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Arab Univ.
J. Agric. Sci.,
Ain Shams Univ.,
Cairo, 22(1), 29-41, 2014

MAXIMIZING POTATO PRODUCTION VIA NITROGEN FERTILIZATION AND PLANT SPACING

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Keywords: Potato, Nitrogen, In row spacing, Chemical analysis, Marketable yield, Net income

ABSTRACT

The potato plants (*Solanum tuberosum* L.) *vs.* valor were exposed to different levels of nitrogen fertilizer (60, 100, 140, 180 kg N/feddan (4200 m^2)) and in-row plant spacing (12.5, 25 and 50 cm) for maximizing the yield production to match food security needs under climate change impacts on Delta region, Egypt. The experiment was carried out during two growing seasons (2010/2011 and 2011/2012) in split plot design at El-Bossily Farm, Agricultural Research Center, El-Behira Governorate, Egypt. The vegetative growth characteristics and yield parameters were measured. The result of this study verified that increasing nitrogen level up to 180 kg N/feddan significantly increased the vegetative growth, total and marketable yields than the other N treatments. The in-row plant spacing 50 cm was significantly increased vegetative growth and yield (kg/plant), but the total yield (kg/m^2) had different trend. The highest total yield /m^2 was obtained by 12.5 cm treatment. The interaction effect of 180 kg/feddan of N and 12.5cm in-row plant spacing were increased the total tuber yield (kg/m^2) significantly. In contrary, the best marketable yield (tubers > 35 mm) /m^2 was obtained by 25 and 50 cm in-row plants. This study was concluded that the best agronomic practices for potato production obtained by application 180 kg N/feddan of with in-row plant spacing 25 cm treatment. The economical consideration of the different treatments showed that the best total net income was obtained by 180 kg/feddan N with 50 cm in-row plant spacing.

(Received October 30, 2013)
(Accepted February 5, 2014)

1. INTRODUCTION

The global climate is changing, and agriculture will need to adapt to the changes to ensure sustainability and survival. Agriculture will also have to contribute to the mitigation of climate change (**IPCC, 2007**). Many researchers had studied the climate change impacts (temperature and CO2 increase, extreme weather events, drought and etc.) on water use efficiency, nitrogen management and production of potato (**Rosenzweig *et al* (1996), Holden and Brereton (2006), Daccachea *et al* (2011) and Xiao *et al* (2013)**).

The potato (*Solanum tuberosum* L.) is one of the most widely grown tuber crops in the world and contributes immensely to human nutrition and food security (**Karim *et al* 2010**). **Rahemi *et al* (2005)** indicated that the yield of potatoes, as other crops, is dependent on many factors like the amount of available nutrients in the soil, plant spacing, cultivars etc. The rate of N applied to irrigated potatoes primarily depends on the cultivar and date of harvest, expected yield goal, amount of soil organic matter, and the previous crop. Response to N by potato is typical to other crops of the first increment of fertilizer usually brings about the greatest response in yield, followed by a more gradual increase with succeeding N increments. As the N rate increases, however, the potential for losses also increases. In addition to environmental concerns due to excessive N applications, high rates of N can detrimentally affect potato production by promoting excessive vine growth, delaying tuber maturity, reducing yields, decreasing specific gravity, increasing brown center and inducing knobby, malformed and hollow tubers **(Abo-Hussein, 1995).** Selecting a realistic N rate is therefore important for both production and environmental standpoint. Unfortunately, the effect of excess N on tuber quality is dependent on soil moisture and temperature as well as the cultivar grown. **Haase *et al* (2007)** found that tuber N uptake and nitrate concentration were significantly influenced by amount of nitrogen fertilizer. Also, nitrogen uptake increases number of tubers per plant, tuber weight, qualitative and quantitative aspects of tuber. Limitation of Nitrogen can considerably reduce the growth of potato plant and the tuber yield. So that, for beneficial growth and maximum tuber yield, Nitrogen must be added in organic or inorganic form **(Goffart *et al* 2008)**. Mineral Nitrogen fertilization can increase shoot weight, leaf area, plant height and subsequently total yield of potato **(Zelalem *et al* 2009)**.

Maher, (2002) reported that with increasing plant density, the mean tuber weight decreased, and in low densities the number of harvested tubers decreased. Increasing the plant density led to the decrease of mean tuber weight and tuber number and yield per unit area (**Somarin *et al* 2010**). **Rahemi *et al* (2005)** reported that, the intra-row spacing had a marked effect on yield. Increasing the density can increase the yield in three ways. First, the green leaves will cover the soil earlier and will absorb more sunlight and lead to more assimilation. Second, few lateral shoots will grow and the third is that the growth of tubers will start earlier (**Kishorekumar *et al* 2006**). The results of soil analysis showed that the amount of organic carbon, which can supply part of the N required by the plant is low, therefore the crop showed a good response to nitrogen fertilizer and with increasing fertilizer, the yield increased too (**Galeev, 1993; Zavalin & Gremitskikh, 1994**). On the other hand, as plant density increases, the yield per plant decreases. This effect is due to the increase in inter-plant competition for water, light and nutrients (**Arsenault *et al* 2001**). The plant density in potato affects some of the important plant growth such as total yield, tuber size distribution and tuber quality (**Mayer, 2002 and Samuel *et al* 2004).**

Gronowicz *et al* (1990) studied the effect of seed spacing on rows and N fertilizer rate (70-100 kg N ha-1) on Duet cultivar. They concluded that yield increased with choosing lesser seed spacing and higher N fertilizer rates. Many scientists have studied the effect of N fertilizer rates and seed spacing on yield of potato cultivars. Singh (1995) applied different N treatments on potatoes and found that the best N fertilizer rate is 200 kg N ha-1 and produced highest yield. **Iqbal *et al* (1999)** in a farm experiment obtained the highest yield with 250 kg N ha-1. **Barakat *et al* (1994)** also found that Diamant cultivar produced highest yield and dry matter with 285 kg N ha-1.

Khan, (1993) studied the effect of seed spacing on rows from 10 to 20 cm in Diamant cultivar. The same author concluded that the yield decreased with increasing seed spacing. **Rajadurai (1994) and Negi *et al* (1995)** established an experiment to compare intra-rows spacing on potato yield. He concluded that increasing the seed spacing from 20 to 50 cm decreased the yield, and highest yield obtained with 20 cm seed spacing.

The main objective of this work is to maximize potato productivity, by the study of the effect of different nitrogen rates and plant spacing, in order to match food security needs under climate change impacts,

2. MATERIALS AND METHODS

2.1. Experimental site

The experiment was carried out at the El-Bossily Farm, El-Behira Governorate, in the North West of the Nile delta of Egypt during the winter period of the 2010/2011 and 2011/2012 seasons. El-Bossily Farm is located at latitude 31.40° N and longitude 30.40 °E with an altitude of 3 m above sea level. The average temperature in November ranges from 17°C to 23˚C, while in December it ranges from 12˚C to 19°C and in January it ranges from 9°C to 15°C.

2.2. Plant material

The potato (*Solanum tuberosum* L.), cv., "Valore" cultivar, was cultivated at the middle of October and harvested at the middle of February, for the first and second seasons, in a sandy soil. The tubers were treated with fungicide, to protect the germination from fungal infection, and exposed to indirect light, to get successful germination, for 10 - 14 days before cultivation. The plants were grown in lines with 0.75 m between every two lines with different distances between in-row plants.

2.3. The experimental treatments & design

Two factors were investigated under this study: The first involved four Nitrogen levels (N1 (60 kg/ feddan), N2 (100 kg/ feddan), N3 (140 kg/ feddan) and N4 (180 kg/ feddan)) combined with the second factor of in-row plant density with three in-row seed distances (D1, 12.5 cm (10.7 plant m^2), D2, 25 cm (5.3 plant m^2) and D3, 50 cm (2.7 plant m^2)). The experiment was set up as a 4 x 3 factorial arranged in a split-plot design (SPD). The N applications located as main plot while the in-row plant distance as sub plot with three replications in each treatment. Thus, there were 12 treatment combinations. The plot area performed in 12 rows x 20 m length to take an area of 180m^2. **Table (1)** show the average soil analysis of the experiment before cultivation during the two tested seasons.

Table 1. Analysis of soil chemical and physical properties of the experiment before cultivation

Chemical properties							
EC dS/m	pH	Ca^{++} meq/l	Mg^{++} meq/l	Na^+ meq/l	K^+ meq/l	HCO_3^- meq/l	Cl^- meq/l
3.00	7.89	30	10	14.26	1.66	2.5	12.6
Physical properties							
Sand %	Silt%	Clay %	Texture	FC %	PWP %	Bulk density g/cm^3	
95.31	0.40	4.30	Sandy	16.7	5.65	1.44	

Ammonium nitrate (33% N) was the nitrogen source that used in this study. The different nitrogen applications began after 3 weeks of transplanting and stopped 4 weeks before harvesting. The application of Ammonium nitrate was done two times per week and the amount varied according to the growth stage of potato.

2.4. Plant and climate measurements

Samples of three plants from each experimental plot were taken to determine growth parameters after 70 days from planting as follows: plant height, number of leaves, number of brunch per plant, canopy fresh and dry weight. The yield component was measured at the end of the season as follows: tubers weight (g/m^2 and g/plant) and the number of tubers/m^2, as well as marketable yield (tubers > 35 mm). Daily maximum and minimum air temperature and relative humidity were recorded from El-Bossily farm metrological station.

2.5. Nutrient tested

The N, P, K contents were determined in leaf samples dried at 70ºC in an air forced oven for 48 h . Blades of 20 fully mature leaves were collected from each replicate for chemical analysis. Samples of leaves were taken 60 days from planting date at the two seasons. Dried leaves were digested in H_2SO_4 and the following mineral contents were estimated: phosphorous and potassium in the acid digested solution by colorimetric method (Ammonium Molybdate) using spectrophotometer and flame photometer **(Chapman and Pratt, 1961**). Total nitrogen was determined by Kjeldahl method according to the procedure described by (**FAO 1980**).

2.6. Data analysis

Collected data was analyzed using SAS Statistical program. Data were subjected to analysis of variance (ANOVA) at $P<0.05$ according to **Steel and Torrie (1980)** while significant differences were detected, using mean separation, by **Waller and Duncan (1968).**

2.7. Economical considerations

The economical analysis after considering the cost of potato tuber seed application per feddan (4200 m^2) was determined. The incomes from potato yield were used according to the formula **(CIMMYT, 1988)**:

Net Income = value of obtained yield - cost of cultivation inputs and practices;

2.8. Agriculture practices

Potato plants were irrigated using drippers of 4 l/hr capacity. The chemical fertilizers were injected within irrigation water system. The fertigation was programmed to work 2 times/day and the duration of irrigation time depended upon the season.

All other agricultural practices of potato cultivation were in accordance with standard recommendations for commercial growers by the Ministry of Agriculture, Egypt.

3. RESULTS AND DISCUSSION

3.1. The effect of different N levels and in-row spaces on potato vegetative growth

The effect of different nitrogen levels and plant spacing on vegetative growth characters is illustrated in **Table (2)**. Increasing nitrogen level led to the increase of potato vegetative growth. The highest vegetative growth in terms of plant height, number of leaves, number of branches and fresh and dry weight was obtained using the highest nitrogen level (180 kg/feddan) followed by 140 kg/feddan. The lowest vegetative growth was obtained using the lowest nitrogen level treatment (60 kg/feddan).

Table 2. The effect of different nitrogen levels and plant spacing on vegetative growth characters in seasons 2010/2011 and 2011/2012

N levels	2010/2011				2011/2012			
	Plant in-row spaces				Plant in-row spaces			
	Plant height (cm)							
kg/Feddan*	**12.5 cm**	**25 cm**	**50 cm**	**Mean**	**12.5 cm**	**25 cm**	**50 cm**	**Mean**
60	53.0de	52.4ef	47.0g	**50.8C**	58.3de	57.2ef	51.7g	**55.7D**
100	54.2cd	52.7de	51.2f	**52.7C**	59.4cd	58.2de	56.1f	**57.9C**
140	57.8b	55.0c	54.2cd	**55.6B**	62.7b	60.5c	59.4cd	**60.9B**
180	63.2a	58.3b	55.4c	**58.9A**	69.3a	63.8b	60.5c	**64.5A**
Mean	**57.1A**	**54.6B**	**51.9C**		**62.4A**	**59.9B**	**56.9C**	
	No. of leaves/plant							
60	28.2h	32.3g	38.2e	**32.8D**	25.2h	30.7g	40.2e	**38.9D**
100	31.5g	36.1f	40.3e	**35.9C**	32.8f	40.3e	43.5cd	**30.7C**
140	38.7e	42.4d	44.0c	**41.7B**	40.3e	42.4d	43.5cd	**42.1B**
180	42.7cd	49.1b	54.4a	**48.7A**	44.5c	51.9b	57.8a	**54.8A**
Mean	**35.2C**	**39.9B**	**44.2A**		**34.7C**	**41.3B**	**48.8A**	
	No. of branches/plant							
60	4.0i	4.3h	5.5d	**4.7C**	4.3i	4.5h	5.7d	**4.9C**
100	4.3h	4.5g	5.6c	**4.8C**	4.5h	4.7g	5.8d	**5.0C**
140	4.6g	5.1e	6.3b	**5.3B**	4.8g	5.3e	6.6b	**5.6B**
180	4.9f	5.8c	7.0a	**5.9A**	5.1f	6.0c	7.3a	**6.1A**
Mean	**4.5C**	**4.9 B**	**6.1A**		**4.6C**	**5.1B**	**6.4A**	
	Canopy Fresh weight (g/plant)							
60	294f	325e	332d	**325D**	300f	329e	338d	**322D**
100	319e	325e	338cd	**340C**	326e	330e	345cd	**333 C**
140	338cd	343c	357b	**325B**	345cd	351c	364b	**353B**
180	344c	363b	394a	**367A**	351c	370b	402a	**374A**
Mean	**324C**	**339B**	**355A**		**330C**	**345B**	**362A**	
	Canopy dry weight (g/plant)							
60	38.5h	42.4g	43.2f	**41.4D**	39.0i	43.1g	44.1f	**42.1**
100	41.9g	44.8de	43.9ef	**43.6C**	42.2h	43.2g	44.9e	**43.5**
140	44.3e	45.4d	46.4c	**45.4B**	44.9e	45.7d	47.4c	**46**
180	44.8de	47.2b	51.3a	**47.8A**	45.7d	48.2b	52.3a	**48.7**
Mean	**42.4C**	**44.9B**	**46.2A**		**42.9C**	**45.1B**	**47.2A**	

* Feddan = 4200 m^2

As for potato number of leaves, number of branches and canopy fresh and dry weight per plant under different in-row plant spacing, differences among the studied treatments were significant. Increasing distance between plants from 12.5 to 50 cm led to the increase in vegetative growth during the two studied seasons. Plant height had a different trend, the 12.5 cm in-row plant spacing had the highest plant height value followed by 25 cm treatment. The lowest plant height was obtained with 50 cm in-row plant spacing.

There were significant differences among the interaction effect between different nitrogen levels and different in-row plant spacing. The highest vegetative growth characters obtained using 180 kg/feddan combined with 50 cm in-row plant spacing. Except plant height treatment, the best combination was 180 kg/feddan of nitrogen with 12.5 cm in-row plant spacing **(Table 2)**.

3.2. The effect of different N levels and in-row spaces on Potato tuber yield

As for potato tubers yield, differences among the nitrogen level treatments were significant. Increasing nitrogen application from 60 to 180 kg/feddan led to the increase in tubers weight during the two studied seasons. The same trend was true for the total yield and marketable yield (tubers diameter > 35 mm) per square meter.

Regarding the effect of different plant spaces on potato tubers yield per plant, data showed that 50 cm plant space had the highest significant potato yield per plant in comparison with other in row plant spacing treatments during the two studied seasons as presented in **Table (3)**.

The tubers yield per square meter had another trend. The 12.5 cm in row plant spacing gave the highest total tubers yield followed by 25 cm. The lowest yield was obtained by 50 cm in row plant spacing treatment.

Table (3) illustrated that the marketable yield per square meter had a different trend. The highest marketable yield gained by 25 and 50 cm plant space without significant differences. The lowest marketable yield obtained by 12.5 cm. This means that the 12.5 cm in-row plant spacing led to the increase in total tubers yield with a decrease in marketable yield.

Regarding the interaction effect between different nitrogen levels and plant spacing as presented in **Table (3)**, there were significant differences among studied treatments in the two studied seasons. The highest tuber yield per plant obtained using 180 kg/feddan nitrogen level with 50 cm in-row plant spacing, while the lowest yield per plant was obtained using 60 kg/feddan combined with 12.5 cm plant space. The tuber yield per square meter had another trend. The highest yield was obtained with 12.5 cm plant spacing combined with 180 kg/feddan. Finally, the highest marketable yield per square meter was obtained with 25 and 50 cm plant spacing combined with 180 kg/feddan nitrogen level.

3.3. The effect of different N- levels and in-row spaces on nutrient content (%) of potato leaves

The effect of different N- levels on nutrient content of potato leaves are illustrated in **Table (4)**. Data showed that increasing nitrogen from 60 to 180 kg/feddan led to the increase n N, P and K (%) contents of potato leaves.

As for N, P and K (%) contents of potato leaves, differences among the studied treatments were significant. Longer plant in-row spacing led to the increase in N, P and K (%) in potato leafs during the two studied seasons.

Referring to the combination between different nitrogen levels and in-row plant spacing, at 180 kg/feddan nitrogen combined with 50 cm in-row spacing had the highest values of N, P and K (%) in potato leaves. The lowest measurements of N, P and K (%) contents were obtained by the application of 60 kg/feddan nitrogen level combined with 12.5 cm in-row plant spacing.

3.4. Relationship between yield of tubers /feddan and nitrogen levels for potato plants

When the data of marketable tubers yield per feddan were regressed against the different levels of nitrogen, a linear relationship was obtained between them **(Fig.1)**. The equation was:

$$y = 28.53x - 127.55$$

This equation gave a good fit to the data, and the co-efficient of determination (R^2= 0.995) showed that the increase in marketable tuber yield per feddan occurred with the application of high levels of nitrogen and was justifiable until 180 kg/ feddan N.

3.5. Relationship between yield of tubers/ feddan and plant spacing in Potato

A positive linear relationship was observed between marketable yield of tubers per feddan and plant spacing when the data was regressed **(Fig. 2)**. The equation was:

$$y = 29.619x - 227.74$$

On the other hand, the equation gave a good fit to the data and the value of the co-efficient of determination (R^2 = 0.631) and showed that the fitted regression line had a significant regression coefficient. The increase in marketable tuber yield per feddan occurred for in-row spacing up to 50cm.

3.6. The Economic consideration of different treatments

The costs of using different nitrogen level and in-row plant spacing for potato are shown in **Tables (5) and (6)**. The economic consideration considered the cost of nitrogen fertilizer in ammonium nitrate form and tuber seed cost. In this study the other costs of production such as labor, inputs, irrigation etc. were not considered because they were the same as in different treatments.

Table 3. The effect of different nitrogen levels and plant spacing on yield component in seasons 2010/2011 and 2011/2012

N levels	2010/2011				2011/2012			
	Plant in-row spaces				Plant in-row spaces			
	Potato yield Kg / plant							
kg/feddan*	**12.5 cm**	**25 cm**	**50 cm**	**Mean**	**12.5 cm**	**25 cm**	**50 cm**	**Mean**
60	0.33i	0.47g	0.82c	**0.64D**	0.34i	0.48g	0.84c	**0.55D**
100	0.35i	0.52f	0.84c	**0.68C**	0.36i	0.53f	0.86c	**0.58C**
140	0.39h	0.58e	0.91b	**0.75B**	0.40h	0.59e	0.93b	**0.64B**
180	0.45g	0.61d	0.95a	**0.78A**	0.46g	0.62d	0.97a	**0.68A**
Mean	**0.38C**	**0.54B**	**0.88A**		**0.39C**	**0.55B**	**0.90A**	
	Potato yield kg / m^2							
60	2.70f	2.47g	2.22i	**2.46D**	2.75e	2.52g	2.26i	**2.51D**
100	2.90d	2.74e	2.28i	**2.64C**	2.96d	2.79e	2.32h	**2.69C**
140	3.10c	3.08c	2.46h	**2.88B**	3.16c	3.14c	2.51g	**2.94B**
180	3.29a	3.24b	2.56g	**3.03A**	3.36a	3.30b	2.61f	**3.09A**
Mean	**2.99A**	**2.88B**	**2.38C**		**3.06A**	**2.94B**	**2.43C**	
	marketable yield kg / m^2							
60	1.42h	1.53g	1.66f	**1.54D**	1.44h	1.56g	1.69f	**1.57D**
100	1.81e	1.98d	1.97d	**1.92C**	1.85e	2.01d	2.00d	**1.96C**
140	2.08c	2.35b	2.32b	**2.25B**	2.12c	2.39b	2.37b	**2.30B**
180	2.37b	2.63a	2.60a	**2.53A**	2.42b	2.68a	2.64a	**2.59A**
Mean	**1.92B**	**2.12A**	**2.14A**		**1.96B**	**2.17A**	**2.18A**	
	Number of tuber / m^2							
60	77.3d	46.3g	28.4i	**50.7D**	78.9e	47.2h	28.9j	**51.7D**
100	83.3c	51.4f	29.1hi	**54.6C**	84.9c	52.4g	29.7j	**55.7C**
140	88.9b	55.8e	31.5hi	**58.7B**	90.7b	56.9f	32.1j	**59.9B**
180	93.6a	58.8e	32.7h	**61.7A**	95.5a	60.0f	33.3i	**62.9A**
Mean	**85.8A**	**53.1B**	**30.4C**		**87.5A**	**54.1B**	**31.0C**	

* Feddan = 4200 m^2

The tuber cost per feddan were calculated under different in-row plant spacing. The highest tuber seed costs was under 12.5 cm in row plant spacing followed by 25 cm treatment. The highest net income was gained by 50cm in row plant spacing followed by 25cm. The lowest total net income was obtained by 140 kg N per feddan combined with 50cm in-row plant spacing during the two seasons. These results revealed that; the highest total incomes not matching with the total marketable yield. The yield increased with the increasing in nitrogen levels from 140 to 180kg N per feddan, but these increasing of the yield with the180 kg N per feddan didn't cover the cost of fertilizer.

Increasing nitrogen amounts up to 180 kg/feddan led to the increase in tubers' number. In some studies, it has been shown that the number of tubers, with suitable applications of nitrogen levels, was significantly higher than other levels.

Also, it has been approved that with increasing nitrogen level, number of tuber was increased (**Khajehpour, 2006**). This may be due to that nitrogen fertilizer increased potato leaf area, which increased the amount of solar radiation intercepted and consequently increased plant height and dry matter production of different plant parts (**Krishnippa, 1989**).

Table 4. The effect of different nitrogen levels and in row plant spacing on N, P and k (%) contents of potato leaves in seasons 2010/2011 and 2011/2012

N levels	2010/2011				2011/2012			
	Plant in-row spaces				Plant in-row spaces			
	Nitrogen %							
kg/feddan*	**12.5 cm**	**25 cm**	**50 cm**	**Mean**	**12.5 cm**	**25 cm**	**50 cm**	**Mean**
60	2.10i	2.16h	2.22g	**2.16D**	2.14i	2.22h	2.31g	**2.23D**
100	2.31f	2.35f	2.40e	**2.35C**	2.36f	2.42f	2.50e	**2.42C**
140	2.41e	2.44e	2.55d	**2.47B**	2.46e	2.52e	2.65d	**2.54B**
180	2.73c	2.81b	2.94a	**2.83A**	2.78c	2.89b	3.05a	**2.91A**
Mean	**2.39C**	**2.44B**	**2.53A**		**2.44C**	**2.52B**	**2.63A**	
	Phosphor %							
60	0.23g	0.28f	0.32e	**0.28D**	0.24g	0.29f	0.33e	**0.29D**
100	0.33e	0.37d	0.39c	**0.36C**	0.34e	0.37d	0.40c	**0.36C**
140	0.36d	0.39c	0.42b	**0.39B**	0.35d	0.39c	0.43b	**0.39B**
180	0.39c	0.43b	0.48a	**0.43A**	0.40c	0.44b	0.50a	**0.45A**
Mean	**0.33C**	**0.37B**	**0.40A**		**0.33C**	**0.38B**	**0.42A**	
	Potassium %							
60	2.52g	2.57f	2.60e	**2.56D**	2.65g	2.75e	2.83d	**2.74D**
100	2.60e	2.63d	2.66d	**2.63C**	2.72f	2.81d	2.90c	**2.81C**
140	2.63d	2.65d	2.72c	**2.67B**	2.76e	2.83d	2.96b	**2.85B**
180	2.71c	2.76b	2.80a	**2.76A**	2.85c	2.95b	3.05a	**2.95A**
Mean	**2.62C**	**2.65B**	**2.70A**		**2.75C**	**2.84B**	**2.94A**	

* Feddan = 4200 m^2

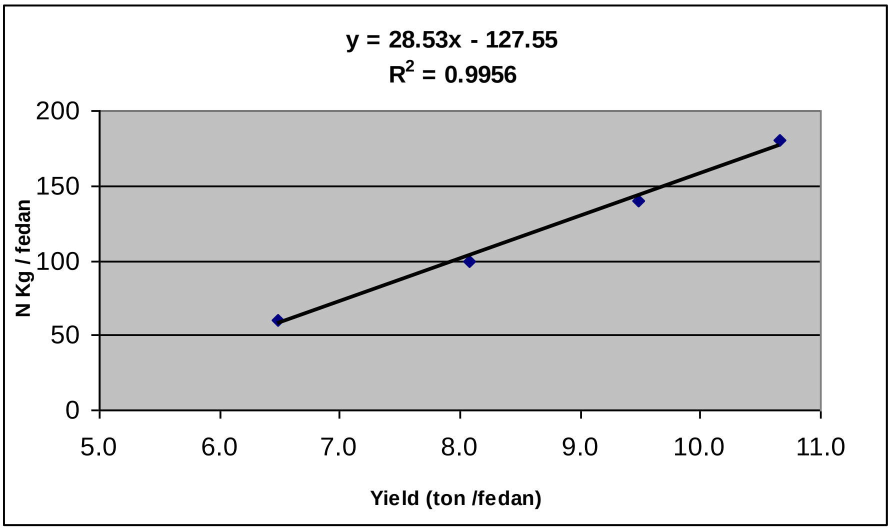

Fig. 1. Relationship between Yield of Tubers per feddan and Nitrogen Levels in Potato

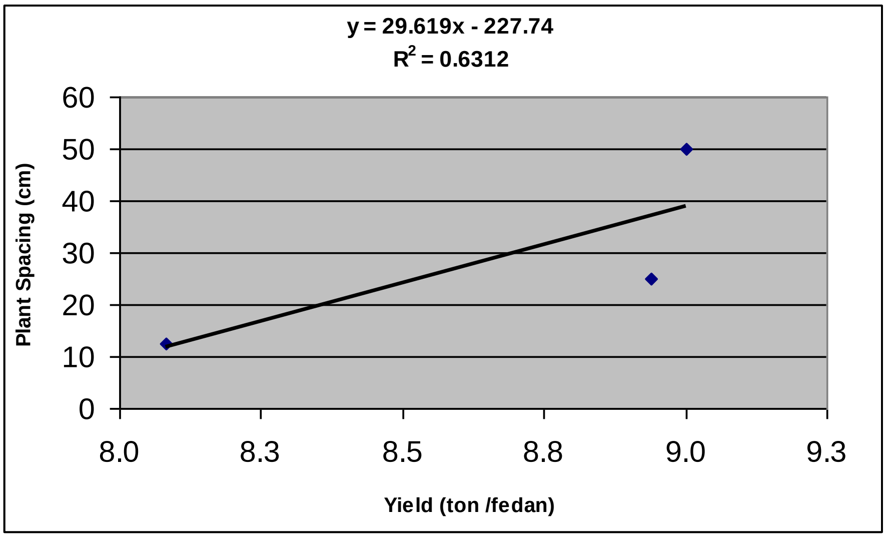

Fig. 2. Relationship between Yield of Tubers per feddan and Plant Spacing in Potato

Table 5. Economic analysis of potato production under differences on gross profit due to the application of different nitrogen levels and in-row plant spacing for the first season 2010/2011

Treatments		Seed rate	Seed Cost	Total Seed Cost	Nitrogen application NH4NO3 form	Fertilizer cost	Total fertilizer cost	Total marketable yield	Average Price	Gross return	TOTAL Net income
Plant spacing	Nitrogen level kg/feddan	Kg/ Fed	L.E. /kg	L.E. ha	kg/ Feddan	L. E. / kg	L. E. / kg	kg/ Feddan	L.E. /kg	L.E. / Feddan	L.E. /Feddan
50 cm	60				189		530	8208		12313	9232
	100	850		2550	316		884	9667		14500	11066
	140				442		1237	10833		16250	12463
	180				568		1591	6917		10375	6234
Mean					379		1061	8906		13359	9749
25 cm	60				158		442	8250		12375	6833
	100	1700	3	5100	189	2.80	530	9792	1.5	14688	9057
	140				316		884	10958		16438	10454
	180				442		1237	6375		9563	3225
Mean					568		773	8844		13266	7392
12.5cm	60				189		530	7542		11313	582
	100	3400		10200	316		884	8667		13000	1916
	140				442		1237	9875		14813	3375
	180				568		1591	5917		8875	-2916
Mean					379		1061	8000		12000	739

Feddan = 4200 m^2 tuber cost per feddan were calculated under different in-row

Table 6. Economic analysis of potato production under differences on gross profit due to the application of different nitrogen levels and in-row plant spacing for the second season 2011/2012

Treatments		Seed rate	Seed cost	Total Seed Cost	Nitrogen Application NH4NO3 form	fertilizer cost	Total fertilizer Cost	Total Marketable yield	Average Price	Gross Return	TOTAL Net ncome
Plant spacing	Nitrogen level kg/feddan	Kg/ Fed	L.E. /kg	L.E. ha	kg/ Feddan	L.E./kg	L.E. / kg	kg/ Feddan	L.E. /kg	L.E. / Feddan	L.E. / Feddan
50 cm	60				189		530	7042		10563	7482
	100	850		2550	316		884	8333		12500	9066
	140				442		1237	9875		14813	11025
	180				568		1591	11000		16500	12359
	Mean				379		1061	9063		13594	9983
25 cm	60				189		530	6500		9750	4120
	100	1700	3	5100	316	2.80	884	8375	1.5	12563	6579
	140				442		1237	9958		14938	8600
	180				568		1591	11167		16750	10059
	Mean				379		1061	9000		13500	7339
12.5cm	60				189		530	6000		9000	-1730
	100	3400		10200	316		884	7708		11563	479
	140				442		1237	8833		13250	1813
	180				568		1591	10083		15125	3334
Mean					379		1061	8156		12234	974

Feddan = 4200 m^2

Another possibility, it may be the effect of increasing nitrogen supply on the enhancement of potato plant growth, and consequently increasing the demand for absorbing more nutrient, which creates favorable conditions for photosynthesis and metabolites translocation (**Marguerite *et al* 2006**). The obtained results were in agreement with those reported by **Barkat *et al* (1991)**, **Gaber and Sarg, (1998)**, and **Al-Moshileh *et al* (2005)**. Tuber production per plant are directly correlated with the number of main stems per plant and significantly affected by intra-plant competition (**Bussan *et al* 2007**). By the way, increasing plant numbers increased the number of stems grown from the planted tuber; consequently increase the number of produced tubers per stem. Thus, increase the plant density leads to the increase in tubers number per plant unit (**Khajehpour, 2006**). **Marguerite *et al* (2006)** and **Alam *et al* (2007)** revealed that tuber yield per unit area was increased with increasing nitrogen fertilizer. According to **Jamaati-e-Somarin *et al* (2009)**, in high plant densities, number of tubers and yield of potato is increased.

The tuber yield is mostly affected by rates of nitrogen application. This is probably due to the increase in the number of tubers and tubers yield (**Marschner, 1995**). With regard to the fact that increasing plant density, the number of produced tuber is increased, it can be said that increasing in the number of tuber may result in the increase in tuber total weight per unit area, while the increase in density, increases the competition between and within plants, and hence leads to the decrease of available nutrients for each plant (**Karafyllids *et al* 1997**).

Applied nitrogen has a lower effect on the number of tubers but a higher effect on tuber size. This directly increases tuber mean weight (**Koochaki and Sarmadnia, 2001**). **Alvin *et al* (2007)** showed that with the increase in plant density plant dry matter decreased in each plant but increased per unit area. It can be said that all factors affect tuber yield, and total plant dry matter (**Hashemidezfooli *et al* 1998)**. **Arnout, (2001)** revealed that high rates of applied nitrogen can increase tuber weight.

4. CONCLUSION

This study reveals the importance of the economic factor in reaching the right decision. The results indicated that the highest yield obtained by the intra-row distance 12.5cm and 180kg N/feddan while the economic factor disagrees with these results and gave another vision about the best economic treatment (50 cm combined with 140 kg N/feddan). The economic factor beside the best agricultural practices should be taken into consideration with potato cultivation.

5. REFERENCES

Abo-Hussein, S.D.A. (1995). Studies on potato fertigation in newly reclaimed lands. **M.Sc. Thesis, Fac. Agric., Ain Shams Univ., Cairo, Egypt. 80 p.**

Alam, M.N., Jahan, M.S., Ali M.K., Ashraf M.A., Islam, M.K. (2007). Effect of vermicompost and chemical fertilizers on growth, yield and yield components of potato in barind soils of Bangladesh. **J. Appl. Sci. Res., 3(12): 1879-1888.**

Al-Moshileh, A.M., Errbhi, M.A. and M.I. (2005). Motawei. Effect of Various Potassium and Nitrogen Rates and Splitting Methods on Potato under Sandy and Arid Environment Conditions. Emir**. J. Aric. Sci, 17(1): 1-9.**

Alvin, J.B., Mitchell, P.D., Copas, M.E. and Driliias, M.J. (2007). Evaluation of the Effect of Density on Spud Yield and Tuber Size Distribution. **Crop. Sci., 47: 2462-2472.**

Arnout, V.D. (2001). Yield and Growth Components of Potato and Wheat under Organic Nitrogen Management. Agron**. J., 93: 1370-1385**.

Arsenault, W.J., LeBlanc, D.A., Tai, G.C.C. and Boswall, P. (2001). Effects of nitrogen application and seed piece spacing on yield and tuber size distribution in eight potato cultivars. **American J. Potato Res., 78: 301–309.**

Barakat, M.A.S., Al-Araby, S.M. and El-Adgham, F.I. (1994). Varietal response of potato to graded dose of nitrogen and potassium. **Alexandria J. Agric. Res., 39: 399–414.**

Beraga, L. and Caeser, K. (1990). Relationships between numbers of main stems and yield components of potato (*Solanum tuberesom L. CV. Erntestolz*) as influenced by different day length. **Potato Res., 33: 257-267.**

Bussan, A.J., Mitchell, P.D., Copas, M.E. and Drilias, M.J. (2007). Evaluation of the effect of density on potato yield and tuber size distribution. **Crop Sci. 47: 2462–2472.**

Chapman, H.D. and Pratt, F. (1961). Methods of Analysis for Soils, **Plants and Water. Univ. of Calif., 35: 6-7.**

CIMMYT, (1988). An Economic Training Manual: From Agronomic Data to Farmer ecommendations, **Mexico, pp. 60-79.**

Daccachea, E.K. Weatherheada, M.A. Stalhamb and Knoxa, J.W. (2011). Impacts of climate change on irrigated potato production in a humid climate. **Agricultural and Forest Meteorology 151: 1641-16543**.

Erdem, Y., Seshril, S., Erdem, T. and Kenar, D. (2006). Determination of crop water stress index for irrigation scheduling of bean (Phaseolus vulgaris L.). **Turk J Agric. 30: 195-202.**

FAO, (1980). Soil and Plant Analysis. **Soils Bulletin 38: 250 p.**.

FAO, (2006). FAOSTAT Agricultural Data. Agricultural production, crops, primary. United Nations Food and Agriculture Organization. http// FAOSTAT.FAO.org

FAO, (2008). International year of the potato**.** http://www.potato2008.org/en/-aboutiyp/

Gabr, S.M. and S.M. (1998). Sarg, Response of Some New Potato Cultivars Grown in Sandy Soil to Different Nitrogen Levels. **Alexandria Journal of Agricultural Research, 43: 33-41.**

Galeev, R.R. (1993). The effect of fertilizers on yield and quality of potatoes on leached chernozemes of western Siberia. **Agrokhimiya, 12: 27-32.**

Goffart, J.P., Olivier, M. and Frankinet, M. (2008). Potato crop nitrogen status assessment to improve N fertilization management and efficiency: Past-Present-Future**. Potato Research 51: 355-383**.

Gronowicz, Z., Fordońs, G. and Klicka, I. (1989). Effect of Florovit fertilization and row spacing on the yield of new varieties of pea. Conference; Natural and agronomic conditions for the production of legumes. **Part II. IUNG. Puławy, pp. 116–122.**

Haase, T., Schuler, C. and Heb, J. (2007). The effect of siferant N and K sources on tuber nutrient uptake, total and geaded yield of potatoes (*Solanum tuberosum* L.) for processing**. Eur. J. Agron., 26: 187-197.**

Hashemidezfooli A., Koochaki A., and Banayanavval, M. (1998). Crop plant improvement (translation). Jehad Daneshgahi Mashhad press. **Mashhad. Iran, ISBN 964-6023-05-3. 350 p.**

Holden, N.M. and Brereton, A.J. (2006). Adaptation of water and nitrogen management of spring barley and potato as a response to possible climate change in Ireland. **Agricultural Water Management, 82: 297–317.**

Iqbal, M.M., S.M. Shah, W. Mohammad and Nawaz, H. (1999). Field response of potato subjected to water stress at different growth stages. In: Crop yield response to deficit irrigation. Kirda, C., Moutonnet, P., Hera, C., Nielsen, D.R. (eds.), **Kluwer Academic Publishers, The Netherlands, pp. 49-58.**

Israelsen, O.W. and Hansen, V.E. (1962). Irrigation Principles and Practices, third edition, John Wiley and Sons, **Inc New York, 447 p.**

Jagroop, S., Mohan, S., M.S. Saimbhi, Kooner, K.S., Singh, J. and Sing, M. (1993). Growth and yield of potato cultivars as affected by plant density and potassium levels. **J. India Potato Association, 20: 279-282.**

Jamaati-e-Somarin, Sh., Tobeh, A., Hassanzadeh, M., Hokmalipour, S. and Zabihi-e-Mahmoodabad, R. (2009). Effects of plant density and nitrogen fertilizer on nitrogen uptake from soil and nitrate pollution in potato tuber. **Res. J. Environ. Sci., 3(1): 122-126.**

Jensen, M.E. (1973). Consumptive Use of Water and Irrigation Requirements. 215 p. Amer. Soc. Civ. Eng. New York.

Karim, M.R., Hanif, M.M., Shahidullah, S.M., Rahman, A.H.M.A., Akanda, A.M. and Khair, A. (2010). Virus free seed potato production through sprout cutting technique under net-house. **African J. Biotech., 9: 5852–5858**.

Khajehpour, M. (2006). Industrial production plants. Isfahan University Publications University **Jihad., 580 p.**

Khan, J. (1993). Effects of row-width and plant density whitin-rows on the growth and tuber yield of potato crop**. Sarhad J. Agric., 9: 551–556.**

Kijne, J.W., Barker, R. and Molden, D. (2003). Water productivity in agriculture: limits and opportunities for improvement. **CAB International, Wallingford, UK, 1: 89-102**.

Kishorekumar, A., Abdul Jaleel, C., Manivannan, P., Sankar, B., Sridharan, R., Somasundaram, R. and Panneerselvam, R. (2006). Differential effects of hexaconazole of Chinese potato**. Acta Biol. Szegediensis 50: 127-129.**

Koochaki, A. and Sarmadnia, G.H. (2001). Physiology of crop plants (translation). Jehad Daneshgahi Mashhadpress. **Mashhad. Iran. Edition Number: 9. ISBN: 964-6023-92-4, 400 p.**

Krishnappa, K.S. (1989). Dry matter and nutrient concentration in Kufri jyoti potato as affected by fertilizer application. Current **Res. Univ. Agric. Sci., 18(11): 158-160.**

Locascio, S.J. and Smasstrla, A.G. (1996). Water application scheduling by Pan Evaporation for drip irrigated tomato**. J. Amer. Soc. Hort. Sci. 121: 63-68.**

Maher, M.J. (1996). The effect of planting density on the production of potato minituber under protection. Proceedings of the Agricultural Research Forum, **March 23 and 24, pp. 1-13.**

Marguerite, O., Jean-Pierre, G. and Jean- François, L. (2006). Threshold Value for Chlorophyll Meter as Decision Tool for Nitrogen Management of Potato. **Agron J., 98: 496-506.**

Marschner, H. (1995). Mineral Nutrition of Higher Plants. 2nd Ed. Academic Press, 826 p.

Meyer, K.M. (2002). **Impact of Nitrogen Management Strategies on Yield, N-use Efficiency and Rhizoctonia Diseases of Irish Potato.** M.Sc. thesis, Graduate Faculty, North Carolina State University, USA, 90 p.

Negi, S.C., Shekhar, J. and Saini, J.P. (1995). Effects of seed size and spacing on potato production. **Indian J. Agri. Sci., 65: 286–293.**

Norwood, C.A. (2000). Water use and yield of limited-irrigated and dry land corn. **Soil Sci. Soc. Am. J. 64:365–370.**

Rahemi, A., Hasanpour, A., Mansoori, B., Zakeri, A. and Taghavi, T.S. (2005). The Effects of Intra-Row Spacing and N Fertilizer on the Yield of Two Foreign Potato Cultivars in Iran. **Int. J. Agric. Biol., 7: 705-707.**

Rajadurai, S. (1994). Effect of seed tuber size and planting space on growth, yield and tuber size distribution of potato in irrigated red-yellow latosols of the dry zone. **J. National Sci. Council Sri Lanka., 22: 115–23.**

Rosenzweig, C., Phillips, J., Goldberg, R., Carrollh, J. and Hodges, T. (1996). Potential Impacts of Climate Change on Citrus and Potato Production in the US. **Agricultural Systems, 52: 455- 479.**

Saeedi, M.R. (2007). Effect of tumor size and nitrogen on some growth parameters, quantitative and qualitative characteristics of potato tubers. M.Sc. Thesis, Faculty of Agriculture, University of Mohaghegh Ardabili, **119 p.**

Samuel, Y.C., Essah, D., Holm, G. and Delgado, J.A. (2004). Yield and quality of two US red potatoes: Influence of nitrogen rate and plant population. Proceedings of the 4th International Crop Science Congress Brisbane, **Australia, 26 Sep-1 Oct., pp. 171-179.**

Singh, M.V. (1995). Nitrogen needs of potato when planted on different dates. **J. Indian Potato Association., 22: 101–105.**

Snedicor, G.W. and Cochran, W.G. (1981). Statistical methods. **7th Iowa State Univ. Press, Iowa, USA.**

Somarin, S.J., Mahmoodabad, R.Z. and Yari, A. (2010). Yield and yield components of potato (*Solanum Tuberosum* L.) tuber as affected by nitrogen fertilizer and plant density**, Australian J. of Basic and App. Sci., 4(8): 3128-3131.**

Steel, R.G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics: A Biometrical Approach, **2nd edition. McGraw Hill Book Co., Inc. New York, USA, ISDN:0070665818, pp. 183-193.**

Turner, L.B. (1991). The effect of water stress on the vegetative growth of white clover (*Trifolium repens* L.), comparative of long-term water deficit and short-term developing water stress. **J. Exp. Bot., 42: 311–316.**

Waddell, J.T., Gupta, S.C., Moncrief, J.F., Rosen, C.J. and Steele, D.D. (1999). Irrigation and Nitrogen Management Effects on Potato Yield, Tuber Quality, and Nitrogen Uptake. **Agron J., 91: 991-997.**

Waller, R.A. and Duncan, D.B. (1969). Ways for the symmetric multiple comparison. Problem Am. **Stat. Assoc J. 19: 1485-1503.**

Xiao G., Fengjua, Z., Zhengjib, Q. and Yubic, Y. (2103). Impact of climate change on water use efficiency by wheat, potato and corn in semiarid areas of China. Agriculture, **Ecosystems and Environment 181: 108-114.**

Zandstra, J.W. and Liptay, A. (1999). Nutritional effects on transplant root and shoot growth. A. Review. **Acta Hort. 504: 23-31.**

Zavalin, A.A. and Gremitskikh, O.A. (1994). The effect of fertilizers on the yield and quality of potatoes on derno-gley soil. **Agrokhimiya, 3: 60–9.**

Zelalem, A., Ekalign, T.T. and Nigussies, D. (2009). Response of potato (*Solanum tuberosum* L.) to different rates of Nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia, **African Journal of Plant of Plant Science 3: 16-24.**