level of probability, ** Significant at 0.01 level of probability and ns not significant

Tuber chemical composition

Data presented in Tables (7 and 8) showed that irrigation potato up to 100% of ET0 significantly ($p<=0.01$) increased all chemical composition during the both growing seasons.

Increasing irrigation level from 75% to 100% of ET_0 caused a significantly increase in the concentrations of N, P, K, reducing sugars, non-reducing sugars and total sugars in tubers, in both seasons. Also, it caused a significant increase in the concentrations of vitamin C (mg/100 g f. w.) and tubers starch percentage, compared to the other treatment during both seasons. Similar results were reported by Fatahallah *et al.* (2014), Midan and Tantawy (2013) on snap beans and Ahmed *et al.* (2013) on pepper plants.

On the other hand, application of chicken manure produced the highest values of all chemical composition of potato during both growing seasons. Atti and Al-Sahaf (2007) reported that using organic fertilizer (poultry manure) led to increase the percentage of mycorrhiza colonies in potato roots which attributed to the manure containing of unspecified types of mycorrhiza spores, which participate increase in the proportion of roots injury, also organic manure contains some fungi such as *Trichoderma spp.* that share with mycorrhiza fungi in positive interactions to stimulate growth (Abou EL-Khair *et al.,* 2011). Also, Ahmed *et al.* (2015) reported that increasing of farmyard manure levels enhanced starch percentage, crude protein percentage.

Organic material is used to prevent or improve the negative stresses effects on plants and yield decreasing. Increasing the organic matter, improve the soil structure and increase water and air permeability by root developing in soil (Hassanpanah and Azimi, 2012).

Many researchers have mentioned the beneficial effects of organic fertilizer including the increase of hydraulic conductivity, raising the water holding capacity, changing the soil pH (increase or decrease in the pH, depending on soil type and characteristics of organic fertilizer). Asiegbu and Oikeh (1995) elevated the soil aggregation and water infiltration, reducing the frequency of plant diseases. (Tagoe *et al.,* 2008). So, the use of animal manure has been reported as a potential factor for better vegetative growth and increased tuber yield (Najm *et al.,* 2013). The use of animal manure has been reported as a potential factor for better vegetative growth and increased tuber yield (Najm *et al.,* 2013).

In general, using of organic manures is very important not only for increasing the potato yield but also for maintaining soil health. Then, irrigation of potato at 100% of ET_0 and fertilizing with chicken manure lead to the highest values of vegetative growth and yield, thus it is recommended to use these treatments as agricultural practices in similar areas for potato production

Table (7). Chemical composition of potato tuber as affected by irrigation level, organic manure fertilization and their interaction during 2016 growing season

Treatments		2016 season						
		N (%)	P (%)	K (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Starch (%)
Main effect of irrigation level (A), % of ET_0								
100		2.04	4.17	0.68	0.74	0.144	0.597	13.7
75		1.20	4.00	0.61	0.71	0.135	0.582	13.49
50		1.86	3.75	0.54	0.68	0.121	0.560	13.26
25		1.77	3.52	0.53	0.66	0.109	0.545	12.93
LSD (0.05)		0.04**	0.03**	0.03**	0.01**	0.01**	0.01**	n.s
Main effect of organic manure (B)								
Control		1.61	3.27	0.49	0.599	0.11	0.485	13.24
Cows manure		1.79	3.64	0.55	0.657	0.12	0.533	13.34
Sheep manure		1.99	4.04	0.63	0.730	0.13	0.599	13.35
Chicken manure		2.21	4.49	0.70	0.812	0.14	0.665	13.46
LSD (0.05)		**0.01****	**0.01****	**0.01****	**0.10****	**0.01****	**0.01****	**0.26***
Interaction effect								
Irrigation level, % of ET_0	**Organic manure**							
100	Control	1.72	3.53	0.605	0.626	0.121	0.507	13.18
	Cows manure	1.92	3.93	0.747	0.696	0.135	0.561	13.38
	Sheep manure	2.13	4.37	0.832	0.773	0.150	0.625	14.24
	Chicken manure	2.37	4.85	0.527	0.861	0.169	0.694	13.13
75	Control	1.62	3.39	0.585	0.605	0..139	0.493	12.93
	Cows manure	1.81	3.77	0.652	0.673	0.119	0.548	12.93
	Sheep manure	2.01	4.19	0.727	0.748	0.132	0.609	12.85
	Chicken manure	2.23	4.66	0.472	0.831	0.151	0.677	13.04
50	Control	1.58	3.18	0.525	0.599	0.113	0.474	13.43
	Cows manure	1.75	3.54	0.582	0.639	0.111	0.528	13.38
	Sheep manure	1.95	3.93	0.650	0.709	0.123	0.586	13.69
	Chicken manure	2.17	4.37	0.422	0.788	0.137	0.651	13.53
25	Control	1.50	2.98	0.480	0.560	0.093	0.467	13.8
	Cows manure	1.67	3.32	0.535	0.622	0.103	0.494	14.15
	Sheep manure	1.86	3.69	0.592	0.691	0.114	0.576	13.44
	Chicken manure	2.07	4.10	0.540	0.768	0.127	0.641	13.39
Interaction LSD (0.05)		**	**	**	n.s.	n.s.	n.s.	n.s

Table (8). Chemical composition of potato tuber as affected by water stress and organic manure application and their interaction during 2017 growing season

Treatments		2017 season						
		N (%)	P (%)	K (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Starch (%)
Main effect of irrigation level (A), % of ET_0								
100		2.12	4.34	0.75	0.78	0.15	0.63	14.08
75		2.00	4.16	0.65	0.76	0.14	0.62	13.89
50		1.93	3.90	0.58	0.72	0.12	0.59	13.68
25		1.82	3.66	0.534	0.70	0.11	0.59	13.2
LSD (0.05)		**0.13****	**0.03****	**0.03****	**0.004****	**0.005****	**0.01****	**0.8****
Main effect of organic manure (B)								
Control		1.67	3.40	0.53	0.627	0.11	0.514	13.44
Cows manure		1.86	3.79	0.59	0.696	0.12	0.571	13.5
Sheep manure		2.11	4.20	0.66	0.774	0.14	0.642	13.67
Chicken manure		2.23	4.67	0.73	0.860	0.15	0.706	4.14
LSD (0.05)		**0.10****	**0.005****	**0.003****	**0.001****	**0.001****	**0.01****	**0.02****
Interaction effect								
Irrigation level, % of ET_0	**Organic manure**							
100	Control	1.79	3.67	0.635	0.664	0.128	0.535	13.71
	Cows manure	1.99	4.11	0.702	0.734	0.143	0.594	13.83
	Sheep manure	2.22	4.54	0.785	0.819	0.159	0.661	13.16
	Chicken manure	2.46	5.04	0.872	0.912	0.177	0.735	14.04
75	Control	1.68	3.52	0.550	0.642	0.119	0.523	13.22
	Cows manure	1.89	3.92	0.615	0.713	0.132	0.581	12.6
	Sheep manure	2.09	4.35	0.682	0.793	0.147	0.647	12.93
	Chicken manure	2.32	4.84	0.757	0.881	0.163	0.721	14.05
50	Control	1.64	3.31	0.490	0.608	0.106	0.502	13.26
	Cows manure	1.82	3.68	0.547	0.677	0.117	0.559	14.18
	Sheep manure	2.03	4.08	0.602	0.751	0.130	0.622	13.87
	Chicken manure	2.25	4.54	0.680	0.835	0.145	0.690	14.22
25	Control	1.56	3.10	0.450	0.593	0.098	0.495	14.45
	Cows manure	1.74	3.45	0.500	0.659	0.112	0.551	13.71
	Sheep manure	2.10	3.83	0.560	0.732	0.120	0.638	13.8
	Chicken manure	1.90	4.26	0.625	0.812	0.134	0.679	14.27
Interaction LSD (0.05)		**ns**	******	********	******	******	**ns**	**ns**

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الملخص العربي

إستجابة البطاطس لمستويات مياه الرى والتسميد بالأسمدة العضوية تحت نظام الرى بالتنقيط

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أجريت تجربتان حقليتان في مزرعة كلية الزراعة (سابا باشا) جامعة الأسكندرية خلال موسمي ٢٠١٦، ٢٠١٧ وذلك لدراسة تأثير إستجابة البطاطس لمستويات مختلفة من الرى والتسميد بالأسمدة العضوية تحت نظام الرى بالتنقيط، كانت معاملات الرى (٢٥، ٥٠، ٧٥، ١٠٠% من البخر نتح المرجعي المحسوب من بيانات الارصاد الجوية). اما معاملات التسميد العضوي (سماد الدواجن – سماد الابقار – سماد الخراف) والتى أضيفت بالمعدلات الموصى بها بالاضافة الى معاملة الكنترول (بدون اضافة سماد عضوى). وكان تصميم التجربة قطع منشقة مرة واحدة مع ثلاث مكرارات.

وقد أوضحت النتائج مايلي:

١. تأثرت عناصر النمو الخضرى (طول النبات – الوزن الاخضر والجاف للمجموع الخضرى – دليل مساحة الاوراق – الكلوروفيل الكلى) معنويا بمستويات الرى واضافة الاسمدة العضوية حيث اعطى مستوى الرى ١٠٠ من البخر نتح المرجعى مع سماد الدواجن اعلى القيم.

٢. أدى الري بمعدل ١٠٠% من البخر نتح المرجعى إلي الحصول علي أفضل القيم لصفات المحصول ومكونات المحصول (متوسط وزن الدرنة، قطر وطول الدرنة، المحصول /نبات، المحصول /فدان، وزن الدرنات الصالحة للتسويق، وزن الدرنات غيرالصالحة للتسويق)، أيضاً أعلي القيم للمكونات الكيماوية مقارنة بالمعاملات الآخري في كلا الموسمين.

٣. التسميد العضوي بسماد الدواجن أدى الى الحصول علي أفضل القيم لصفات المحصول ومكونات المحصول كذلك أعلي القيم للمكونات الكيماوية مقارنة بالمعاملات الآخري في كلا الموسمين.

نتائج الدراسة الحالية توصى برى البطاطس عند ١٠٠% من البخر– نتح المرجعى اذا كان هدف المزارع الحصول على اقصى محصول, لكن اذا كان هدف المزارع توفير مياه الرى لاستخدامها لزراعة مساحات اخرى خاصة فى المناطق محدودة الموارد المائية فانه يمكن التوصية بالرى عند ٧٥% من البخر– نتح المرجعى.