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EFFECT OF GYPSUM AND MINERAL NITROGEN FERTILIZATION ON NITROGEN FORMS DISTRIBUTION THROUGH AGRO-SYSTEM AND YIELD OF POTATO GROWN ON A CLAY SOIL UNDER TILE DRAINAGE SYSTEM CONDITIONS

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ABSTRACT

A field experiment was carried out on an alluvial clay soil of a pilot field at Talla area, Minufiya Governorate , Egypt during two successive growth winter seasons 2011 / 2012 and 2012 / 2013 to study the effect of agricultural gypsum application and mineral -N fertilizer (ammonium nitrate , 33 % N) solely or in combination under different distances of tile drain on some soil properties and yield of potato plants (*Solanum tuberosum L.*) Scotland cv . Nieta. Agricultural gypsum was applied at rates of 0 and 3 ton/fed. as a protection dose. Nitrogen fertilizer was added at rates of 0 and 500 kg / fed. (165 kg N / fed.) , which equals 100 % of the recommended dose. The field was provided by tile drains spaced at 30 m with 1.5 m depth. The content of nitrogen forms (NH_4-N and NO_3-N) distribution through different soil depths, ground and drainage waters in relation to time were studied. Water table depth after the first and second irrigations was measured above and midway of the laterals. Ground and drainage waters were analyzed. Tubers and shoots of potato contents of NH_4-N and NO_3-N were determined. The experiment was carried out in a split split - plot design with three replicates .

The obtained data show that ground water depth was increased with increasing the period after irrigation especially after the first irrigation. The greatest increase of ground water depth was found above the laterals. Also , this depth was increased with gypsum application. After the first and second irrigation and harvesting stage, the soil content (mg/kg) from available NH_4-N and NO_3-N was decreased with the increase of soil depth. The greatest decrease of soil content of available N was found above the laterals in the soil treated by gypsum and unfertilized by N especially at harvesting stage. With the different treatments, the soil content of NH_4-N was higher than of NO_3-N. On the other hand, ground and drainage water content (mg/l) of NO_3-N were higher than those of NH_4-N with all treatments under study. Also , this content was increased with both gypsum and N fertilization applications. Soil salinity values were relatively affected by drain spacing treatments. In surface layer , the soil salinity value was 1.35 and 1.54 dSm^{-1} for above and midway (15 m) drain spacing.

Results indicate that the highest tubers yield of potato plants was found in the soil treated by gypsum and fertilized by N above the laterals (16.39 ton / feddan). The highest content (%) of the two N forms in both shoots and tubers were found in the plants grown on above the laterals in the soil treated by gypsum and N fertilizer.

Keywords: Agricultural gypsum ,Tile drainage, Nitrogen fertilization, Potato plants , Chemical composition, Ground and drainage water.

INTRODUCTION

Agricultural gypsum (calcium sulfate - CaSO4 + $2H_2O$) is one of those rare materials that perform in all three categories of soil treatment: an amendment, conditioner and fertilizer. Gypsum is widely used to improve the fertility and functioning of productive soils (Shainberg *et al.* , 1989 and Scott *et al.* , 1993) . It:

- Improves soil structure, aeration and drainage .
- Reduces soil compaction and cracking .
- Improves root penetration .
- Increases soil calcium balance without changing pH .
- Increases available sulphur in the soil .
- Stabilizes the organic components of the soil .

On the other hand , nitrogen is an essential element required for plant nutrition , but the excessive application of mineral fertilizers led to increase production cost. The residual of mineral fertilizers has seriously affected the quality of agricultural products people's health and caused environmental pollution. Therefore , a great interest has been generated to apply bioorganic and inorganic fertilizers to establish a good ecoenvironment (Basak , 2006). In many instances , less than 60 % of the added N is recovered in the crop and soil with the remainder being lost by processes such as volatilization , leaching , immobilization and denitrification. Thus , it is necessary to develop fertilizer management practices that can reduce losses and increase the nitrogen use efficiency (Yusron and Phillips , 1997).

Installation of subsurface drainage system in soils results in indirect effects on improving soil physical, chemical and hydrological properties, such as lowering water table, which lead to better structure of top soil, higher infiltration and porosity (Antar, 2000). The results obtained by Abdel-Aal *et al.* (2006) revealed that , soil salinity values were relatively affected by drain spacing treatments. Also they results indicated that spacing treatments highly affect sugar beet root diameters and lengths and consequently crop yield. Root diameters increased by decreasing drain spacing. There was an increment in sugar beet production with narrow drains spacing treatments.

Potato (*Solanum tuberosum L.*) is considered one of the world major staple food crops as it produces more dry matter and protein per hectare than the major central crops (Burton,1989). Potato tubers are eaten in more countries than any other crop. Potato tubers in the global economy are the fourth important crop after the three cereals namely wheat, rice and maize. The main production areas of potato are in Europe and in the Russia, which account for nearly 56% of the output (Vreugdenhil *et al.,* 2007). In Egypt, potato is one of the most important vegetable crops grown under Egyptian conditions. According to the recorded data obtained from the department of Agricultural Economics and Statistics, Ministry of Agriculture and Land Reclamation, the cultivated area of potato in 2009 reached about 329721 feddans, which yielded 3659244 tons of tubers with an average of about 11.098 tons per feddan (Taha , 2011).

On the other hand , potato plants have high nutrients requirements , especially N- fertilizers , largely due to its shallow root system and short growth duration, but its recovery of fertilizer-N is often quite low (Acland, 1980). The low efficiency is partly due to a shallow root system that is usually confined to top 60 cm of soil, with 90 % of the root length in the surface 25 cm of the soil profile (Tanner *et al.,* 1982).Therefore , the liberal application of mineral N-fertilizers to maintain adequate level of N in the rhizosphere, leads to the accumulation of excessive levels of NO_3-N in the plant (Maynard *et al.*,1976 and Taha , 2011) as well as contribute to high NO_3-N content of ground water.

The aim of this investigation is to study , the effect of individual and combined applications of mineral nitrogen fertilization and gypsum on some soil properties and yield of potato plants grown on a clay soil under tile drainage system conditions. Evaluation of drainage performance and the different from distance of lateral were studied. Also , the content of nitrogen forms (NH_4-N and NO_3-N) distribution through different soil depths, ground and drainage waters in relation to time were studied.

MATERIALS AND METHODS

A field experiment was carried out on an alluvial clay soil of a pilot field at Talla area, Minufiya Governorate , Egypt during two successive growth winter seasons 2011 / 2012 and 2012 / 2013 to study the effect of agricultural gypsum application and mineral - N fertilizer (ammonium nitrate , 33 % N) solely or in combination under different distances of tile drain on some soil properties and yield of potato plants (*Solanum tuberosum L.*) Scotland cv . Nieta and its content of NH_4-N and NO_3-N through plant life. The field had tile drains with a 30 m space and 1.5 m depth. Before planting , representing soil samples of the experiment soil were taken separately at soil depths of 0 - 20, 20 - 40 and 40 - 60 cm above the laterals (A) and at midway of laterals (B). Soil samples were air-dried, ground and sieved through a 2 mm sieve. The prepared samples were analyzed for some physical and chemical properties and also for its contents of available NH_4-N and NO_3-N according to the methods described by Cottenie *et al.* (1982) and Kim (1996). The obtained data were recorded in Table (1). At the same time , samples of both ground water and drainage water were taken from observation wells and from the drain for pH , EC (dS m^{-1}) and the content (mg / l) of NO_3-N and NH_4-N determinations according to the methods described by Chapman and Pratt (1961). The obtained data were recorded in Table (2).

The experimental design was a split split - plot design with three replicates. The main factor was agricultural gypsum treatments (G) ,the sub factor was nitrogen fertilization treatments (F) and the sub - sub factor was the distance from the laterals (D). The area of each plot was 30 m^2 (6 m length x 5 m width). Before planting , at final soil preparation , all plots were fertilized by ordinary super phosphate (15.5 % P_2O_5) at a rate of 60 kg P_2O_5 / fed. Then, the experimental plots were divided into two main groups ,the first group was untreated by agricultural gypsum, while the second group was treated by gypsum at a rate of 3 ton gypsum / fed., as a protection dose .

Table (1): Some physical and chemical properties of the studied soil at two distances (A and B) from the lateral before potato planting.

properties and units	Distance from the lateral					
	A (0 m)			B (15 m)		
	0-20 (cm)	20-40 (cm)	40-60 (cm)	0-20 (cm)	20-40 (cm)	40-60 (cm)
Particles size distribution (%)						
Sand	18.5	14.9	14.2	18.5	14.9	14.2
Silt	33.5	32.5	32.1	33.5	32.5	32.1
Clay	48.0	52.6	53.7	48.0	52.6	53.7
Texture grade	Clay	Clay	Clay	Clay	Clay	Clay
pH 1:2.5(soil:water) susp	7.45	7.50	7.52	7.56	7.63	7.65
EC in soil paste (dS/m)	1.35	1.52	2.11	1.54	1.68	2.29
Organic matter (%)	1.80	0.88	0.65	2.03	1.03	0.67
Calcium carbonate (%)	2.05	3.14	1.80	2.02	2.53	1.80
Total nitrogen (%)	0.155	0.087	0.075	0.169	0.093	0.080
Available nitrogen (mg/kg)	134	118	104	147	128	117
Available NO_3-N (mg/kg)	108	95	82	113	99	91
Available NH_4-N (mg/kg)	26	23	22	34	29	26

Table (2): Chemical analysis of ground and drainage water in the used soil before potato planting.

Water source	EC (dS/m)	pH	Nitrogen content (mg / l)		
			NO_3-N	NH_4-N	Total – N
Ground	5.50	8.35	4.80	1.98	6.78
Drainage	3.56	7.80	2.50	1.15	3.65

*** Mean values at the two seasons.**

Two weeks before planting, certified potato seed tubers of the Scotland cv . Nieta were subjected to chitting process in order to promote green sprouting by exposing them to an indirect light under high relative humidity conditions. Seeding tubers at a rate of 1350 kg tubers / fed. , thus seed tubers ranging from 35-55 mm in size with 2-3 sprouts were sown on 11th October 2011 and 15th October 2012 in the first and second seasons. Potato seed pieces were set at 20 cm between each other and in depth of about 15 cm in rows. The distance between rows was 60 cm. All farming processes for potato plants were carried out according to the recommendations of Egyptian Ministry of Agriculture. After planting directly, the sub main plots were divided into two equal groups , the first group was left without nitrogen fertilization, while the second group was fertilized with ammonium nitrate (NH_4NO_3 , 33 % N) with an application rate of 500 kg/fed. (165 kg N / fed.) which equal 100 % of the recommended dose, in two equal doses (at planting and with first irrigation). Also, all plots were fertilized by potassium sulphate (K_2SO_4 ,48% K_2O) at an application rate of 90 kg K_2O / fed. , in two equal doses (at planting and after 50 days from planting). The sub - sub plots or the distances from the laterals were above (A) and at midway (B) of the laterals. The ground water table depth was recorded by daily reading of observation wells after the first and second irrigations and samples of ground water were taken from observation wells every 3 days after the first (1) and the second (2) irrigation at the distance of A and B of the each treatments under study and its content of nitrogen (NO_3-N + NH_4-N) as mg/l were determined according to the method described by Chapman and Pratt (1961) and recorded based on the mean values. Also, at 1,4,7,10 and 13 days after the same irrigations, samples of drainage water were taken from the collectors and analyzed for NH_4-N and NO_3-N (mg / l) determination.

Before the second (2) and the third (3) irrigations and at harvesting stage (after 115 day from planting), soil samples were taken from the depths of 0 - 20, 20 - 40 and 40 - 60 cm at the distances A and B of each studied treatment. The collected soil samples were prepared for available nitrogen (NO_3-N + NH_4-N) as mg / kg analysis according to the method described by Cottenie *et al.* (1982) and Kim (1996).

Vegetative samples of potato shoots were taken from each treatment directly before the second (2) and the third (3) irrigations. At harvest stage (after 115 days from planting) , potato plants were harvested and the yields of tubers were weighed as ton / fed. All plant samples were air-dried then oven-dried at 70°C until the weights became constant, ground and analyzed for its content of total N, NO_3-N and NH_4-N was determined according to the methods described by Chapman and Pratt (1961) and Cottenie *et al.* (1982).

Yield data were subjected to statistical analysis according to Gomez and Gomez (1984) . Least significance difference (L. S. D.) at 0.05 probability was applied for comparing means .

RESULTS AND DISCUSSION

Ground Water Table Level

The data of water table level (cm) with time after the first and second irrigations (1 and 2) above (A) and at midway (B) of laterals (0 and 15 m) as presented in Table (3) show that , in both unfertilized and fertilized soils and at different distances of laterals there are no clear differences between ground water table at the same day after the first and second irrigation. On the other hand , these differences were more clear as a result of gypsum application. This effect was found above and at midway of the laterals. These findings were attributed to the aggregation effect of gypsum on soil particles which followed by an increase of soil total porosity , infiltration rate and draw down water movement (Shainberg *et al.* , 1989 ; Scott *et al.* , 1993 and El-Sanat , 2003). At the same day , the level of ground water after the first irrigation was more down compared with that measured after the second irrigation. This trend was found with the different treatments under study. Generally , with the different treatments under study , the depth of ground water above the laterals was more than that at midway of the laterals. These findings means that , water table level above laterals dropped faster , with larger amount than that in midway between laterals specially in the soil treated by gypsum. Ibrahim et al. (1999) ; Antar (2000) and El - Hadidy *et al.* (2003) obtained similar results.

Table (3) : Average* water table depth (cm) after the first (1) and the second (2) irrigation above (A) and midway (B) of the laterals as affected by the studied treatments.

Days after irrigate-ion	Without gypsum								With gypsum							
	Unfertilized soil				Fertilized soil				Unfertilized soil				Fertilized soil			
	(1)		(2)		(1)		(2)		(1)		(2)		(1)		(2)	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	60	31	42	30	62	35	47	33	70	38	55	31	74	40	60	35
2	71	39	50	36	74	43	59	41	80	45	64	40	85	48	70	45
3	82	46	61	42	85	52	70	48	88	48	72	45	93	57	78	54
4	90	51	66	48	90	58	80	54	95	56	79	56	100	64	86	61
5	91	59	70	53	92	64	84	62	101	64	85	60	105	69	90	68
6	92	62	79	65	94	67	88	70	105	70	89	62	109	74	94	74
7	94	70	83	68	96	71	90	74	108	77	92	68	111	76	97	78
8	99	72	89	70	99	76	91	78	110	81	95	73	113	80	99	81
9	100	79	90	75	101	80	92	81	110	82	97	80	115	84	101	84
10	104	81	91	82	103	84	94	83	112	87	98	83	115	88	102	86
11	105	82	94	82	106	88	96	86	112	90	99	86	116	91	103	90
12	106	89	95	85	107	90	98	88	113	91	100	90	116	93	104	91
13	107	90	96	86	108	92	100	89	114	92	101	91	117	95	105	92
14	109	92	98	87	109	94	101	90	115	93	102	92	118	96	106	93
15	110	93	100	88	110	95	102	92	116	95	103	94	119	97	108	95
16	110	93	102	90	111	96	103	94	117	97	104	95	120	98	108	97
17	111	94	103	91	112	97	104	95	118	100	105	96	121	99	108	98
18	112	96	104	93	113	98	105	96	119	100	106	98	122	100	109	99
19	113	98	105	95	114	99	106	97	120	101	106	99	122	101	109	100
20	114	99	106	97	115	100	107	98	120	102	107	100	122	102	110	101
21	115	100	107	99	115	100	108	99	120	102	108	101	123	103	110	102

*Measured during two growing seasons at above and midway of the laterals .

Nitrogen in Soil

The soil contents of available N (mg / kg) which measured as NH_4-N and NO_3-N among different soil depths before the second (2) and third (3) irrigations as affected by the studied treatments were recorded in Table (4). These data show that with all treatments , the soil content of either NH_4-N or NO_3-N was decreased with the increase of soil depth. These findings may be resulted from the high content of soil fine fractions and organic matter in the surface layers compared to the subsurface layer (El- Sherif , 2005 and El-Mleegy , 2007). At the same depth and with different treatments under study , the soil content of NH_4-N was higher than the content of NO_3-N. This trend may be resulted from the high ability of NH_4 adsorption by negative charges presented on the surface of soil compounds especially clay and organic matter . Also , NO_3 is characterized by more solubility and faster leaching with irrigation water to down depths and ground water (Abd El-Galil , 2006 and El-Mleegy , 2007).

Regarding the effect of drainage treatments under study, the obtained data in Table (4) shows that the soil content (mg / kg) of total available nitrogen , NH_4-N and NO_3-N among different soil depths above the laterals was lower than that found at midway of the laterals. This finding may be resulted from the faster and large amounts of irrigation water removed above the lateral compared with those occurred at far from the distances of the lateral associated with high leaching amounts of different N forms (Antar , 2000 and El - Hadidy *et al.* , 2003). Also , this trend may be resulted from the high absorbed amounts of nitrogen by plants grown above the lateral associated with the greater rate of plant growth compared with other locations. These findings were found at the different soil depths in both gypsum and N fertilization treatments under study in the two growing seasons. The same data showed that , gypsum application was associated by a decrease in soil content of the determined available forms in both fertilized and unfertilized soils above and at midway of the laterals. These decreases may be resulted from the improving effect of gypsum on physical and chemical properties specially soil aggregation , aeration , soil reaction (pH) and others. Such changes were associated by more leaching amounts of nitrogen and also by high rates of plant growth (Mohamad , 2009). Under different drainage treatments , the contents of determined N forms in the fertilized soil were higher than those determined in the unfertilized soil (El-Mleegy , 2007 and Mohamad and Tantawy , 2012).

Regarding the data of soil content of the determined N forms which recorded in Table (4) , it may be noted that among different soil depths at different distances of laterals in both gypsum and N fertilization treatments , the high content (mg/kg) of the determined N forms was found before the second irrigation and the lowest one was found after plant harvest. These findings may be resulted from the increased amounts of N absorbed by plants with the increase of plant age and also was resulted from the increase of the leached amounts of N with irrigation water to ground and drainage water with the time increase throughout the growing season. In this respect , Oosterbaan (1994) and Bol'shakov *et al.*(1996) investigated similar results .

Table (4) : The soil content (mg / kg) of available NH_4-N , NO_3-N and total – N (T- N) and its vertical distribution above (A) and at midway (B) of the laterals before second (2) and third (3) irrigation and at harvest stage as affected by the studied treatments .

Treatments G*	Treatments N**	Distance from Laterals (m)	Soil depth (cm)	(2) NH_4-N (mg / kg)	(2) NO_3-N (mg / kg)	(2) T – N (mg / kg)	(3) NH_4-N (mg / kg)	(3) NO_3-N (mg / kg)	(3) T – N (mg / kg)	At harvest NH_4-N (mg / kg)	At harvest NO_3-N (mg / kg)	At harvest T – N (mg / kg)
Without	Without	A (0)	0 – 20	92.5	26.5	119.0	85.0	25.0	110.0	75.5	22.5	98.0
			20 – 40	86.0	22.0	108.0	81.0	21.0	102.0	72.5	21.0	93.5
			40 – 60	82.5	21.0	103.5	80.0	21.0	101.0	70.0	20.0	90.0
			Mean	**87.0**	**23.2**	**110.2**	**82.0**	**22.4**	**104.4**	**72.7**	**21.2**	**93.9**
		B (15)	0 – 20	103.0	27.5	130.5	96.0	26.5	122.5	90.0	25.0	115.0
			20 – 40	97.5	22.5	120.0	92.5	22.0	114.5	85.0	21.5	106.5
			40 – 60	88.0	22.0	110.0	85.0	21.0	106.0	81.0	20.0	101.0
			Mean	**96.2**	**24.0**	**120.2**	**91.2**	**23.2**	**114.4**	**85.4**	**22.2**	**107.5**
	With	A (0)	0 – 20	115.0	40.0	155.0	125.0	30.0	155.0	105.0	35.0	140.0
			20 – 40	105.0	40.0	145.0	90.0	40.0	130.0	95.0	35.0	130.0
			40 – 60	100.0	35.0	135.0	90.0	35.0	125.0	90.0	30.0	120.0
			Mean	**106.7**	**38.4**	**145.0**	**101.7**	**35.0**	**136.7**	**96.7**	**33.4**	**130.0**
		B (15)	0 – 20	135.0	60.0	195.0	125.0	50.0	175.0	120.0	45.0	165.0
			20 – 40	130.0	55.0	185.0	110.0	55.0	165.0	115.0	40.0	155.0
			40 – 60	130.0	35.0	165.0	115.0	40.0	155.0	95.0	40.0	135.0
			Mean	**131.7**	**50.0**	**181.7**	**116.7**	**48.4**	**165.0**	**110.0**	**41.7**	**151.7**
With	Without	A (0)	0 – 20	90.2	24.8	115.0	83.5	23.7	107.2	80.8	22.5	103.3
			20 – 40	84.1	21.2	105.3	81.5	20.5	102	77.8	20.1	97.9
			40 – 60	81.2	19.9	101.1	79.6	19.5	99.1	75.9	19.2	95.1
			Mean	**85.2**	**22.0**	**107.1**	**81.5**	**21.2**	**102.7**	**78.2**	**20.6**	**98.8**
		B (15)	0 – 20	97.5	26.5	124.0	93.5	25.5	119.0	85.0	23.5	108.5
			20 – 40	94.0	22.5	116.5	90.0	21.5	111.5	81.0	21.0	102.0
			40 – 60	85.0	22.0	107.0	82.0	21.0	103.0	78.5	20.0	98.5
			Mean	**92.2**	**23.7**	**115.9**	**88.5**	**22.7**	**111.3**	**81.5**	**21.5**	**103.0**
	With	A (0)	0 – 20	132.5	52.8	185.3	126.8	48.6	175.4	100.5	31.5	132.0
			20 – 40	124.6	43.6	168.2	120.7	42.5	163.2	96.5	28.7	125.2
			40 – 60	118.9	34.5	153.4	114.8	33.1	147.9	84.3	24.2	108.5
			Mean	**125.3**	**43.6**	**169.0**	**120.8**	**41.4**	**162.2**	**93.8**	**28.1**	**121.9**
		B (15)	0 – 20	140.0	50.0	190.0	135.2	50.0	185.2	110.0	35.0	145.0
			20 – 40	130.0	45.0	175.0	123.4	35.0	158.4	105.0	30.0	135.0
			40 – 60	120.0	35.0	155.0	116.5	35.0	151.5	90.0	25.0	115.0
			Mean	**130.0**	**43.3**	**173.3**	**125.0**	**40.0**	**165.0**	**101.7**	**30.0**	**131.7**

G* = gypsum treatments and N** = mineral – N fertilization treatments .

Ground Water Content of Nitrogen

Ground water content of total nitrogen , NH_4-N and NO_3-N (mg/l) which recorded in Table (5) show that with different treatments under study the concentration of both NH_4-N and NO_3-N in ground water was decreased with the increase of time after both the first and second irrigation. This means that , most of the leached nitrogen was occurred directly after irrigation and at short time of N fertilizer application. At the different days of irrigation , the concentration of both NH_4-N and NO_3-N in ground water measured after the first irrigation was lower than those determined after the second irrigation. These findings could be resulted from the faster movements and greater amounts of irrigation water resulted in a greater dilution of ground water after the first irrigation compared with that occurred after the second irrigation (Table, 3). This trend was found in both gypsum and N fertilization treatments in the two growing seasons. The data of the concentration of NH_4-N and NO_3-N in ground water also show that with all treatments under study , the concentration of NO_3-N in ground water was higher than that measured for NH_4-N. This finding may be resulted from the high solubility of NO_3-N form and its movement with leaching water compared with that of NH_4-N (Bol'shakov *et al.,* 1996 and Ibrahim *et al.,* 1999). The same data show that gypsum application in both fertilized and unfertilized soils was associated with more leaching of NH_4-N and NO_3-N. So , the ground water in the soil treated by gypsum have a high concentration of both NH_4-N and NO_3-N compared with that found in the untreated soil . Generally , with the two gypsum treatments , the concentration of NH_4-N and NO_3-N in ground water in the fertilized soil was higher than that measured in the ground water in the unfertilized soil either after the first or the second irrigation in the two growing seasons.

Drainage Water Content of Nitrogen

The data of drainage water concentration (mg / l) of NH_4-N and NO_3-N as presented in Table (6) illustrated that , the high concentration of either of NH_4-N or NO_3-N was found at the first days of irrigation and decreased at the later days. These findings were in good relations with the large amounts of irrigation water moved from soil to drains which characterized by high content of leached NH_4-N and NO_3-N, where these amounts were decreased with increasing time after irrigation (Ibrahim *et al.,* 1999 and Antar , 2000). This trend was found in both gypsum and N fertilization treatments in the two growing seasons. At different days after irrigation , the concentration of NH_4-N and NO_3-N in drainage water after the first irrigation was lower than those found after the second irrigation. These findings could be resulted from the high amounts of irrigation water caused more dilution of drainage water after the first irrigation compared with that occurred after the second one. The obtained data also show that at the same day after the first and second irrigation, the concentration of NO_3-N in the drainage water was higher than those of NH_4-N in the two growing seasons with both gypsum and N fertilization treatments . These findings were resulted from the high solubility and leaching rate of NO_3-N form compared with NH_4-N form.

Table (5) : Ground water content of total N (T-N) , NH4 –N and NO3 – N (mg / l) after different days of first (1) and second (2) irrigation as affected by the studied treatments .

Days after irrigation	Without gypsum application												With gypsum application											
	Unfertilized soil						Fertilized soil						Unfertilized soil						Fertilized soil					
	(1)			(2)			(1)			(2)			(1)			(2)			(1)			(2)		
	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	T – N (mg/l)
1	2.10	5.80	7.90	2.30	5.95	8.25	2.65	7.10	9.75	3.00	7.40	10.40	2.25	5.92	8.17	2.42	6.10	8.52	2.98	7.30	10.20	3.25	7.60	10.85
4	1.98	5.60	7.58	2.18	5.90	8.08	2.50	7.00	9.50	2.80	7.25	10.05	2.15	5.70	7.85	2.25	5.98	8.23	2.62	7.12	9.74	3.07	7.42	10.49
7	1.90	5.52	7.42	2.10	5.75	7.85	2.38	6.88	9.26	2.65	7.12	9.77	2.03	5.60	7.63	2.13	5.85	7.98	2.55	6.98	9.53	2.90	7.30	10.20
10	1.78	5.25	7.03	1.98	5.50	7.48	2.30	6.80	9.10	2.51	6.98	9.49	1.95	5.32	7.27	2.03	5.58	7.61	2.45	6.87	9.32	2.65	7.18	9.83
13	1.60	4.90	6.50	1.82	5.15	6.97	2.25	6.65	8.90	2.40	6.85	9.25	1.88	5.05	6.93	1.90	5.23	7.13	2.39	6.72	9.11	2.50	7.00	9.50
16	1.52	4.80	6.32	1.65	4.92	6.57	2.15	6.48	8.63	2.30	6.77	9.07	1.62	4.90	6.52	1.70	5.08	6.78	2.31	6.60	8.91	2.38	6.94	9.32
19	1.45	4.70	6.15	1.55	4.80	6.35	2.10	6.40	8.50	2.23	6.65	8.88	1.53	4.78	6.31	1.60	4.90	6.50	2.24	6.50	8.74	2.30	6.80	9.10
21	1.40	4.65	6.05	1.44	4.68	6.12	2.07	6.35	8.42	2.15	6.45	8.60	1.48	4.71	6.19	1.54	4.72	6.26	2.15	6.42	8.57	2.25	6.60	8.85
Mean	1.72	5.15	6.87	1.88	5.33	7.21	2.30	6.71	9.01	2.51	6.93	9.44	1.86	5.25	7.11	1.95	5.43	7.38	2.46	6.81	9.27	2.66	7.11	9.77

*Mean values at the two growing seasons ..

The data presented in Table (6) showed that , unfertilized and fertilized soils , gypsum application resulted in a decrease of drainage water content of both NH_4-N and NO_3-N in the two growing seasons. These decreases may be resulted from the large amounts of draw down water associated with gypsum application which resulted in a dilution of ground water. Generally , with all the studied treatments , the concentration (mg / l) of NH_4-N and NO_3-N in drainage water in the soil fertilized with nitrogen was higher than those found in the unfertilized soil. Abu-Sinna (1991) obtained similar results .

Table (6) : Drainage water content of total soluble N (T-N) , NH_4 –N and NO_3 - N (mg / l) at different days of (1) and second (2) irrigation as affected by the studied treatments .

Gypsum treatments	Days after irrigation	Unfertilized soil						Fertilized soil					
		(1)			(2)			(1)			(2)		
		NH_4 – N (mg / l)	NO_3 – N (mg / l)	T – N (mg / l)	NH_4 – N (mg / l)	NO_3 – N (mg / l)	T – N (mg / l)	NH_4 – N (mg / l)	NO_3 – N (mg / l)	T – N (mg / l)	NH_4 – N (mg / l)	NO_3 – N (mg / l)	T – N (mg / l)
Without	1	1.4	3.5	4.9	1.5	3.8	5.3	1.6	5.1	6.7	1.8	5.5	7.3
	4	1.3	3.1	4.4	1.5	3.6	5.1	1.6	4.7	6.3	1.7	5.3	7.0
	7	1.3	2.5	3.8	1.4	2.8	4.2	1.4	4.1	5.5	1.5	4.5	6.0
	10	1.1	2.2	3.3	1.3	2.4	3.7	1.2	3.8	5.0	1.5	4.0	5.5
	13	0.9	2.2	3.1	1.1	2.4	3.5	1.2	3.8	5.0	1.2	3.4	4.6
	Mean	**1.2**	**2.7**	**3.9**	**1.4**	**3.0**	**4.4**	**1.4**	**4.3**	**5.7**	**1.5**	**4.5**	**6.1**
With	1	1.5	3.8	5.3	1.6	3.9	5.5	1.8	5.5	7.3	2.1	6.1	8.2
	4	1.4	3.5	4.9	1.5	3.6	5.1	1.8	5.0	6.8	1.9	5.7	7.6
	7	1.4	2.9	4.3	1.4	3.2	4.6	1.6	4.4	6.0	1.8	4.9	6.7
	10	1.2	2.6	3.8	1.3	2.8	4.1	1.4	4.1	5.5	1.5	4.4	5.9
	13	1.1	2.5	3.6	1.2	2.6	3.8	1.4	4.0	5.4	1.5	4.3	5.8
	Mean	**1.3**	**3.1**	**4.4**	**1.4**	**3.2**	**4.6**	**1.6**	**4.6**	**6.2**	**1.8**	**5.1**	**6.8**

***Mean values at two growing seasons.**

Potato Yield

Yield of potato tubers (ton / fed.) as affected by gypsum application and nitrogen fertilization at two distance from the laterals was recorded in Table (7). These data show that gypsum application led to increase in the obtained tubers yield of potato. These increases were found in both fertilized and unfertilized soils above and at midway of the laterals in the two grown seasons . The obtained increase of tubers yield as a result of gypsum application may be attributed to the improving effect of added gypsum on soil properties and increasing nutrients availability (Mohamad , 2009). Also , the obtained data show that the high response of potato plants to N fertilization where the obtained yield of tubers in the fertilized soil was high significant increase than that obtained from the unfertilized soil above and at midway of the laterals in the two growing seasons. These findings show the nitrogen fertilization is importance for potato plants growth (Marschner, 1998 and Darwish *et al.,* 2003). These results are in agreement with those obtained by Chen and Hutchinson (2008 and 2009) and Taha (2011). In both gypsum and nitrogen fertilization treatments , the tubers yields of potato plants grown above the laterals significant increase than those of plants grown between the laterals. These results may be attributed to the more improved effects of tile drainage on soil physical and chemical properties especially above the laterals (Antar , 2000 ; Salem *et al.* , 2004 and Agbede , 2010). The efficiency use of nitrogen fertilization on potato plants may be supported by the calculated relative change values (RC , %) of the tubers yield produced from fertilized soil compared with that produced from unfertilized soil as recorded in Table (7). At different distances (A and B) from the laterals , the calculated values of RC were positive in the two grown seasons with the two treatments of gypsum. These results are in agreement with those obtained by Rodrigues *et al.*(2008) and Taha (2011).

Table (7) : Tubers yield (ton / fed.) of potato at different distances (A and B) of lateral as affected by the studied treatments .

Growing seasons	Without gypsum application						With gypsum application					
	Unfertilized soil		Fertilized soil		RC (%)		Unfertilized soil		Fertilized soil		RC (%)	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
First	8.35	7.68	14.22	12.12	70.30	57.81	9.10	8.44	16.02	13.55	76.04	60.55
Second	8.05	7.41	14.30	12.65	77.64	70.72	9.25	8,72	16.75	13.60	81.08	55.96
Mean	8.20	7.55	14.26	12.39	73.97	64.27	9.18	8.58	16.39	13.58	78.56	58.26

Statistical analysis (L.S.D. at 0.05 level) of the studied variables of potato (tubers yield) as affected the studied treatments .

Growing seasons	Gypsum (G)	Fertilizer (F)	Distance (D)	G. F.	G. D.	F. D.	G. D. F.
First	3.045**	5.655**	-2.555**	6.558**	N.S.	N. S.	N.S.
Second	1.843*	6.106**	-3.383**	6.798**	N.S.	N.S.	N.S.

Potato Content of Nitrogen

The presented data in Table (8) show the nitrogen (NH_4-N and NO_3-N) content (%) of shoots and tubers of potato plants as affected by the studied treatments. These data show that, with different treatments of gypsum and N fertilization , both shoots and tubers content of NH_4-N and NO_3-N above the laterals was higher than that in the plants at midway of the laterals , where the lowest content was found in the plants grown in the middle distance between the laterals. This trend may be resulted from the high plant growth above the lateral which associated with greater yield compared with other distance. This trend may be explained based on the dilution effect as mention by Marschner (1998) and Basak (2006). Also , these findings could be resulted from the greater amounts of leached nitrogen with drainage water above the laterals compared with that leached at midway of the laterals. This trend was found in gypsum application and mineral N - fertilization treatments in the two grown seasons . At different distances , shoots content of N after the second irrigation was lower than that found after the first irrigation. This trend may be also explained based on the dilution effect (Basak , 2006). The data also show that , at the distance of A and B in the unfertilized and fertilized soils , gypsum application resulted in an increases of shoots and tubers content (%) of both NH_4-N and NO_3-N in the two growing seasons.Tubers and shoots content (%) of NH_4-N in the different treatments under study was higher than the content (%) of NO_3-N in the two growing seasons. Generally , tubers and shoots content of either NH_4-N or NO_3-N in the fertilized soil was higher than those in the unfertilized soil. This trend was found in the two growing seasons, Mauromicale *et al.* (2006) and Taha (2011) obtained similar results.

Table (8): Shoots and tubers of potato plants content (%) of total N (T – N) , NH_4 – N and NO_3 – N as mean values in the two grown season before the second (2) , tired (3) irrigations and at harvest stage above (A) and midway (B) of the laterals as affected by the studied treatments.

Gypsum treatments	Nitrogen treatments	Distance from laterals	Shoots						Tubers		
			Before (2)			Before (3)			At harvesting stage		
			NH_4 – N (%)	NO_3 – N (%)	T – N (%)	NH_4 – N (%)	NO_3 – N (%)	T – N (%)	NH_4 – N (%)	NO_3 – N (%)	T – N (%)
Without	Without	A	1.050	0.450	1.500	0.980	0.420	1.400	1.710	0.020	1.730
		B	0.900	0.320	1.220	0.830	0.320	1.280	1.610	0.016	1.626
	With	A	1.820	0.830	2.650	1.750	0.600	2.350	2.250	0.030	2.280
		B	1.600	0.650	2.250	1.420	0.500	1.920	1.950	0.022	1.972
With	Without	A	1.175	0.500	1.675	1.015	0.460	1.475	2.120	0.022	2.142
		B	1.000	0.400	1.400	0.900	0.380	1.280	1.650	0.017	1.667
	With	A	2.007	0.910	2.917	1.860	0.730	2.590	2.500	0.035	2.535
		B	1.700	0.700	2.400	1.550	0.550	2.100	2.010	0.025	2.035

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تأثيرالجبس و التسميد النيتروجيني المعدني علي توزيع صور النيتروجين خلال النظام الزراعي ومحصول البطاطس النامية في أرض طينية تحت نظام الصرف المغطى

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أجريت تجربة حقلية على الأرض الرسوبية الطينية بحقل تجريبي بمنطقة تلا- محافظة المنوفية خلال موسمي نمو شتويين متتاليين (٢٠١١ /٢٠١٢ و٢٠١٢ / ٣ ٢٠١) على نبات البطاطس صنف إسكوتلند نيتا و ذلك لتقييم الأثر الفردي و المشترك لكل من إضافة الجبس بمعدل (صفر و ٣ طن / فدان) كجرعة وقائية و السماد المعدني النيتروجيني (نترات الأمونيوم ، ٣٣٪ ن) بمعدل صفر و ١٠٠٪ من الجرعة الموصي بها و التي تساوي ٥٠٠ كجم نترات الأمونيوم / فدان (١٦٥ كجم ن / فدان) . و ذلك تحت مسافات صرف مغطى مختلفة (فوق و عند منتصف المسافة بين الحقليات) علي بعض خواص التربة و نمو و محصول نبات البطاطس. و المنطقة تحت الدراسة منفذ بها نظام صرف مغطي خطوط الحقليات علي مسافات ٣٠ متر و بعمق ١,٥ متر. و تم قياس عمق الماء الأرضي عند فترات زمنية مختلفة. كما تم دراسة المحتوي الميسر من صور النيتروجين (النيتروجين الأمونيومي و النيتروجين النتراتي) فيما بين أعماق التربة المختلفة و علي مسافات مختلفة من الحقليات (فوق و عند منتصف المسافة بين الحقليات) وأيضا تم تقديرهما في الماء الأرضي و ماء الصرف و في عرش البطاطس (المجموع الخضري) و في الدرنات سواء الموجودة فوق أو عند منتصف المسافة بين الحقليات و ذلك عند فترات نمو مختلفة و تحت جميع معاملات الدراسة . و أجريت التجربة في تصميم قطع منشقة مرتين في ثلاث مكررات .

و قد أظهرت النتائج زيادة عمق الماء الأرضي بزيادة الفترة الزمنية بعد الري و خاصة بعد الرية الأولى و قد إزداد هذا العمق مع إضافة الجبس و أيضا في المنطقة التي فوق الحقليات. كما إنخفض محتوي الأرض (مجم/كجم) من النيتروجين الأمونيومي وكذلك النتراتي بزيادة عمق الأرض و ذلك بعد الرية الأولى و الثانية و عند الحصاد ، و كان هذا المحتوي من النيتروجين الميسر أكثر إنخفاضا فوق الحقليات و في الأراضي المعاملة بالجبس و الغير مسمدة بالسماد النيتروجيني المعدني و عند مرحلة الحصاد . تحت جميع معاملات الدراسة وجد أن محتوي التربة من النيتروجين الأمونيومي أكبر من محتواها من النيتروجين النتراتي و كلاهما يقل بزيادة عمق التربة . و من ناحية أخري فإن محتوي (مجم/ لتر) الماء الأرضي و ماء الصرف من النيتروجين النتراتي أكثر من النيتروجين الأمونيومي و قد إزداد هذا المحتوى مع إضافات كل من الجبس و السماد النيتروجيني . و قد تأثرت ملوحة التربة نسبيا بالمسافة بين الحقليات حيث كانت ملوحة الطبقة السطحية ١,٣٥ و ١,٥٤ ديسيسيمنز / م فوق و عند منتصف المسافة بين الحقليات.

و قد بينت النتائج أن أعلي محصول لدرنات البطاطس كان موجودا في الأرض المعاملة بكل من الجبس و السماد النيتروجيني المعدني و الموجودة فوق الحقليات (١٦,٣٩ طن / فدان). و أيضا فإن أعلي محتوي (٪) من صورتي النيتروجين في كل من العرش (المجموع الخضري) و الدرنات كان في النباتات النامية عند منتصف المسافة بين الحقليات و في الأرض المضاف لها الجبس و السماد النيتروجيني .

و توصي هذه الدراسة بضرورة إضافة الجبس الزراعي و الإهتمام بالصرف المغطي حيث أنه يؤدي إلي زيادة كفاءة التسميد النيتروجيني و تزداد هذه الكفاءة بتقليل المسافة بين الحقليات كما توصي أيضا بضرورة الإهتمام بالتسميد النيتروجيني لنبات البطاطس حيث أنه يؤثر في زيادة الإنتاجية.

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