Integrated management for irrigation and nitrogen fertilization for potato crop

M. H. Elagouz [1,*], S. M. Abou-Shleel [1], A. A. Belal [2], and Y. G. M. Galal [3]

[1] *Environment and Bio- Agriculture Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.*
[2] *National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt*
[3] *Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Egypt*

* Corresponding author E-mail: Mohamed_ Elagouz @ azhar.edu.eg. (M. Elagouz)

ABSTRACT:

In potato cropping systems, nitrogen and water availability are essential factors for production. In this regard, water and nitrogen fertilizers management are considered a challenge in potato production. Therefore, this study aimed to explore the effect of N source and rate in collaboration with different irrigation water levels on the vegetative growth, yield, and quality of potato tubers. To achieve this objective, a pot experiment was conducted during season 2020/2021 at Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. Experimental treatments consist of two drip irrigation water regimes (100 and 80% ETc), two N fertilizer sources (urea, and ammonium nitrate), which applied at three N fertilizer rates (120, 100, and 80%) of the recommended dose. Significant increments in vegetative growth, yield, and quality of potato tubers were detected under 100% ETc. Comparison between fertilizer sources reflected the superiority of ammonium nitrate which induced the highest values in all measured parameters, while the N rate of 120% achieved the highest values followed by 100%, then 80%. Regarding the interaction effect among irrigation levels, N sources and rates revealed that the 100% ETc with the addition of ammonium nitrate at the rate of 120% gave the highest significant values of vegetative growth traits (plant height, number of leaves and vegetation fresh weight). Similarly, the highest yield and best tuber quality parameters (tuber number, yield/plant, N, proteins, carbohydrates, and starch content were induced by the same treatment of 120% ammonium nitrate rate in combination with 100% ETc.

Keywords: Irrigation regime; N fertilizer source and rate; productivity; and quality of potato tubers.

INTRODUCTION:

Potato (Solanum tuberosum L.) is currently grown in a wide area all around the world. Potato is the fourth most significant food crop in the world and the largest non-cereal food crop after maize, wheat, and rice. One of the most significant plants used as a food source is the potato. In catastrophe situations, it is a useful strategy to avoid food insecurity (Rabia et al., 2021). Given its large yield and high nutritional content, the potato is a crucial crop for food security and can be used in place of cereal crops (Zhang et al., 2017; Tolessa, et al., 2017; Koch et al., 2019). According to FAO statistics database estimates, in 2019, around the world more than 370 million tons of potatoes were produced, an increase of 333.6 million tons in 2010 (FAO, 2020). Collectively, Egypt is one of the top 20 producers of potato worldwide and is considered one of Africa's top potato producers. Additionally, Egypt is one of the major exporters of fresh and frozen potato goods, especially to European markets (Rabia et al., 2021). Since agriculture is the main user of water, conserving such resources necessitates their efficient usage. The management of water resources and nitrogen fertilization are important and major factors that limit potato production and quality. The method of using water in agriculture is necessary to maintain agricultural productivity, especially in places that cannot use the current irrigation systems So, irrigation management has a big chance to reduce water scarcity and deficit in semi-arid areas. Additionally, improving irrigation management to maximize water efficiency is crucial, given its cost and shortage of supply, (Ierna and Mauromicale, 2012). Controlling production level in potato cropping systems requires adequate water and nitrogen supplies (Badr et al., 2012). the availability of water in the soil leads to the transfer of nutrients to the root surface through flow, which results from transpiration and absorption of appropriate amounts of water, which increases the availability of nitrogen uptake by the roots, (McMurtrie and Näsholm, 2018). The growth stage of potato tubers requires large amounts of water, which is affected by drought due to its shallow root. This confirms the importance of irrigation to reach acceptable tuber productivity and quality, (Liu et al., 2006; Sun et al., 2015). Drip irrigation has many agricultural advantages, providing irrigation water and improving the efficiency of plant nutrition. Therefore, the rationalization of agricultural inputs such as fertilizers and irrigation increased productivity and the cultivation of various crops. The amount of water used is positively related to the tuber yield, (Badr et al., 2010). Lack of soil moisture affects potato crops at all stages of growth, but during tuber commencement and bulking this has a significant impact on production (Ierna et al., 2011). In recent production systems, the aim is to maximize crop productivity and optimize both nitrogen and water use to minimize the risk of N leakage into groundwater. However, there is often conflicting information on the water source and nitrogen management of agricultural crops, it is generally confirmed that the amounts of nitrogen and water have a significant impact on production and quality and that these requirements are related to agricultural crops (Badr et al., 2012). Potato crops need a lot of fertilizer, especially N and K-containing fertilizers (Bélanger et al., 2002). Thus, rationalization of the inputs, including the use of water and fertilizer is requiring increasing food crop cultivation. There is a strong correlation between potato production and fertilizer applications, and using the right fertilizers can greatly increase potato quality and yield, (Šrek et al., 2010). In addition to being a key element in crop yield, nitrogen has a significant impact especially when there is a lack of water (Li et al., 2016). The lack of nitrogen fertilization in potato is indicated by reduced growth and production through the number and weight of tubers (Koch et al., 2019). To ensure high crop yields, a balanced application of nitrogen and irrigation water is necessary. One of the most crucial aspects is also choosing the optimal N source for high yielding, based on the climate and soil type (Šrek et al., 2010). Consequently, the goals of the current study were to track the combined effect of N sources applied at different rates in combination with two different water regimes under a drip irrigation system on the vegetative growth, yield, and quality of potato tuber.

MATERIALS AND METHODS

Pot Experiment

This study was conducted in the green house of Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt (Latitude: 30 17′ 06′′ and Longitude: 31 23′ 45′′). The pot experiment was conducted during the autumn season of 2020/2021 and consisted of two drip irrigation regimes (100 and 80% ETc), two N fertilizer sources i.e. urea, and ammonium nitrate, which applied at three N fertilizer rates (120, 100, 80%) of the recommended dose.

A total of 60 pots were randomly distributed in the greenhouse following a completely randomized block design. Three doses of N fertilizer were used for each: Urea: 100% (326.1 kg fed-1) (equal to 7.2 g pot-1), 120% (391.3 kg fed-1), and 80% (260.9 kg fed-1) of the recommended rates. Ammonium nitrate: 100% (428.8 kg fed-1) (equal to 10 g pot-1), 120% (514.6 kg fed-1), and 80% (343.0 kg fed-1) of the recommended rates.

These rates were split into three equal doses, the first dose was added at soil preparation, while the other two doses on 11 Oct. and 01 Nov. 2020, respectively. Pots fertilization treatments were applied under different water regimes namely 100% and 80%ETc using a surface drip irrigation system. Experimental treatments were distributed in a completely randomized block. All experimental treatments were replicated five times.

Soil analysis

Virgin sand soil samples were collected from the field and exposed to laboratory analysis. The mechanical, some physical, and chemical properties of the experimental soil were analyzed according to Carter and Gregorich, (2008) as shown in Tables (1and 2).

Preparation and cultivation of potato tubers

The pot experiment was set up on 21 September 2020 and harvested on 04 January 2021. Pots with (diameter of 35.5 cm, height of 32.5cm and volume of 20 L.) were packed with 20 kg per each one of sandy soil. Cuts of potato tuber (Spunta cultivar) were cultivated at a rate of 3 cuts per pot. Potato crops were fertilized with a basal recommended dose for using chemical fertilizers according to the Ministry of Agriculture and Soil Reclamation (2020). Drip irrigation water was applied according to the water requirements for potatoes along the growth duration, Reference crop evapotranspiration (ETo) was calculated by the Penman-Monteith equation: (Allan et al., 1998).

ETO = (0.408 Δ (R_n-G) + γ 900/(T+273) U_2 (e_s-e_a))/(Δ+ γ(1+0.34 〖u〗_2)).

ETo = Reference evapotranspiration [mm day-1],

Rn = Net radiation at the crop surface [MJ m-2 day-1],

G = Soil heat flux density [MJ m-2 day-1],

T = Air temperature at 2 m height [°C],

u2 = Wind speed at 2 m height [m s-1],

es = Saturation vapour pressure [kPa],

ea = Actual vapour pressure [kPa],

es - ea = Saturation vapour pressure deficit [kPa],

Δslope = Vapour pressure curve [kPa °C-1],

γ = Psychrometric constant [kPa °C-1].

Measured parameters

To determine the effect of nitrogen rates and irrigation water regimes on the yield and quality of potato tubers, data were collected on growth, yield, and tubers quality component. Plants were randomly selected from each experimental pot at 80 days from the planting date to be used for all growth parameters, i.e., main plant height (cm), the number of stems /plants, leaf number and area (cm2), and vegetation fresh and dry weights (g). The leaf area was determined using a 20-disc sampling per plant, each plant's total leaf area was calculated, dried, and weighed individually. A relationship between disk dry matter and disk area was applied to total leaf dry matter to find the total leaf area, according to Koller, (1972). The plants were weighed and dried in an oven at 70°C for 48 to 72 hours until constant weights then the dried plants were weighed and the dry weight per plant was recorded. Number of tubers, yield/plant, fresh weight of tubers and total tubers yields per plant were estimated. This data was taken 105 days from the cultivation date. At the end of the experimental season, the tuber samples were digested using a concentrated sulfuric acid and hydrogen peroxide mixture, as described by Cotteine, (1980), Tuber quality analyzes were determined based on nitrogen content (%), total protein (%), total carbohydrate (%), and starch content (%). The digests were then subjected to measurement of N using the Micro-Kjeldahl method (Chapman and Pratt, 1961). Protein content (%) in tubers was determined according to Bradford, (1976). The carbohydrate content (%) percentage in leaves was determined using the method DuBois et al., (1956). The percentage of starch content in the tuber was determined according to A.O.A.C, (1995).

Statistical analysis

The collected data on different growth and yield parameters were subjected to analysis of variance (ANOVA) at 5% level of significance by using Minitab statistical software to test the significance of differences and comparison between means of treatments.

RESULTS AND DISCUSSION

Vegetative growth traits

The effect of N sources and different fertilizer rates as well as irrigation water regimes on the vegetative growth parameters (plant height, number of main stems, total leaf area, the number of leaves, vegetation fresh, and dry weight) is presented in Tables (3-5). The exhibited results show a significant increment in parameters of plant growth when irrigated with 100% ETc regime recording the highest values of plant height, number of main stems, number of leaves, total leaf area, and vegetation fresh, and dry weight. While the lowest readings of mentioned parameters were recorded at 80% ETc water regime. These results could be attributed to the fact that potatoes are a crop affected by water deficiency, whereas modest water stress might result in a decrease in the growth factors of vegetation. The current results are consistent with those obtained by Li et al., (2016) who demonstrated that water stress causes a decrease in leaf size and number, which in turn affects photosynthesis and tuber number, size, and yield.

A similar trend was also observed for the effect of the rate of nitrogen fertilizer on the plant height, number of main stems, total leaf area, the number of leaves, vegetation fresh, and dry weight. Where the highest values were obtained at 120%, followed by 100%, while the lowest values were recorded at 80% of the N recommended dose. Using ammonium nitrate resulted in higher values in all studied vegetative parameters than those recorded with urea fertilizer form. Similarly, Ahmed et al., (2009) reported that potato plants fertilized with ammonium nitrate gave the most vigorous vegetative growth, while the use of urea resulted in the weakest plants. Considering the significance of N as one of the primary important elements, N directly contributes to crucial functions in the formation of chlorophyll and growth processes, notably in relation to the vegetative growth parameters of plants Zhu et al., (2021) found that the vigorous vegetative growth of Chinese cabbage was obtained with ammonium nitrate application confirming the preference of NO_3^- followed by NO_3+ NH_4^+ then NH_4^+.

Regarding the first-order interactions, the combination between irrigation regimes and N sources showed that 100% ETc combined with ammonium nitrate applied produced the highest significant values for all vegetation parameters, while 80% ETc with urea obtained the lowest values. As well as the combination of studied irrigation regimes and N rate showed that the plants that were irrigated by 100% ETc with fertilization at a rate of 120% produced the highest significant values in all the studied traits. At the same time, 80% ETc has the lowest value with a rate of 80%. Also, the combination between N sources and rate showed that when ammonium nitrate was used at a rate of 120% it gave the highest significant values for all traits. At the same time, urea recorded the lowest value with 80% except for the number of main stems, which recorded the lowest value when plants fertilized with the rate of 80% forth both N sources. This could be attributed to the enhanced availability of nutrients to the crop which may have resulted in increased photosynthetic efficiency and increased metabolic activities of the plant with an increase in water level and fertilizer rate. Similar findings were obtained by Sriom et al., (2017) reported that vegetative growth increased with increasing fertilizer levels of N. In addition, Ahmed et al., (2009) indicated that the use of ammonium nitrate as a source of N fertilization resulted in a significant increase in all vegetative growth traits, while urea gave the lowest values. In the other hand, Zelalem et al., (2009) reported that N fertilization did not significantly influence the number of stems in potato .

Concerning the interaction effect, the combination of irrigation regimes with different N sources and rates showed that 100% ETc water regime combined with ammonium nitrate applied at 120% of the recommended rate gave the highest values for the number of leaves, plant height, and vegetation fresh weight. Whereas the number of main stems didn't record significant differences between 120 and 100% fertilizer rates of either urea or ammonium nitrate under the highest irrigation water regime 100% ETc. However, supply with ammonium nitrate at 100% ETc irrigation water regime didn't record a significant difference between 120 and 100% fertilizer rates on the total leaf area and vegetation dry weight. On the other hand, values of total leaf area, plant height, number of leaves, total leaf area, and vegetation fresh weight were lower when urea was applied at a rate of 80%, with 80% ETc water regime. However, because of the effects of N sources under the irrigation regime of 80% ETc, it did not lead to significant differences in the number of main stems, and vegetation dry weight. Similar results were previously recorded by Ahmed et al., (2009) where they discovered that all vegetative growth characteristics were influenced by the source and rate of N fertilizer. They added that the use of ammonium nitrate gave the highest values for all vegetative treatments, followed by urea applied at the same rate.

Yield characteristics

The number of tubers and plant yield were significantly different with the use of irrigation water regimes and N sources and rates treatments (Table 6). Despite N sources and rates, the significant increase in the number of tubers, and plant yield were obtained when potato was irrigated with 100% ETc irrigation water regime, recording higher mean values of 3.4 tubers plant-1, and 337.4 g plant-1, respectively, than those recorded with 80% ETc irrigation water regime, where achieved 3.0, and 289.4, for the same sequence. The current findings are in harmony with those obtained by Ierna and Mauromicale, (2012) and Khalil, (2014) they found that when using the 100% ETc, the highest quality and yield of potato tubers were obtained. Also, Salih et al., (2018) stated that high frequency water irrigation produced more fresh tubers than low frequency irrigation. Reduced irrigation considerably reduces yield. Additionally, the stage of stolon generation and tuber formation is sensitive to low-water irrigation. Irrigation regime at levels of 120 and 100% ETc impact on the sensitive stages of water shortage, whether regular growth of the shoots, formation, and growth of tubers (Ierna and Mauromicale, 2012) .

Comparison held between the N sources, despite rates and water regimes, indicated that overall means of tuber numbers and plant yield were higher in the case of ammonium nitrate than urea form recording 3.4 tuber plant-1, and 323.1g plant-1. The pattern of fertilizer rate was 120 > 100 > 80% with tuber number and yield per plant and recording a significant increase in yield /plant. Consistently, Wang et al., (2019) proposed using nitrogen fertilizer, as NO3- or NH4+ NO3- instead of NH4+, which resulted in significant increases in tuber production and potato growth. Increases in the number of tubers after applying nitrogen were reported earlier by Jafari-Jood et al., (2013). Increasing N fertilizer rates significantly increased tuber number/plant, and tuber yield (g)/plant. The improvement in root growth and mineral absorption may be attributable to the availability of mineral nitrogen in potato plant roots (Ahmed et al., 2009). The use of a high dose of nitrogen improved growth and photosynthesis, moreover it have an increase in the weight and number of tubers .

Regarding interactions between irrigation regimes and N sources showed that 100% ETc water regime combined with ammonium nitrate applied produced the highest significant values for tuber number, yield /plant, while 80% ETc with urea detected the lowest values. As well as the combination of irrigation regimes and N rate showed that the plants that were irrigated by 100% ETc with fertilization rate of 120% produced the highest significant values in all the studied traits. At the same time, 80% ETc had the lowest value with a rate of 80%. Also, the combination between N sources and rate showed that when ammonium nitrate was used at a rate of 120% gave the highest significant values for all traits, while the urea recorded the lowest values when it was applied by 80%. These results are consistent with Badr et al., (2012) they found an improvement in tuber yield as a result of the higher amounts of available water, and at the same time, the use of a higher N rate gave a higher yield of tuber crop.

Regarding the effect of the interactions between the N source and fertilizer rates with the irrigation water regimes on the number of tubers, the maximum values were noted at the irrigation regime of 100% ETc with no significant differences for the source of fertilization and the rates of 120 and 100%, while the lowest values were recorded for the rest values of the number of tubers non-significant differences. As for plant productivity, the highest values were at 100% ETc irrigation water regime with no significant differences between fertilization rates 120 and 100% of ammonium nitrate, while the lowest values were at noticed an irrigation regime of 80% ETc when plants fertilized with urea. Similar results were obtained by Yuan et al., (2003) who discovered that tuber yields and numbers increased as irrigation water use increased. Water used for irrigation increased yields by both increasing the number of tubers and their mean weight. In addition, in the study carried out by El-Metwalli and Elnemr, (2020), they reported that lack of irrigation and nitrogen fertilization recorded the highest production of potatoes when the potato plants were treated with 1.25 ETc and 200 kg N ha-1. Thus, In the case of conducting an optimal irrigation system with the use of the appropriate fertilization rate, it leads to maximizing the productivity of the potato plant.

Quality characteristics of the potato crop

The results showed that irrigation water regimes, N source, and rate reflected significant influences on various potato tuber quality parameters in terms of N, protein, carbohydrates, and starch contents (Tables 7 and 8). Whereas the highest significant tuber contents for N (2.3%), protein (10.4%), carbohydrates (50.2%), and starch (12.3%), was occurred when potato plants were irrigated with 100% ETc regimes, the lowest significant values were obtained with the level of 80% ETc regime. These results are in harmony with those obtained by El-Sawy et al., (2022) who indicated that the highest significant values of N, K and P uptake by tuber as well as total chlorophyll content were detected with potato plants irrigated with higher water regime. Additionally, Fernie and Willmitzer, (2001) found similar evidence about the synergistic effect of the high-water regime on increasing protein content comparable to the lowest irrigation water regime. They also found a protein and starch content have positive relationships. Moreover, Salih et al., (2018) reported that irrigation intervals frequently affected the starch accumulation in the tuber and demonstrates how crucial and critical water supply is during the formation and development of the tuber. In general, subjecting plants to water stress had an impact on the protein and starch composition of the tuber as confirmed by (Shayannejad and Ali,2009).

Concerning the N source, the results showed that the percentage of nitrogen in ammonium nitrate has a beneficial effect on tuber quality. When fertilizing plants with ammonium nitrate content of nitrogen, protein, carbohydrates, and starch was obtained, while urea-fertilized plants produced the lowest content. The N, protein, carbohydrates, and starch contents tended to increase with increasing N rates of application. There was a positive and significant difference among the different N rates with respect to N, protein, and carbohydrate contents. Likewise, both protein and carbohydrates had the highest significant increases in the case of 120% N fertilization rate, while the lowest content was induced by the application of 80% fertilization rate. There was no significant difference between 120% and 100% fertilizer-N rates when starch content was concerned. These results agree with those obtained by El-Hadidi et al., (2017) who suggested with increasing rates of N application the starch content of dry matter increased. Also, starch and dry matter content were significantly affected by different levels of N. Similar results reported by Zabihi-e-Mahmoodabad et al., (2011) where they mentioned that increasing N fertilizer application to a certain extent, caused an increase in dry weight of tubers, so that the expected yield of protein increased.

Regarding interactions, the combination between irrigation regimes and N sources the obtained results showed that 100% ETc combined with ammonium nitrate applied produced the highest significant values in all the studied traits, while the plants were received of 80% ETc with urea detected the lowest values. As well as the combination of studied irrigation regimes and N rate showed that the plants that were irrigated by 100% ETc and fertilized by 120% produced the highest significant values in all the studied traits. At the same time, 80% ETc combined with 80% rate had the lowest values of all yield parameters. Also, the combination between N sources and rate showed that when ammonium nitrate was used by rate of 120% gave the highest significant values for all yield traits, while use of urea by 80% recorded the lowest values. These results agree with those obtained by Abdelshafy et al., (2021) showed that the deficit irrigation treatments significantly affected tuber contents and comparable values of reducing sugars, proteins, and ashes. Moreover, increasing N fertilizer rates increases the rate of quality of potato tubers, (Moussa et al., 2018).

The interaction among irrigation regimes, N source, and rate showed a significant influence on N%, protein, carbohydrates, and starch content. The highest Tuber-N content was obtained with the combination of 100% ETc and 120% fertilizer rate for both sources of N fertilizer, and the lowest value was observed at 80% ETc and 80% urea rate. Protein was positively affected as a quality measure related to the interaction. The highest significant difference was recorded at 100% ETc when plants were fertilized with ammonium nitrate, and there was no significant difference among used N rates, while the lowest value was noted at the fertilization of 80% urea with 80% ETc. Regarding the tuber content of carbohydrates and starch, the results revealed that the 100% ETc combined with 120 and 100% from ammonium nitrate and urea recorded the highest values. The lowest value for both carbohydrates and starch was recorded in the case of 80% ETc with the rate of 80% urea. These findings matched with other studies where water deficiency causes physiological disorders in potatoes and a decrease in dry matter and tuber starch content (Carli et al., 2014). Also, Ahmed et al., (2009) found an increase in the nitrogen content of potato tubers when increasing nitrogen fertilization rates. As for the sources of nitrogen fertilization that were studied, there were no statistically significant differences. These results were in line with those of other research that examined protein content and found that increasing N application significantly increased protein content, with plants that got 230 kg N fed-1 of NH4NO3 produced the highest values, while plants that received 130 kg N fed-1 of (NH4)2SO4 produced tubers with the lowest protein content. However, another view holds that when lower levels of irrigation and fertilization with ammonium sulfate were used, higher N content and total protein were obtained in the tubers (Eid et al., 2020).

CONCLUSION

Based on the findings of the present study, potato quality and yield were generally more responsive to the irrigation water regime than to nitrogen fertilizer rates under certain conditions of the study. The response to nitrogen was related to the regime of applied water where the effect of the nitrogen rates required to maximum yield decreased as the water shortage increased. Potato yield and its quality were significantly affected by irrigation treatment, nitrogen source and rate, and interaction of the tested treatments. Results have indicated that the lack of irrigation than the recommended level in the region had a statistically significant effect on the yield and quality of potato, fertilization with ammonium nitrate resulted in the highest values in all studied parameters with a rate of 120%. There were no significant differences when using fertilization with ammonium nitrate at 120 and 100% with each of the parameters of productivity and quality of tubers, whether dry weight, plant productivity, protein, carbohydrates, and starch when using irrigation at 100%. In conclusion, these findings emphasize the significance of figuring out the interaction effect of water and nitrogen at various rates on potato yield to create proper management strategies for sustainable production. The distinction of the most proper management strategy is of great importance especially with the severe climate change impacts.

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Table 1: Some of the mechanical and physical characteristics of experimental soil.

Particle size distribution (%)			Texture class	B. density ($gm.cm^3$)	PWP (%)	F. C (%)	AW (%)
Sand	Silt	Clay					
98.13	1.40	0.47	Sandy soil	1.64	8.10	21.59	13.49

Table 2: Some of chemical characteristics of experimental soil.

pH (1:2.5)		EC (dS/m) at 25°c	CaCO$_3$ (%)	O.M (%)	OC (%)	N (%)	P (%)
7.40		0.28	4.45	0.25	0.10	0.0028	0.0006
Soluble cations (meq / 100g soil)				Soluble anions (meq / 100g soil)			
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
0.5	0.4	1.68	0.18	-	0.52	1.76	0.47

Table 3: Effect of irrigation water regime and N fertilization sources and rates on plant height and number of main stems of potato crop.

Treatments		Plant height (cm)				No. of main stems /plant			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	36.0^{c}	33.9^{d}	23.4^{h}	31.1^{B}	2.4^{abc}	2.2^{abcd}	1.2^{ef}	1.9^{B}
	NH_4NO_3	40.5^{a}	38.0^{b}	26.1^{g}	34.9^{A}	3.0^{a}	2.8^{ab}	1.2^{ef}	2.3^{A}
	Mean	38.3^{A}	36.0^{B}	24.7^{E}	33.0^{A}	2.7^{A}	2.5^{A}	1.2^{C}	2.1^{A}
80	$CO(NH_2)_2$	29.0^{f}	26.2^{g}	18.0^{i}	24.4^{C}	1.8^{cdef}	1.2^{ef}	1.0^{f}	1.3^{C}
	NH_4NO_3	32.2^{e}	30.8^{e}	24.7^{gh}	29.2^{D}	2.0^{bcde}	1.4^{def}	1.0^{f}	1.5^{C}
	Mean	31.5^{C}	28.4^{D}	21.3^{F}	26.8^{B}	1.9^{B}	1.3^{C}	1.0^{C}	1.4^{B}
N source × rate mean	$CO(NH_2)_2$	32.5^{C}	30.1^{D}	20.7^{F}	27.7^{B}	2.1^{AB}	1.7^{B}	1.1^{C}	1.6^{B}
	NH_4NO_3	36.4^{A}	34.4^{B}	25.4^{E}	32.0^{A}	2.5^{A}	2.1^{AB}	1.1^{C}	1.9^{A}
Mean		34.4^{A}	32.2^{B}	23.0^{C}		2.3^{A}	1.9^{B}	1.1^{C}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Table 4: Effect of irrigation water regime and N fertilization sources and rates on number of leaves and total leaf area of potato crop.

Treatments		No. of leaves /plant				Total leaf area (cm^2)			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	30.0^{b}	26.0^{c}	16.4^{f}	24.1^{B}	294.3^{b}	290.9^{b}	183.4^{f}	256.2^{B}
	NH_4NO_3	32.8^{a}	30.6^{b}	17.2^{f}	26.9^{A}	317.4^{a}	305.2^{ab}	214.6^{e}	279.1^{A}
	Mean	31.4^{A}	28.3^{B}	16.8^{E}	25.5^{A}	305.8^{A}	298.1^{A}	199.0^{D}	267.6^{A}
80	$CO(NH_2)_2$	20.4^{e}	19.2^{e}	13.8^{g}	17.8^{D}	264.4^{c}	238.4^{d}	139.5^{h}	214.1^{D}
	NH_4NO_3	22.8^{d}	20.8^{e}	16.2^{f}	19.9^{C}	272.9^{c}	266.8^{c}	164.7^{g}	234.8^{C}
	Mean	21.6^{C}	20.0^{D}	15.0^{F}	18.9^{B}	268.7^{B}	252.6^{C}	152.1^{E}	224.4^{B}
N source × rate mean	$CO(NH_2)_2$	25.2^{B}	22.6^{C}	15.1^{E}	21.0^{B}	279.3^{B}	264.7^{C}	161.4^{E}	235.1^{B}
	NH_4NO_3	27.8^{A}	25.7^{B}	16.7^{D}	23.4^{A}	295.1^{A}	286.0^{AB}	189.7^{D}	256.9^{A}
Mean		26.5^{A}	24.2^{B}	15.9^{C}		287.2^{A}	275.3^{B}	175.6^{C}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Table 5: Effect of irrigation water regime and N fertilization sources and rates on vegetation fresh and dry weight of potato crop.

Treatments		Vegetation fresh weight (g)				Vegetation dry weight (g)			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	148.2^{c}	145.9^{c}	112.4^{f}	135.5^{B}	13.7^{b}	13.0^{b}	10.3^{cd}	12.3^{B}
	NH_4NO_3	182.8^{a}	172.1^{b}	115.7^{ef}	156.8^{A}	15.6^{a}	15.1^{a}	10.4^{cd}	13.7^{A}
	Mean	165.5^{A}	159.0^{B}	114.0^{E}	146.2^{A}	14.6^{A}	14.1^{A}	10.4^{C}	13.0^{A}
80	$CO(NH_2)_2$	129.2^{d}	118.4^{ef}	92.6^{h}	113.4^{C}	11.3^{cd}	10.9^{cd}	10.1^{d}	10.8^{C}
	NH_4NO_3	133.7^{d}	125.3^{de}	90.5^{g}	115.0^{C}	11.7^{c}	11.1^{cd}	10.3^{cd}	11.0^{C}
	Mean	131.5^{C}	121.9^{D}	91.5^{g}	115.0^{B}	11.5^{B}	11.0^{BC}	10.2^{C}	10.9^{B}
N source × rate mean	$CO(NH_2)_2$	138.7^{C}	132.1^{D}	102.5^{E}	124.5^{B}	12.5^{BC}	12.0^{C}	10.2^{D}	11.6^{B}
	NH_4NO_3	158.2^{A}	148.7^{B}	103.1^{E}	136.7^{A}	13.6^{A}	13.1^{AB}	10.4^{E}	12.4^{A}
Mean		148.5^{A}	140.4^{B}	102.8^{C}		13.1^{A}	12.5^{B}	10.3^{C}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Table 6: Effect of irrigation water regime and N fertilization sources and rates on tuber number/plant and yield of potato crop.

Treatments		Tuber number /plant				Yield /plant (g)			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	3.8^{ab}	3.4^{abcd}	2.6^{cd}	3.2^{AB}	354.7^{b}	353.3^{b}	277.1^{fg}	328.3^{B}
	NH_4NO_3	4.4^{a}	3.8^{ab}	2.8^{bcd}	3.7^{A}	386.4^{a}	368.2^{ab}	284.5^{ef}	346.4^{A}
	Mean	4.1^{A}	3.6^{AB}	2.6^{CD}	3.4^{A}	370.5^{A}	360.7^{A}	280.0^{D}	337.4^{A}
80	$CO(NH_2)_2$	2.8^{bcd}	3.2^{bcd}	2.4^{d}	2.8^{B}	318.0^{cd}	302.9^{de}	215.8^{h}	278.9^{D}
	NH_4NO_3	3.6^{abc}	3.4^{abcd}	2.6^{cd}	3.2^{AB}	327.1^{c}	313.3^{cd}	259.1^{g}	299.8^{C}
	Mean	3.2^{BC}	3.3^{B}	2.5^{D}	3.0^{B}	322.6^{B}	308.1^{C}	237.4^{E}	289.4^{B}
N source × rate mean	$CO(NH_2)_2$	3.3^{B}	3.3^{B}	2.4^{D}	3.0^{B}	336.3^{B}	328.1^{B}	246.4^{D}	303.6^{B}
	NH_4NO_3	4.0^{A}	3.6^{AB}	2.7^{C}	3.4^{A}	356.8^{A}	340.8^{B}	271.8^{C}	323.1^{A}
Mean		3.7^{A}	3.5^{A}	2.6^{B}		346.6^{A}	334.4^{B}	259.1^{C}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Table 7: Effect of irrigation water regimes and N fertilization sources and rates on nitrogen and protein content in potato tubers.

Treatments		Nitrogen content (%)				Protein content (%)			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	2.6^{ab}	2.4^{bcd}	1.7^{fgh}	2.2^{B}	11.3^{ab}	11.0^{bc}	8.6^{de}	10.3^{A}
	NH_4NO_3	2.9^{a}	2.4^{bc}	1.9^{efg}	2.4^{A}	13.0^{a}	11.6^{ab}	8.7^{de}	11.1^{A}
	Mean	2.8^{A}	2.4^{B}	1.8^{D}	2.3^{A}	12.1^{A}	11.3^{A}	8.7^{BC}	10.7^{A}
80	$CO(NH_2)_2$	2.0^{def}	1.8^{fgh}	1.5^{h}	1.8^{D}	9.4^{cd}	9.0^{d}	7.3^{e}	8.6^{B}
	NH_4NO_3	2.2^{cde}	2.0^{ef}	1.6^{gh}	1.9^{C}	9.5^{cd}	9.2^{d}	7.8^{de}	8.7^{B}
	Mean	2.1^{C}	1.9^{D}	1.6^{E}	1.9^{B}	9.4^{B}	9.1^{B}	7.6^{C}	8.7^{B}
N source × rate mean	$CO(NH_2)_2$	2.3^{AB}	2.1^{B}	1.6^{C}	2.0^{B}	10.3^{AB}	10.0^{B}	8.0^{C}	9.4^{B}
	NH_4NO_3	2.6^{A}	2.2^{AB}	1.8^{C}	2.2^{A}	11.2^{A}	10.4^{AB}	8.3^{C}	10.0^{A}
Mean		2.4^{A}	2.1^{B}	1.7^{C}		10.8^{A}	10.2^{A}	8.1^{B}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

Table 8: Effect of irrigation water regimes and N fertilization sources and rates on potato tuber content of carbohydrates and starch.

Treatments		Carbohydrates content (%)				Starch content (%)			
Irrigation regime ETc (%)	N Fertilizer source	N rate (%)			Mean	N rate (%)			Mean
		120	100	80		120	100	80	
100	$CO(NH_2)_2$	54.3^{ab}	50.6^{bc}	42.9^{ef}	49.3^{B}	13.1^{ab}	12.7^{b}	8.9^{de}	11.5^{B}
	NH_4NO_3	55.2^{a}	54.7^{a}	43.6^{ef}	51.1^{A}	14.9^{a}	14.7^{a}	9.4^{cde}	13.0^{A}
	Mean	54.7^{A}	52.7^{A}	43.2^{C}	50.2^{A}	14.0^{A}	13.7^{A}	9.1^{BC}	12.3^{A}
80	$CO(NH_2)_2$	45.0^{de}	43.8^{ef}	38.6^{g}	42.5^{D}	9.5^{cde}	9.2^{cde}	8.0^{e}	8.9^{D}
	NH_4NO_3	47.8^{cd}	44.7^{de}	40.4^{fg}	44.3^{C}	10.7^{c}	10.0^{cd}	8.6^{de}	9.8^{C}
	Mean	46.4^{B}	44.2^{BC}	39.5^{D}	43.4^{B}	10.1^{B}	9.6^{B}	8.3^{C}	9.3^{B}
N source × rate mean	$CO(NH_2)_2$	49.6^{A}	47.2^{B}	40.7^{C}	45.9^{B}	11.3^{BC}	10.9^{C}	8.4^{D}	10.2^{B}
	NH_4NO_3	51.5^{A}	49.7^{A}	42.0^{C}	47.7^{A}	12.8^{A}	12.3^{AB}	9.0^{D}	11.4^{A}
Mean		50.6^{A}	48.4^{B}	41.3^{C}		12.0^{A}	11.6^{A}	8.7^{B}	

Mean values in the same column followed by the same letter are not significantly different at $p \leq 0.05$.

الإدارة المتكاملة للري والتسميد النيتروجيني لمحصول البطاطس

محمد حسن العجوز [1,*]، سمير مسعود أبوشليل [1]، عبد العزيز بلال عبد المنطلب [2]، يحي جلال محمد جلال [1]

[1] *قسم البيئة والزراعة الحيوية, كلية الزراعة, جامعة الأزهر, القاهرة, مصر.*

[2] *الهيئة القومية للاستشعار من البعد وعلوم الفضاء, وزارة الدولة للبحث العلمي, القاهرة, مصر.*

[3] *قسم بحوث التربة والمياه, مركز البحوث النووية, هيئة الطاقة الذرية, مصر.*

* البريد الإلكتروني للباحث الرئيسي: Mohamed_ Elagouz @ azhar.edu.eg

الملخص العربي:

يعتبر توفر المياه والنيتروجين من العوامل الأساسية لإنتاج محصول البطاطس. في هذا الصدد، تعتبر إدارة المياه والأسمدة النيتروجينية تحديًا هاما في إنتاج البطاطس. لذلك، تهدف هذه الدراسة إلى تقييم تأثير مصدر ومعدل السماد النيتروجيني بالتكامل مع مستويات الري المختلفة على النمو الخضري والمحصول وجودة درنات البطاطس. ولتحقيق هذا الهدف، تم إجراء تجربة أصص خلال الموسم النيلي لعام 2020 في مزرعة قسم بحوث التربة والمياه، مركز البحوث النووية، هيئة الطاقة الذرية، انشاص، مصر. حيث اشتملت المعاملات التجريبية على مستويين لمياه الري بالتنقيط (100 و 80٪) من البخر-نتح المحصولي، ومصدرين من الأسمدة النيتروجينية (اليوريا، ونترات الأمونيوم)، والتي تم اضافتها في ثلاث معدلات (120، 100، 80٪) من المعدلات الموصي بها. وأوضحت نتائج الدراسة أن هناك زيادة معنوية في النمو الخضري والمحصول وجودة درنات البطاطس التي رويت بمستوي مياه 100٪ من البخر-نتح المحصولي مقارنة بمستوى 80%. كما أشارت نتائج مقارنة مصادر الأسمدة تفوق سماد نترات الأمونيوم حيث أدى إلى الحصول على أعلى القيم في جميع الصفات المدروسة. وبالنسبة لمعدلات التسميد، تبين أن تطبيق السماد النيتروجيني بمعدل 120٪ سجل أعلى القيم تلاها المعدلين 100، 80٪. وفيما يتعلق بتأثير التفاعل بين مستويات الري ومصادر ومعدلات التسميد النيتروجيني، أن المعاملة 100٪ مياه الري مضافة إليها نترات الأمونيوم بمعدل 120٪ أعطت أعلى قيم معنوية لكل صفات النمو الخضري. ومن جانب أخر حققت المعاملة 100 مياه الري مضافة إليها نترات الأمونيوم بمعدل 120% أعلى قيم كمية وجودة المحصول (عدد الدرنات/ نبات، كمية المحصول/ نبات، نسبة المئوية لكلا من (النيتروجين، البروتينات، الكربوهيدرات، النشا).

الكلمات الاسترشادية : نظام الري، مصدر ومعدل السماد النيتروجيني، البطاطس، إنتاجية وجودة درنات البطاطس.