Effect of Different Nitrogen Sources and Rates on Potato Growth, Nutrients Uptake, Yield and Resistance to some Diseases

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Abstract

Two field experiments were conducted to study the effect of N sources as ammonium sulphate (AS), ammonium nitrate (AN) and the combination of AS with either AN or CaN (calcium nitrate) at the rates of 0, 60, 120, 180 or 240 kg N per feddan on potato growth, nutrients uptake, tuber yield and its quality as well as plant resistance to some fungal and bacterial diseases. Adding nitrogen to potato plants as AS in both 1st and 2nd doses followed with AN in 3rd dose was more convenient and had a stimulatory effect on dry weight of leaves and stems per plant, tuber yield as well as tuber quality. Tuber yield significantly increased by split application of a total N rate of 120 and/or 180 kg / fed. At 120 and / or 180 kg N / fed. treatments, nitrate concentration tended to decrease in potato tuber (> 200 mg / kg). Addition of nitrogen at the higher rate (240 kg / N) significantly increased the fungal and bacterial diseases.

Introduction

Potato is one of the most important vegetable crops grown in Egypt for both local consumption and exportation (El-Sayed, 1998). Thus, improving potato crop production and using the most suitable culture practices could increase yield of the crop and solve some problems facing potato production and exportation. Supplying nitrogen to potato plants is most important for tuber yield production. Potato yield have been increased by splitting N application (Abo-Sedera and Shehata, 1994 and Arisha, 1994). In this respect, Satyanarayan and Arora (1985) found that potato plants given 150 kg N resulted in higher tuber yield.

The most important sources of N for fertilization in Egypt are ammonium sulphate and ammonium nitrate. Both NO_3^- and NH_4^+ forms of nitrogen can be taken up by plants (Mengel and Kirkby, 1987). Many plants accumulate nitrate in their roots and above – ground parts, when uptake exceeds metabolic needs. The accumulation of nitrate depends upon many environmental factors e.g. amount and source of nitrogen application (Pate, 1980; Carman and Esther, 1988 and Blom-Zandstra, 1989). In this connection, Corre and Breimer (1979) stated that the permitted residue limit of nitrate concentration in potato tuber was less than 200 mg per kg. Potato diseases infection dramatically increase when excess of nitrogen was used (Cullen and Andrews, 1984 and El-Sayed, 1998).

The objectives of this study were to elucidate the effect of different nitrogen sources and their rates on potato growth, nutrients uptake, tuber yield, and its quality as well as diseases susceptibility of potato.

Materials and Methods

Two field experiments were undertaken during 1997 and 1998 at the Agricultural Experimental Farm, Faculty of Agriculture, Minufiya University. Some physical and chemical characteristics of the alluvial soil under study were determined as described by Chapman and Pratt (1961) as shown in Table (1).

Table 1: Some physical and chemical characteristics of the experimental soil

Property	Value	Property	Value
Mechanical analysis:		**Soluble ions (meq 100 g^{-1}):**	
Coarse sand, %	2.2	Ca^{2+}	0.80
Fine sand, %	17.3	Mg^{2+}	0.45
Silt, %	25.6	Na^{+}	1.50
Clay, %	54.9	K^{+}	0.32
Texture class	clayey	$HCO_3^- + CO_3^=$	1.20
Chemical analysis:		Cl^-	0.41
OM, %	1.98	$SO_4^=$	1.51
pH (1 : 2.5 soil/water sus.)	7.97	Total N, %	0.12
EC (ds / m)	0.62	Available P, ppm	99.00

Tubers of potato cv. Diamond were sown on February 25th, 1997 and February 15th, 1998. Plot area was 17.5 m^2, each consisted of 5 rows (5 m in length × 70 cm width). Sowing distance was 25 cm. The outermost rows of each side were considered as guard rows, meanwhile, the 3 inner rows were used for collecting the experimental data. Moreover, the units were separated from each other by not less than 80 cm to reduce fertilizers overlapping as possible.

Two nitrogen sources were tested i.e. ammonium sulphate (20.5% N), ammonium nitrate (33% N) and the combination of AS with either AN or CaN (calcium nitrate). The amounts of each nitrogen fertilizer were applied in three equal portions as soil application. The first dose was applied at the first irrigation, while the second and third doses were added on 15 and 30 days after the first dose as shown in Table (2). Five rates of nitrogen fertilizer were applied i.e., 0, 60, 120, 180 and 240 kg N per feddan.

Table 2: Time of schedule of the various nitrogen fertilizations

N sources	1st dose (at the 1st irrigation)	2nd dose (15 days after 1st dose)	3rd dose (15 days after 2nd dose)
Ammonium Sulphate (AS)	AS	AS	AS
Ammonium Nitrate (AN)	AN	AN	AN
AS + AN	AS	AS	AN
AS + Calcium Nitrate (CaN)	AS	AS	CaN

A split plot design with three replicates was adopted. Splitting nitrogen sources were allocated randomly to main plots, while the nitrogen levels were randomly assigned to the subplots. In addition to nitrogen fertilizer, each treatment received 300 kg / feddan calcium superphosphate (15.5% P_2O_5) and 200 kg / feddan potassium sulphate (48% K_2O). The superphosphate was totally applied preseeding (during soil preparation), whereas potassium sulphate was added on the same days of nitrogen fertilization in 3 equal doses.
Plant samples were taken after 65 days from sowing, washed, air dried and divided into two parts. The first part was dried at 105°C for dry matter determination. The second one was dried at 70°C for chemical analysis, thoroughly ground and ash by wet digestion, according to Jackson (1958). Total N was determined after Jackson (1958). Total P and K were determined as described by Chapman and Pratt (1961).
Nitrogen use efficiency (NUE), represented by kg DM produced per kg N applied was calculated according to Guillard *et al.* (1995) as follows: (yield at N_x - yield at N_o) / applied N at N_x.
Where, N_x = N fertilized soil, and N_o = unfertilized soil (control).

At harvest time, the tubers were collected and total tuber yield per feddan was determined. Nitrogen concentration in tubers was estimated using semi micro-kjeldahl method as described by (Jackson, 1958) and protein by multiplying N% × 6.25. Nitrate concentration in tubers was estimated using xylenol method according to Balrs and Reekers (1960). Starch content was determined according to A.O.A.C. (1975). Dry matter percent in tubers was determined. Samples of 30 tubers per treatment were stored at room temperature (22 - 26°C) for 4 weeks. The percentage of fungal and bacterial disease incidence was estimated. Data were subjected to statistical analysis of variance according to Gomez and Gomez (1983).

Results and Discussion

1. Dry matter yield: Dry matter yield of potato leaves and stems was significantly increased by different nitrogen sources and rates (Table 3). No significant differences were found among AS, AN and AS plus AN. Meanwhile, it was significantly decreased in case of AS in combination with CaN. The stem dry matter did not express significant differences in response to nitrogen fertilization as AS and AN. Meanwhile, it was significantly decreased by application of AS plus CaN comparing with the other nitrogen forms. The increase in potato dry matter by application of AS plus AN may be due to the increase in NUE in this treatment (Table 7). In this concern, Drouinau and Blanc (1961) found that the addition of NH_4^+–N to NO_3^-–N resulted in highest growth rates.

Increasing the rate of N fertilization progressively increased the dry matter in both leaves and stems. However, no significant differences were detected among the various rates of N application in respecting with dry matter of potato leaves. On the contrary, level of N fertilization significantly increased the stem dry matter. At the rate of 180 kg N / fed. resulted in the greatest yield of dry matter. The excess of N fertilizer to 240 kg N / fed. depressed the dry matter yield as compared to application of 180 kg N/ fed. The interaction between the nitrogen sources and nitrogen rates had a significant effect on dry matter. Supplementation potato with AS plus AN at the rate of 180 kg N/fed. yielded the greatest dry matter in both leaves and stems. Similar results were obtained by Vos and Biemond (1992) and Arisha (1994).

Table 3: Effect of nitrogen sources and rates on dry matter of potato leaves and stems (g / plant) after 65 days from sowing (1998 season)

N sources	AS	AN	AS + AN	AS + CaN	Mean
N rates	Dry matter in leaves g / plant				
0 kg/fed.	15.9	15.8	15.2	16.0	15.7
60 kg/fed.	24.2	24.2	26.1	22.0	24.1
120 kg/fed.	24.5	25.4	27.2	23.2	25.1
180 kg/fed.	28.3	28.4	28.6	24.5	27.5
240 kg/fed.	25.2	25.6	25.5	23.6	25.0
Mean	23.6	23.9	24.5	21.9	–
	Dry matter in stems g / plant				
0 kg/fed.	11.0	11.4	12.2	11.5	11.5
60 kg/fed.	16.2	18.2	18.8	14.8	17.0
120 kg/fed.	18.9	18.1	21.9	17.8	19.2
180 kg/fed.	23.6	23.2	24.2	19.5	22.6
240 kg/fed.	17.7	19.9	17.2	16.2	17.8
Mean	17.5	18.2	18.9	16.0	–

L.S.D. 5%	N sources	N rates	Rates × source
Leaves	1.6	6.4	9.2
Stems	1.4	5.2	7.6

The increase in plant growth may be attributed to the beneficial effects of N on stimulating meristematic activity for producing more tissues and organs, since N plays major roles in the synthesis of structural proteins and other several macromolecules, in addition to its vital contribution in several biochemical processes in the plant related to growth (Marschner, 1986).

2. Plant minerals content: Data in Table (4) show that N, P and K percentages and uptake in potato leaves and stems were increased when potato supplied with AS plus AN as compared with other N sources. On the contrary the nitrogen applied with AS plus CaN gave the lowest value. Higher N uptake rates were observed by Blondel and Blanc (1973) when both N forms (NH_4-N and NO_3-N) were applied to soil. This observation is consistent with earlier reports of Drouineau and Blanc (1961). This beneficial effect of NH_4-N in combination with NO_3-N on growth may be due to reduction of NO_3^- to NH_4^+ which requires energy. It may be supposed that by supplying NH_4^+ energy is conserved and diverted to other metabolic processes including ion uptake and growth. Similar results were reported by Rao and Rains (1976).

With regard to the effect of N rates on N, P and K contents in both potato leaves and stems increased with increasing N rates, however, their values in stems were less than in leaves. Moreover, nitrogen application increased the total nitrogen uptake in both leaves and stems owing to the increase in dry matter. These findings are in good agreement with those obtained by Arisha (1994) and Guillard *et al.* (1995).

3. Tubers yield: Data in Table (5) clearly appears that, there were no significant differences in potato yield among AS, AN and AS plus AN in the first season. Fertilization of potato with AS plus CaN gave the inferior yield and the depression was significant in comparing with the other N forms. With regard to the effect of nitrogen rates on the potato yield, it is evident from Table (5) that the potato yield was increased by increasing nitrogen rates until 180 kg N / feddan in both seasons. The interaction between the effect of nitrogen forms and N rates, the application of AS plus AN at the rate of 180 kg N / fed. gave the highest tuber yield.

Table 5: Effect of different nitrogen sources and rates on tubers yield of potatoes (Ton / fed.)

N sources	AS	AN	AS + AN	AS + CaN	Mean
N rates			**1997 season**		
0 kg/fed.	5.40	5.40	5.40	5.40	5.4
60 kg/fed.	9.10	8.90	9.40	8.10	8.9
120 kg/fed.	10.10	10.0	10.5	9.8	10.1
180 kg/fed.	10.8	10.2	10.9	10.0	10.5
240 kg/fed.	10.3	10.0	10.3	9.8	10.1
Mean	9.14	8.90	9.30	8.62	–
			1998 season		
0 kg/fed.	6.6	6.6	6.6	6.6	6.6
60 kg/fed.	10.0	9.8	10.9	10.0	10.2
120 kg/fed.	11.3	10.9	11.3	10.5	11.0
180 kg/fed.	11.7	11.5	12.1	10.9	11.6
240 kg/fed.	9.2	9.0	9.1	8.5	9.0
Mean	9.8	9.6	10.0	9.3	–

L.S.D. 5%	N sources	N rates	Rates × source
1997	0.65	3.80	4.50
1998	0.35	3.50	5.50

The increment in yield was combined with a substantial increase in both protein and starch contents in tuber (Table 6). It may be also due to the increase in plant growth as a consequence of increasing nitrogen rate. The yield is a function of physiological plant growth, consequently, increasing the translocation and accumulation of carbohydrates to tubers. These results are in accordance with those obtained by Khalil (1990) and Arisha (1994), Abo-Sedera and Shehata (1994).

4. Tubers quality: It is obvious from Table (6) that dry matter, starch and protein contents of potato tubers were increased by adding AS in combination with AN as compared to other nitrogen sources. Meanwhile, the application of nitrogen as AS plus CaN gave the minimum values.

Data in Table (6) reveal that, the increasing N rates led to increase in starch and protein yields of tubers until 180 kg N / feddan. Meanwhile, the supplementation of nitrogen to potato plants at the higher rates decreased the starch and protein contents. These results are in agreement with those obtained by Anand and Krishnappa (1992) and Arisha (1994).

The nitrate concentration in potato tubers was not significantly affected by different nitrogen sources. The application of nitrogen rates until 180 kg N / feddan gave the lower NO_3 than 200 mg / kg. On the contrary, the high rate of N (240 kg N) gave the higher NO_3 than 200 mg / kg. In this concern, Custic *et al.* (1994) stated that increased N levels led to an increase in nitrate content of the crop tissues without significant increase in yield. The permitted residue limit of nitrate in potato tuber was 200 mg / kg (Carter and Bosma, 1974; Corre and Breimer, 1979 and Blom-Zondstra, 1989).

5. Nitrogen use efficiency: It is clear from Table (7) that the NUE decreased gradually as the rate of the nitrogen fertilizer increased. Adding nitrogen as AS in combination with AN improved the NUE as compared with other nitrogen forms. At rates > 60 kg N / feddan, NUE values were decreased. These results are in accordance with those obtianed by Varvel and Pterson (1990) and Gurillard *et al.* (1995).

Table 6: Effect of different nitrogen sources and rates on tuber quality of potato, (1998 season)

Characters / N-Sources	Dry matter %	Starch %	Starch kg/fed.	Protein %	Protein kg/fed.	NO_3 ppm
AS	23.5	17.60	1725	8.13	796	95
AN	24.9	17.21	1657	8.00	768	117
AS + AN	25.4	18.00	1800	8.25	825	104
AS + CaN	21.8	15.60	1451	7.88	733	96
L.S.D. 5%	1.2	1.35	152	0.20	62	N.S.
N levels						
0 kg/fed.	20.8	17.6	1162	5.00	330	40
60 kg/fed.	25.2	18.0	1836	7.06	724	100
120 kg/fed.	24.9	18.5	2079	8.44	924	131
180 kg/fed.	25.2	18.9	2192	9.69	1125	165
240 kg/fed.	23.5	17.0	1530	11.75	1062	210
L.S.D. 5%	1.3	1.0	560	2.36	680	25.0

Table 7: Effect of nitrogen sources and rates on nitrogen use efficiency in potato plants (1998 season)

N-sources / N-rates	AS	AN	AS + AN	AS + CaN	Mean
0 kg/fed.	–	–	–	–	–
60 kg/fed.	56.7	53.3	71.7	56.7	59.6
120 kg/fed.	39.2	35.8	39.2	32.5	36.7
180 kg/fed.	28.3	27.2	30.6	23.9	27.0
240 kg/fed.	10.8	10.0	10.4	7.9	9.8
Mean	33.8	31.6	38.0	30.3	

6. Potato diseases: The application of different sources and rates of nitrogen were studied to illustrate their effects on control of fungal and bacterial diseases (Table 8). The application of AS led to a significant decrease in most potato diseases incidence (soft rot, black leg, late blight and dry rot) as compared with other nitrogen forms. Meanwhile, brown rot disease showed a positive correlation with the adding of nitrogen as AS in combination with CaN.

The application of nitrogen at higher rate (240 kg N / fed.) led to an increase in most potato diseases incidence, this may be due to the presence of high nitrogen level causes depression in secondary toxic metabolites produced by many antagonists (Turner, 1971). Increasing the nitrogen rate in soil, also led to increase numbers of saprophytic bacteria which compete with antagonists for oxygen space, consequently reduce the effect of these antagonists (Cullen and Andrews, 1984). This also is due to the presence of high N content in plant which makes these plants able to absorb more water as a consequence. The high content of water in tubers leads to increasing susceptibility of tubers to be invaded by different pathogenic bacteria (Robert, 1975).

Generally, adding nitrogen to potato plants as AS in combination with AN seemed to have stimulatory effect for tuber yield and its quality. Application of nitrogen to potato plants at the rate of 180 kg N / fed. led to a good tuber yield and a decrease in nitrate concentration as well as potato diseases.

Table 8: Effect of different nitrogen sources and rates on potato diseases incidence after 4 weeks storage (1998 season)

N-Sources	Brown-rot %	Soft-rot %	Black-leg %	Common-scab %	Late blight %	Dry-rot %
	a. Nitrogen sources					
AS	9.0	2.7	4.6	1.80	1.25	7.2
AN	9.1	6.8	9.4	0.00	2.60	7.9
AS + AN	10.7	5.5	5.7	0.78	2.90	9.2
AS + CaN	8.3	4.3	8.9	1.50	1.50	8.8
L.S.D. 5%	2.1	3.4	3.8	0.8	1.0	1.8
	b. Nitrogen rates					
0 kg/fed.	7.3	4.3	2.1	0.00	2.60	7.3
60 kg/fed.	7.7	4.4	6.2	0.60	2.73	8.2
120 kg/fed.	8.7	4.9	6.7	0.73	2.90	8.3
180 kg/fed.	9.9	5.2	6.9	0.95	3.00	9.1
240 kg/fed.	10.9	5.9	8.5	1.50	3.50	9.2
L.S.D. 5%	2.8	1.9	5.3	1.2	1.4	2.0

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