Response of Maize to Nitrogen Sources and Application Rates in a Calcareous Soil at Nubaria Region in Egypt

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ABSTRACT: A field experiment was conducted at the experimental farm of Nubaria Agricultural Research Station, Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation (MALR), El-Behiera Governorate, Egypt. The aim of the study was to evaluate the effect of different nitrogen fertilizer sources(anhydrous ammonia, Aque ammonia, Urea ammonium nitrate, Ammonium nitrate and urea) and rates (60, 90, and 120kg N/fed) on maize growth parameters (plant height, weight, and leaf area), yield components (ear weight, and 100-grain weight), stover and grain yields, NPK uptake, and N-use efficiency of maize grown in a calcareous soil. A split-plot design with three replicates were used. Five nitrogen sources represented the main plots and three N-rates represented the sub-plots. Maize SC 162 cultivar was used. The results indicated that, there were significant effects of the tested treatments on growth parameters (plant height, plant weight, and leaf area) and yield components (ear weight and 100-grain weight) parameters. These results showed no significant effect of N-sources on maize stover and grain yields. The highest grain yield of (2.98 ton/fed) was recorded for the liquid urea ammonium nitrate treatment (LUAN), while the lowest (2.76 ton/fed) was recorded for ammonium nitrate (AN) treatment. The N-rate treatments had a significant effect on maize stover and grain yields. The grain yields of 3.4, 3.1, and 2.01 ton/fed were recorded for the 120, 90, and 60 kg N/fed treatments, respectively. Results revealed also that, NPK (%), NPK uptake and total NPK uptake were significantly affected by N-sourceand N-rate treatments. There was no effect of N-sourcetreatments on N-use efficiency (NUE). The highest NUE (33.83 kg grain/kg) N was recorded for the LUAN treatment, while the lowest (30.89 kg grain/kg) N was for the urea treatment. The N-rate treatments had significant effect on NUE. and the obtained values were 34.3, 33.5 and 28.3 kg grain/kg N for 60, 90, and 120 kg N/fed treatments, respectively.

Key words: maize, anhydrous ammonia, aqua ammonia. NPK uptake, N-use efficiency.

INTRODUCTION

Maize is one of the strategic cereal crops cultivated in Egypt. It is important for the Egyptian economy since it is a source of human food and animal feed. The cultivated area of maize under surface irrigation method in 2012 was 679,508 hectares with average productivity 6.87 ton/ha. There is a gap between production and consumption of maize in Egypt estimated at 45% (Ouda *et al.*, 2016).The productivity of the crop decreased in recent years because of decline in soil fertility status (Sharif *et al.,* 2004).Among the various factors of production, the nutrient management has been recognized as the most significant factor limiting the yield levels in maize.

Nitrogen is the most important fertilizer element in plant production determining vegetative growth and productivity. Fertilizers common to crop production usually contain nitrogen in one or more of the following forms: nitrate, ammonia, ammonium or urea. Choice of N source can be important in maximizing the efficiency of fertilizer use and in protecting environmental quality. Improved fertilizer management is required to grow crops successfully on soils especially calcareous soils. To avoid ammonia volatilization, fertilizers containing ammonium-N or urea should be moved into the root zone with rainfall or irrigation, or be incorporated into the soil (Stehouwer and Johnson, 1990).All applied N-fertilizer sources eventually convert completely to the nitrate-N source. This form of nitrogen is not held tightly by soil particles and can be leached from the soil profile with excessive rains, especially on lighter-textured soils. Nitrate-containing fertilizers, including UAN solutions and ammonium nitrate, are susceptible to leaching loss as soon as they are applied. Urea can convert to nitrate-N in less than two weeks in late spring; and thereafter is susceptible to leaching loss. Anhydrous ammonia converts more slowly to nitrate-N because of its initial toxic effects on the soil microbes responsible for the conversion of ammonium-N to nitrate-N (Nielsen, 2006).

Stehouwer and Johnson (1990) reported that the application of anhydrous ammonia (NH_3) to soil without loss or crop damage depends on management factors such as N rate, plant spac and depth of application. The extent of any direct NH_3 loss following fertilization with anhydrous ammonia would depend largely on the NH_3-retention capacity of the soil, the amount of N applied per length of band and the depth of application. Loss of anhydrous ammonia (AA) as ammonia gas at the time of application is dependent on the depth of injection and the soil moisture status. Anhydrous ammonia applications should be made in moist soil (Larsonet*et al.*, 2014).

The depth of injection relates to the distance the ammonia would have to move to be lost to the atmosphere (Schmitt and Rehm, 1993).Long term research showed that, on average, anhydrous ammonia is approximately 10% more effective as a N-carrier in corn production than are urea based fertilizers.. If, however, conditions are such that little N loss will occur, urea based fertilizers are equivalent to anhydrous ammonia in their efficiency (Johnson, 2015).

Urea ammonium nitrate (UAN) is a preferred nitrogen source because it is a liquid that can be applied easily and quickly, and can be placed more precisely than other nitrogen sources. The UAN is a combination of urea and ammonium nitrate and has N content of 28-32% (Jhala, 2013). The UAN liquid solutions can be applied as a band on the surface with drops, even on fairly large corn field, or by injection. When applying N, especially as UAN or other sources containing urea, it needs to be placed into the soil profile or losses due to volatilization is possible.

Anhydrous ammonia (AA), urea (U), urea ammonium nitrate (UAN), ammonium nitrate (AN), and ammonium sulfate (AS) are readily soluble N fertilizers, and are common synthetic fertilizers used in row-crop agriculture. The UAN form of N fertilizer comes in liquid form and is considered a useful source of fertilizer N in mixing with other nutrients or chemicals (Millar *et al.*, 2010a).

The result of several researches indicated that, injection of anhydrous ammonia can result in higher corn grain yield compared to surface applied urea or urea-ammonium nitrate solution in no-tillage and high crop residue levels. However, urea has a major disadvantage in that considerable amounts of N can be lost through volatilization if it is not incorporated into soil soon after application (Mengel *et al.*, 1982;Chen *et al.*, 2008). (Hanan *et al.*, (2008) showed that grain yield and oil content of maize plant increased significantly when ammonia gas was applied at 140kg N/fed. Rauan (1986) and Abd El-Kader *et al.*, (2007) reported that, when the anhydrous ammonia was injected before sowing, it produced higher yield and minerals uptake than other nitrogen sources. Darwish (1989) found a positive effect of N fertilization on grain yield, straw and whole plant of corn grown in alluvial soil. This effect was in the order of ammonia gas > ammonium sulphate> ammonium nitrate > urea. The results of Yakout and Grish (2002), Zohry and Farghaly, (2003) and Siam *et al.* (2008), showed that, the addition of ammonia gas fertilizer significantly increased plant height, fresh and dry weight, weight of leaves, ear weights, weight of grain and straw yields of maize as compared with urea fertilizer. El-Doubyet *al.* (2001) found that maize grain yield was significantly increased when N rate increased.

Stecker *et al.* (1993) reported greater N fertilizer use efficiency and yields(0.42Mg/ha^{-1}) were obtained with ammonium nitrate for no-till corn than with surface-applied urea. Jemison and fox (1994) and Sogbedji *et al.* (2000) showed that, poor N-use efficiency can be caused by a number of loss mechanisms including leaching, ammonia volatilization, denitrification, and biological immobilization. Zhang *et al.* (2012) stated that, N-use efficiency in most crops is low, and in many trials, less than 50% of the applied N is found in the crop at harvest.

The objective of this study was to evaluate the effect of different nitrogen fertilizer sources (gaseous, liquid, and solid) and rates (60, 90, and 120kg N/fed) on maize growth parameters (plant height, weight, and leaf area), yield components (ear weight, and 100-grain weight), stover and grain yields, NPK uptake, and N-use efficiency grown in a calcareous soils at EL-Nubaria region, Egypt.

MATERIALS AND METHODS

A field experiment was conducted during the 2015 summer growing season at the experimental Farm of Nubaria Agricultural Research Station, Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation (MALR), Egypt. The station is located at 30° 54´ N, 29° 57´ E, and 25m above sea level. The aim of the study was to evaluate the effects of different nitrogen fertilizer sources (gaseous, liquid, and solid) and N-rates on maize production and N-use efficiency in a calcareous soil at EL-Nubaria region, Egypt.

Disturbed soil samples from three depths (0-20, 20-40, and 40-60 cm) were collected before planting to determine the main physical, chemical, and nutritional characteristics. Particle size distribution (sand, silt and clay percentages) and soil texture class was determined by the hydrometer method according to FAO (1980). Electrical conductivity (EC), and soluble anions and cations concentrations in soil paste extract were measured. Soil reaction (pH), organic matter (OM), total calcium carbonate ($CaCO_3$), mineral N (soluble NO_3+NH_4), Olsen P($NaHCO_3$- extractable), and exchangeable K were determined according to Page *et al.* (1982).The characteristics of the soil samples are presented in (Table1).

Table (1). The main physical, chemical, and nutritional characteristics of the experimental soil before planting

Soil Characteristics	Soil depth, cm		
	0-20	20-40	40-60
Particle size distribution			
Sand %	53.36	46.40	49.06
Silt %	10.00	12.00	10.00
Clay %	33.64	41.60	40.94
Soil Texture Class	Sandy Clay	Clay Loam	Clay Loam
pH, 1:2.5 soil: water suspension	8.21	8.18	8.18
EC_e, dS m^{-1}	4.37	4.24	4.41
Soluble cations, meq l^{-1}			
Ca^{2+}	20.00	20.00	20.33
Mg^{2+}	17.00	14.00	13.00
Na^{+}	5.64	6.94	10.83
K^{+}	1.07	1.02	0.33
Soluble anions, meq l^{-1}			
CO_3^{2-}	nil	nil	nil
HCO_3^{-}	4.00	4.00	3.33
Cl^{-}	9.66	6.50	4.00
SO_4^{2-}	30.05	31.46	37.16
$CaCO_3$, %	22.99	26.08	26.20
OM, %	0.46	-	-
KCl extractable N, $mgkg^{-1}$	173.00	150.26	134.13
$NaHCO_3$ Extractable P, $mgkg^{-1}$	15.60	17.36	16.26
Amm. Acetate Extractable K, $mgkg^{-1}$	216.66	176.66	210.00
DTPA Extractible Microelements, $mgkg^{-1}$			
Fe	2.49		
Zn	0.53		
Mn	2.00		
Cu	1.45		

A split plot experimental design with three replicates was used to conduct the field trials. Sources of nitrogen represented the main plots, and three rates of nitrogen represented the sub-plots. The tested treatments were:

<u>sources of nitrogen (main plots):</u>

- Anhydrous ammonia (AA), 80% N (gas),was applied by injection machine to 20 cm depth.
- Liquid ammonia (LA), 28% N (liquid),was add throe irrigation system (Fertigation)
- Liquid Urea/Ammonium nitrate (LUAN), 28-32% N (liquid),was add throe irrigation system (Fertigation)
- Ammonium nitrate (AN), 33.5% N (solid),was add by spreading.
- Urea (U), 46.5% N (solid),was add by spreading.

<u>Nitrogen rates (sub-plots):</u>

- 60 kg N/fed
- 90 kg N/fed
- 120 kg N/fed

Seeds of Maize crop (*Zea Maize* cv. SC 162) were sown on the 23rd,june2015 and were harvested on the 20th October, 2015. During land preparations, P-fertilizer in the form of super phosphate (MCP, 15.5% P_2O_5) at the rate 15 kg P_2O_5/fed was added. During the growing season, K-fertilizer as (potassium sulfate) K_2SO_4 (48% K_2O) at the rate of 48 kg K_2O/fed was applied. All other farming practices (i.e., irrigation, weed, and diseases control, and others) were done according to the common practices followed at the Nubaria research station.

During the growing season, several agronomic and physiological parameters were measured. The data were collected three times during the growing season, before each fertilization dose (35 and 50 days after planting) and 120 days at harvesting. The recorded parameters were plant height (cm), plant weight (g), and leaf area (cm^2), as average of long and width for three leaves× 0.75 (Stickler, 1964). At harvest, ear weight (kg), 100-grain weight (g), Stover and grain yields (ton/fed) were also recorded. Plant height (cm) was measured from the ground surface to the top of the tassel. Grain yield (ton/fed) and the ears of the two inner rows were harvested (120 days after planting). Ears were weighted and random sample of 5 kg was taken from each plot to measure shelling percentage and moisture content in grains. Grain yield was adjusted to 15.5% moisture content. Weight of 100-grain (g) was taken randomly from grains of the same 5 samples after shelling.

At harvest time, grain samples were collected, air-dried, crushed, and prepared for laboratory analysis. Plants and grain samples were wet-digested using concentrated sulphuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) according to FAO method (FAO, 1980).

Macro-elements (N, P, K) were determined in plant samples. The N, P, and K concentrations were determined using semi-automatic nitrogen distillation unit, spectrophotometer 21D and Jenway flame photometer, respectively, according to Westerman (1990). The calculations of macro elements, uptake, and N-use efficiency components were made according to Huggins and Pan (1993). N-use efficiency values were calculated as follows:

Nitrogen use efficiency(NUE)= Grain yield (Kg)/N fertilizer units (kg)

Soil samples at 0-20, 20-40, and 40-60 cm were regularly collected before the application of nitrogen fertilizers to study the effect of the tested treatments on the concentration of nitrate-N and ammonium-N forms (mineral N) in the soil. The (efficiency of N-fertilizer use was determined according to Huggins and Pan (1993).

Analyses of variance was performed using SAS software (SAS, 1989). Comparisons among means of the different treatments were carried out using Duncan's multiple range tests as presented by Steel and Torrie (1984).

RESULTS AND DISCUSSION

Effect on maize growth parameters:

The effect of N-sources and N-rate treatments on plant height, plants weight, and leaf area at different sampling dates is presented in Tables 2,3 and 4. For the effect on plant height, results indicated that there was a significant effect of the tested treatments on plant height. Average highest(Table 2) maize plant height of (225.33)cm was recorded for the LUAN treatment, while the average shortest plant was recorded under the U treatment. Results showed also that, increasing N-rate from 60 to 120 kg N/fed significantly increased plant height and the obtained values were 192.33, 201.93, and 224.67cm for the 60, 90, and 120 kg N/fed treatments, respectively. It is also clear that, the combined effect of LUAN and 120 kg N/fed treatment resulted in the highest maize plant (276.67cm).

Table (2).The plant height (cm) at different sampling dates effected as influenced by nitrogen sources and rates

N-source	N-ratekg/fed	Before 2nd dose		Before 3rd dose		At harvest	
Anhydrous Ammonia (AA)	60	55.00	69.33C*	188.33	197.78A	197.67	208.11B
	90	75.00		198.33		210.00	
	120	78.00		206.67		216.67	
Liquid Ammonia (LA)	60	65.00	88.33A	178.33	186.11C	180.00	193.22D
	90	90.00		185.00		191.33	
	120	110.00		195.00		208.33	
Liquid Urea/Ammonium Nitrate (LUAN)	60	64.00	84.33AB	181.67	192.22B	191.00	225.33A
	90	85.00		193.33		208.33	
	120	104.00		201.67		276.67	
Ammonium Nitrate (AN)	60	70.00	89.11A	185.00	192.22B	199.00	203.56BC
	90	75.00		193.33		203.33	
	120	122.33		198.33		208.33	
Urea (U)	60	74.33	78.67B	173.33	181.67C	194.00	201.33C
	90	75.00		183.33		196.67	
	120	86.67		188.33		213.33	
LSD 0.05 for N-sources			**7.101**		**4.69**		**6.458**
Average 60 kg N rate		65.67c		181.3c		192.33c	
Average 90 kg N rate		80.00b		190.7b		201.93b	
Average 120 kg N rate		100.2a		198.0a		224.67a	
LSD 0.05 for N-rates		**3.337**		**3.52**		**5.696**	

*Means with the same letter are not significantly different.

On plant weight, the results showed significant effect of the tested treatments on (Table 3), this measured parameter, The average heaviest plants of 163.42 and 162.34g were recorded from LA and U treatments, respectively, while the average lightest plant of 147.61g was recorded for AN treatment. Results showed also that, increasing N-rate from 60 to 120 kg N/fed significantly increased plant weight. The obtained values were 145.0, 156.11, and 169.59g for the 60, 90, and 120 kg N/fed treatments, respectively. It is also clear that, the combined effect of AA and 120 kg N/fed treatment resulted in the heaviest maize plant of 194.39g.

Table (3). Theplant weight (g/ plant) at different sampling dates as effected by N sources and rates

N-source	N-rate kg/fed	Before 2nd dose		Before 3rd dose		At harvest	
Anhydrous Ammonia (AA)	60	10.21		80.49		128.61	
	90	15.22	14.67D*	83.36	100.97A	151.23	158.08B
	120	18.57		139.07		194.39	
Liquid Ammonia (LA)	60	12.77		80.49		138.32	
	90	13.84	15.91C	83.36	87.04B	166.50	163.42A
	120	21.11		139.07		185.44	
Liquid Urea/Ammonium Nitrate (LUAN)	60	10.73		43.92		117.45	
	90	20.45	17.43B	60.51	55.88E	148.89	153.05C
	120	21.13		63.23		192.80	
Ammonium Nitrate (AN)	60	12.18		46.57		162.41	
	90	18.98	17.18B	58.32	59.15D	177.29	147.61D
	120	20.37		72.56		103.13	
Urea (U)	60	14.57		33.09		178.20	
	90	20.24	18.40A	86.63	85.35C	136.64	162.34A
	120	20.39		136.33		172.17	
LSD 0.05 for N-sources			**0.562**		**0.88**		**1.531**
Average 60 kg N rate		12.09c		53.03c		145.00c	
Average 90 kg N rate		17.75b		74.44b		156.11b	
Average 120 kg N rate		20.31a		105.57a		169.59a	
LSD 0.05 for N-rates		**0.207**		**0.831**		**1.091**	

*Means with the same letter are not significantly different.

The results showed that average largest leaf area of 548.30 cm^2 was recorded under the AN treatment and it was significantly higher than all other treatments(Table4). Results revealed that, the smallest leaf area values of 445.44 and 451.6 cm^2 were recorded for the U and LA treatments,(Table 4) respectively.

Results showed also that, increasing N-rate from 60 to 120 kg N/fed significantly increased leaf area. The obtained values were 427.17, 476.09, and 561.7 cm^2 for the 60, 90, and 120 kg N/fed treatments, respectively. It is also clear that, the combined effect of AN and 120 kg N/fed treatment resulted in the largest maize leaf area of 659.78 cm^2.

The obtained results are in agreement with those reported by El-Naggar and Amer (1999) and El-Douby *et al.* (2001).They found that maize plant height, dry weight, and grain yield were significantly increased when N rate is increased.

Table (4).The leaf area (cm^2) at different sampling dates as effected by nitrogen sources and rates

N-source	N-rate kg/fed	Before 2nd dose		Before 3rd dose		At harvest	
Anhydrous Ammonia (AA)	60	89.13		361.46		450.45	
	90	142.77	140.90E*	376.25	407.71A	477.29	498.16B
	120	190.79		485.42		566.75	
Liquid Ammonia (LA)	60	97.29		300.59		395.00	
	90	146.65	150.08D	315.62	327.91C	414.92	451.96C
	120	206.31		367.50		545.96	
Liquid Urea/Ammonium Nitrate (LUAN)	60	87.89		316.96		421.75	
	90	191.35	164.88B	323.79	330.50C	491.40	497.81B
	120	215.40		350.77		580.27	
Ammonium Nitrate (AN)	60	107.42		244.37		430.20	
	90	152.46	157.31C	330.37	350.02B	554.92	548.30A
	120	212.06		475.31		659.78	
Urea (U)	60	123.33		265.08		438.47	
	90	197.67	179.79A	315.93	309.09D	441.92	445.44C
	120	218.37		346.25		455.92	
LSD 0.05 for N-sources			**5.237**		**10.29**		**15.12**
Average 60 kg N rate		101.01c		279.69c		427.17c	
Average 90 kg N rate		166.18b		332.39b		476.09b	
Average 120 kg N rate		208.59a		405.05a		561.74a	
LSD 0.05 for N-rates		**3.654**		**8.64**		**19.30**	

*Means with the same letter are not significantly different.

Effect on maize grain, stover yields and yield components:

The effect of N-source and N-rate treatments on maize yield component parameters (ear weight and 100-grain weight) and on maize stover and grain yields is presented in Tables 5 and 6. There was significant effect of the tested treatments on ear weight. Average ear weight values of 0.279, 0.258, 0.252, 0.250, and 0.224 kg were recorded for the LUAN, AA, AN, U, and LA treatments, respectively(Table 5). Results showed also that, increasing N-rate source 60 to 120 kg N/fed significantly increased ear weight. The obtained values were 0.184, 0.236, and 0.311kg for the 60, 90, and 120 kg N/fed treatments, respectively. It is also clear that, the combined effect of LUAN and 120 kg N/fed treatment resulted in the highest maize ear weight of 0.35kg.

On100-grain weight, the results revealed that average values were significantly affected by N-form and N-rate treatments. The highest average 100-grain yield (31.82g) was recorded under the LA treatment, while the lowest value of (28.18g)was reported for the U treatment (Table 5) . The results showed also that, average 100-grain weight values of 31.68, 29.19, and 30.53g were recorded for the 60, 120, and 90kg N/fed treatments, respectively.The results indicated also that, the combined effect of AN and 120 kg N/fed treatment resulted in the heaviest 100-grain weight (33.78g).

Table (5).The ear weight* (kg) and 100-grain weight (g) as affected by nitrogen sources and rates

N-source	N-rate kg/fed	Ear weight (kg)		100-grain weight (gm)	
Anhydrous Ammonia (AA)	60	0.19	0.258AB**	33.15	30.60B
	90	0.27		29.88	
	120	0.31		28.78	
Liquid Ammonia (LA)	60	0.18	0.224B	32.23	31.82A
	90	0.22		32.20	
	120	0.30		31.03	
Liquid Urea/Ammonium Nitrate (LUAN)	60	0.19	0.279A	32.10	30.76B
	90	0.30		29.30	
	120	0.35		30.89	
Ammonium Nitrate (AN)	60	0.18	0.252AB	30.53	30.92B
	90	0.27		28.45	
	120	0.30		33.78	
Urea (U)	60	0.18	0.250AB	30.40	28.18C
	90	0.28		25.95	
	120	0.29		28.20	
LSD 0.05 for N-sources			**0.054**		**0.433**
Average 60 kg N rate		0.184 c		31.68 a	
Average 90 kg N rate		0.263 b		29.15 c	
Average 120 kg N rate		0.311 a		30.53 b	
LSD 0.05 for N-rates		**0.032**		**0.37**	

*Means with the same letter are not significantly different.
**average weight of ears for three plants.

Table 6 showed that, there were no significant effect of the N-sources treatments on maize stover and grain yields, while N-rate treatments significantly affected both parameters. As for stover yield, the results indicated that the highest average stover yield value (9.61 ton/fed) was obtained from the LA treatment, while the lowest value of 9.16 ton/fed was recorded from the AA treatment. The average stover yield values of 6.8, 9.96, and 11.43 ton/fed were recorded for the 60, 90, and 120kg N/fed treatments, respectively. The combined effect of LA and 120kg N/fed treatment recorded the highest stover yield (11.84 ton/fed).

(Table 6) indicated that the highest average grain yield (2.98 ton/fed) was obtained from the LUAN treatment, while the lowest (2.76 ton/fed) was recorded from the AA treatment. The value average grain yield values of 2.011, 3.122, and 3.397 ton/fed were recorded for the 60, 90, and 120kg N/fed treatments, respectively. The combined effect of AA and 120kg N/fed treatment recorded the highest grain yield (3.54 ton/fed). The obtained results were in line with those of by Yakout and Grish (2002), Siam *et al.* (2008), and Zohry and farghaly, who showed that, the addition of ammonia gas fertilizer significantly increased plant height, fresh and dry weight, weight of leaves, ear weights, weight of grain and straw yields of maize as compared with urea fertilizer. These increases could be due to the amount of metabolic synthesized by plants as a result of increasing nitrogen levels. Also, Ali and Anjum (2017) concluded that increasing nitrogen levels (130, 160, and 180 kg N ha^{-1}) at optimum level can give a maximum growth and yield traits and quality of maize.

Table (6). The stover and grain yields (ton/fed) as affected by nitrogen sources and rate

N-source	N-rate(kg/fed)	Stover yield (ton/fed)		Grain yield (ton/fed)	
Anhydrous Ammonia (AA)	60	6.81		2.01	
	90	9.47	9.16 A*	3.16	2.90 A
	120	11.18		3.54	
Liquid Ammonia (LA)	60	6.80		2.03	
	90	10.18	9.61 A	2.99	2.77 A
	120	11.84		3.30	
Liquid Urea/Ammonium Nitrate (LUAN)	60	6.58		2.14	
	90	9.94	9.33 A	3.29	2.98 A
	120	11.47		3.51	
Ammonium Nitrate (AN)	60	7.06		1.92	
	90	9.89	9.42 A	3.08	2.76 A
	120	11.30		3.29	
Urea (U)	60	6.74		1.95	
	90	10.34	9.48 A	3.09	2.79 A
	120	11.36		3.35	
LSD 0.05 for N-sources			**0.878**		**0.288**
Average 60 kg N rate		6.80 c		2.011 c	
Average 90 kg N rate		9.96 b		3.122 b	
Average 120 kg N rate		11.43 a		3.397 a	
LSD 0.05 for N-rates		**0.377**		**0.137**	

*Means with the same letter are not significantly different.

Nitrogen content in soil and NPK concentration and uptake by plants:

Table 7.indicated, in general, that N-contents decrease with increasing soil depth, and with decreasing nitrogen rate. Results revealed that N-contents in different soil layers under the Liquid Urea/Ammonium Nitrate (LUAN) treatment were higher than N-contents from all other treatments. The lowest N-contents in soil layers were recorded under the ammonium nitrate (AN) and urea (U) treatments. Results indicated for the anhydrous ammonia (AA) source, which is injected at land preparation, that the N-contents at different soil layers after the 3rd fertilization were comparable to those of AN and U treatments. The obtained results are in agreement with those reported by Nielsen (2006) who reported that anhydrous ammonia converts more slowly to nitrate-N than ammonium nitrate and urea because of its initial toxic effects on the soil microbes responsible for the conversion of ammonium-N to nitrate-N.

As for the effect of N-source and N-rate treatments on NPK (%), NPK uptake and total uptake in maize stover and grains (Table 8), the results indicated that there was a significant effect of the treatments on the tested parameters. The statistical analysis indicated that NPK concentrations in grains

Table (7).The N contents (mg/kg) in the soil at different sampling dates as affected by nitrogen sources and rates

N-source	N-rate kg/fed	After 1st fertilization			After 2nd fertilization			After 3rd fertilization		
		0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Anhydrous Ammonia (AA)	60	257.8	193.3	109.2	252.6	140.7	82.0	140.0	75.6	70.0
	90	260.0	249.2	134.4	252.0	187.8	92.4	179.2	84.0	70.0
	120	399.6	273.3	226.0	316.4	268.8	140.0	204.4	148.4	84.0
Liquid Ammonia (LA)	60	263.3	160.0	95.2	197.8	158.9	75.7	182.0	100.8	67.3
	90	289.2	204.0	123.2	274.5	193.3	90.4	190.4	126.0	81.3
	120	365.2	240.8	204.0	310.0	218.4	193.2	267.2	151.2	98.2
Liquid Urea/Amm. Nitrate(LUAN)	60	256.0	280.0	198.9	286.0	175.7	90.0	249.2	170.8	86.8
	90	327.6	319.3	308.0	274.0	254.4	212.9	252.2	247.5	204.5
	120	498.9	419.3	308.0	444.8	360.4	21.4	442.5	333.2	207.4
Ammonium Nitrate (AN)	60	270.8	197.2	193.3	223.3	195.2	183.8	134.5	50.4	44.9
	90	290.8	241.8	198.0	235.2	210.0	186.8	159.6	95.3	81.2
	120	295.0	300.0	240.8	288.4	288.4	218.4	203.7	187.9	170.8
Urea (U)	60	201.6	123.2	110.2	153.3	109.2	92.4	130.6	84.0	52.6
	90	294.0	183.0	148.5	215.7	115.7	98.0	142.5	98.7	70.0
	120	306.3	267.3	182.0	298.0	203.7	115.7	270.5	193.3	106.5

*Means with the same letter are not significantly different.

and stover of maize plants were significantly affected by nitrogen forms, where liquid ammonia (LA) gave the highest N, P and K% values in stover than other N-forms.

This result could be explained by the endorsement effect of liquid ammonia on maize growth (Table 6), consequently enhanced its ability to nutrients uptake. As for the effect on NPK concentrations in grain, the results showed that the highest N% was recorded for the AA treatment, and the highest P and K% were recorded for the urea treatment. With regard to N-rates, the results revealed that, increasing nitrogen up to 120 kg/fed had markedly increasing in N, P and K concentrations in both grains and stover. The increase of nutrients in maize grains and stover may be due to the increase in root growth per unit soil volume caused by increasing nitrogen level and accordingly increased the rate of nutrients uptake.

Table (8) indicated that total P and K uptake by maize grains and stover were significantly affected by nitrogen sources, while there was no effect on N-uptake. The highest total N, P, and K uptake values were recorded for liquid ammonia (LA) treatment as compared with the other N-sources. The increase in total nutrients uptake due to LA application is mainly due to its effect on maize growth. As for the effect of N-rates, results showed that increasing nitrogen rates significantly increased total N, P, and K uptake.

Nitrogen use efficiency (NUE):

The effect of N-source and N-rate treatments on NUE is presented in Table 9.Results indicated that, there were no significant effect of the N-source treatments on NUE values, while there were significant effect of the N-rate treatments on NUE values. Results showed that the highest average NUE value of 33.83 kg grain/kg N was obtained from the LUAN treatment, while the lowest value of 30.89 kg grain/kg N was recorded from the urea treatment. There were no significant difference between NUE values recorded from 60 and90 kg N/fed treatments, while both rates were significantly higher than that of 120kg N/fed. Average NUE values of34.2933.52 and28.31kg grain/kg N were recorded for the60, 90, and 120,kg N/fed treatments, respectively. The combined effect of LUAN and 90kg N/fed treatment recorded the highest NUE value of 36.52 kg grain/kg N.

Table (8).The values NPK (%), NPK-uptake, and total NPK-uptake by maize grain and stover yields at harvest time as affected by the tested treatments

Treat.	Maize stover						Maize grains						Total uptake		
	N %	P %	K %	N-uptake kg/fed	P-uptake kg/fed	K-uptake kg/fed	N %	P %	K %	N-uptake kg/fed	P-uptake kg/fed	K-uptake kg/fed	N-uptake kg/fed	P-uptake kg/fed	K-uptake kg/fed
AA	1.00AB*	0.31B	2.32C	91.92A	29.58B	188.3C	1.39A	0.32C	6.32D	4.07A	1.06B	18.4A	96.0A	30.6B	233.3B
LA	0.99AB	0.37A	2.53A	94.25A	36.21A	246.3A	1.36BC	0.38BC	6.40C	3.77A	1.06B	17.8A	98.0A	37.3A	264.1A
LUAN	1.00AB	0.26D	2.33C	93.78A	24.96C	217.1AB	1.38AB	0.41AB	6.45B	4.10A	1.23A	19.2A	97.9A	26.2C	236.4B
AN	1.01A	0.32B	2.21D	94.55A	29.87B	209.5AB	1.35C	0.41AB	6.41C	3.77A	1.16AB	17.8A	98.3A	31.0B	227.3B
Urea	0.96B	0.29C	2.35B	92.87A	28.27BC	220.9AB	1.35C	0.46A	6.58A	3.78A	1.28A	18.5A	96.7A	29.6BC	239.B
LSD	**0.028**	**0.015**	**0.016**	**7.77**	**4.063**	**52.55**	**0.019**	**0.069**	**0.023**	**0.383**	**0.126**	**1.836**	**8.082**	**4.147**	**21.701**
60 N	0.99b	0.26c	2.27c	66.97c	17.99c	154.2c	1.35c	0.37b	6.31c	2.73c	0.73c	12.7c	69.7c	18.7c	166.8c
90 N	1.01a	0.31b	2.35b	100.45b	31.27b	233.7b	1.36b	0.41ab	6.40b	4.21b	1.32b	19.98b	104.7b	32.6b	253.7b
120 N	0.99ab	0.35a	2.42a	113.0a	40.07a	261.5a	1.40a	0.42a	8.58a	4.76a	1.42a	22.4a	117.8a	41.9a	299.8a
LSD	**0.021**	**0.013**	**0.009**	**4.48**	**1.698**	**26.72**	**0.009**	**0.04**	**0.016**	**0.184**	**0.066**	**0.898**	**4.538**	**1.695**	**9.208**

*Means with the same letter are not significantly different.

Table (9).Nitrogen use efficiency (NUE, kg grain/kg N) as affected by N –sources and rates treatments

N-source	N-rate kg/fed	NUE (kg grain/kg N)	
Anhydrous Ammonia (AA)	60	33.50	32.07 A*
	90	35.07	
	120	29.53	
Liquid Ammonia (LA)	60	33.89	31.54 A
	90	33.26	
	120	27.47	
Liquid Urea/Ammonium Nitrate (LUAN)	60	35.72	33.83 A
	90	36.52	
	120	29.25	
Ammonium Nitrate (AN)	60	32.06	31.24 A
	90	34.26	
	120	27.42	
Urea (U)	60	32.44	30.89 A
	90	32.33	
	120	27.89	
LSD 0.05 for N-sources			**3.186**
Average 60 kg N rate		34.29 a	
Average 90 kg N rate		33.52 a	
Average 120 kg N rate		28.31 b	
LSD 0.05 for N-rates		**1.639**	

*Means with the same letter are not significantly different.

CONCLUSION

From the obtained results it could be concluded that:

1. Applying N-fertilizer in the form of liquid urea ammonium nitrate (LUAN) achieved the highest maize grain yield of 2.98 ton/fed.
2. Increasing N-rate from 60 to 120 kg N/fed had a significant effect on maize stover and grain yields. The grain yields of 3.4, 3.1, and 2.01 ton/fed were recorded for the 120, 90, and 60 kg N/fed treatments, respectively.
3. NPK (%), NPK uptake, and total NPK uptake were significantly affected by N-form and N-rate treatments.
4. The highest NUE value of 33.83 kg grain/kg N was recorded for the LUAN treatment, while the lowest value of 30.89 kg grain/kg N was obtained from the urea treatment.
5. The N-rate treatments had significant effect on NUE. The obtained values were 33.5, 34.3, and 28.3 kg grain/kg N for the 60, 90, and 120 kg N/fed treatments, respectively.
6. The use of liquid urea ammonium nitrate at the rate of 120 kg N/fed can be recommended for maize production in the calcareous soils of Nubaria region.

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الملخص العربى

إستجابة الذرة لمصادر ومعدلات النيتروجين في أرض جيرية بمنطقة النوبارية ، مصر

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أجريت تجربة حقلية خلال موسم النمو الصيفي لعام ٢٠١٥ في المزرعة التجريبية لمحطة البحوث الزراعية بالنوبارية (٣٠ ° ٥٤ شمالا، ٢٩ ° ٥٧` شرقا، و٢٥ مترا فوق مستوى سطح البحر) مركز البحوث الزراعية , وزارة الزراعة واستصلاح الأراضي محافظة البحيرة، مصر. تهدف الدراسة تقييم تأثير مصادر مختلفة للنيتروجين (الغازية والسائلة والصلبة)(ومعدلاته ٦٠، ٩٠، و ١٢٠ كجم N/ فدان) على الصفات المورفولجيه والمحصوليه لنباتات الذرة (إرتفاع النبات والوزن ومساحة الورقة وزن الكوز، ووزن ١٠٠ حبة) ومحصول الحبوب ، وامتصاص النتروجين والفسفور والبوتاسيوم، وكفاءة استخدام النتروجين في التربة الجيرية في منطقة النوبارية، مصر. تم استخدام تصميم القطع المنشقة مع ثلاث مكررات لإجراء التجربة الحقلية. شكلت خمسة مصادر للنيتروجين القطع الرئيسية وثلاثة معدلات للنتروجين تمثل القطع التحت رئيسيه. تم استخدام صنف الذرة SC 162. وقد أشارت النتائج إلى وجود تأثيرات معنوية للمعاملات المختبرة على (ارتفاع النبات، وزن النبات، مساحة الورقة ومكونات المحصول وزن الكوز و ووزن ١٠٠ حبة).

وأظهرت النتائج عدم وجود تأثير معنوي للصور المختلفة النيتروجين على محصول الذرة ومحصول الحبوب واظهرت النتائج أن أعلى محصول للحبوب يبلغ ٢.٩٨ طن / فدان لمعاملة (نترات اليوريا أمونيوم السائله، بينما سجلت أقل قيمة للمحصول هي ٢.٧٦ طن / فدان لمعاملة نترات الأمونيوم الصلبة. وكان لمعاملات معدلات النتروجين تأثير كبير على محصول الذرة والحبوب. وسجل محصول الحبوب ٣.٤، ٣.١، ٢.٠١ طن / للفدان لمعدلات إضافة ١٢٠، ٩٠، و ٦٠ كجم نتروجين/ فدان على التوالي. وأظهرت النتائج أيضا أن النسبة المئوية لأمتصاص كلا من النتروجين والفوسفور والبوتاسيوم و الأمتصاص الكلى منها قد تأثرت بصور النتروجين ومعدلات الاضافة. لم يكن هناك أي تأثير للمعاملات على كفاءة استخدام النتروجين. وكانت أعلى قيمة لكفاءة الأستخدام ٣٣.٨٣ كجم حبوب / كجم نتروجين للمعاملة : يوريا- نترات الامونيوم السائلة، في حين كانت أدنى قيمة هي ٣٠.٨٩ كجم حبوب / كج نتروجين لمعاملة اليوريا. وكان لمعدلات الاضافة تأثير كبير على قيمة كفاءة الاستخدام. وكانت القيم التي تم الحصول عليها هي ٣٣.٥، ٣٤.٣، و ٢٨.٣ كجم حبوب / كجم نتروجين للمعاملات ٩٠، ١٢٠، و٦٠ كجم نتروجين / فدان ، على التوالي.

ومن النتائج المتحصل عليها يمكن التوصية باستخدام اليوريا امونيوم نيترات السائلة بمعدل ١٢٠ كجم نيتروجين / فدان في زراعات الذرة الشامية تحت ظروف الاراضي الجيرية بمنطقةة النوبارية .