

GROWTH, YIELD , QUALITY AND NUTRIENT UPTAKE OF POTATO (*Solanum tuberosum*, L.) AS AFFECTED BY TWO NITROGEN SOURCES APPLIED AT VARIOUS RATIOS

Khalil, A. A.

Soil, Water and Environment Res., Institute, Agric. Res. Center, Giza, Egypt

ABSTRACT

A field experiment was carried out at the Experimental Res. Farm of El-Kassasin Horticultural Research Station, Ismailia Governorate, (Around 30°26' N 31°59' E) during two successive seasons; 2009/2010 and 2010/2011 to study the effects of applying two different nitrogen sources ammonium sulphate (AS) and ammonium nitrate (AN), at the same rate of 140 kg N fed⁻¹, and their ratios on growth, yield marketable, quality and nutrient uptake of potato (*Solanum tuberosum* L.; CV. Nicola). A completely randomized design was established with 5 treatments, i.e., (AS) / (AN) ratios of 100/0, 0/100, 75/25, 50/50, 25/75 and. Each treatment had 3 replications. Representative samples were taken after 75 days and the yield was harvested after 120 days. Dry weights of tubers, at the harvest were increased significantly with all mixed nitrogen treatments as compared with single AS or AN. The enhanced growth with mixed nitrogen was greatest at 25% (AS) Ammonium Sulphate + 75% (AN) Ammonium Nitrate. Such treatment produced maximum dry matter (24.20%), total yield (13.765 kg.fed⁻¹) and N,P and k uptake and marketable yield (%86.6) followed by the treatment having 50% AS +50% AN. Usage of 140 kg N fed⁻¹ applied as a mixture of 25% AS+75% AN achieved 17% and 11% increment of total yield compared to 100% of AS application and 100% AN, respectively.

The study stressed on paying attention to selection of sources of N fertilizers and their ratios for potato plants grown in sandy soil.

Keywords: potato (*Solanum tuberosum* L.), nutrient uptake, Dry matter, N sources, Ammonium sulphate to ammonium nitrate ratio, Marketable yield.

INTRODUCTION

Potato (*Solanum tuberosum*, L.) is one of the most important world food crops. It comes after rice, wheat and maize. Among vegetable crops being planted in Egypt, potato occupies higher rank in terms of exportation and local consumption. It is consumed in different forms such as boiled or fried and many different processed products like chips, french fries, flakes, powder, potato papad etc. Quality attributes of potato tubers particularly size, dry matter, starch and sugar contents are of prime concern for potato growers, in order to attain good prices for their produce (Pandey and Sarkar, 2005; Pandey et al., 2009). Nitrogen fertilization is a key factor for potato quality processing, besides its influence on potato size preferred for fresh consumption.

Not only tuber size is affected by nitrogen but also by starch content and sugar content. Nitrogen as a major element being essential for plant growth, is available to plants in two forms namely nitrate nitrogen (NO₃⁻-N) and ammonium nitrogen (NH₄⁺-N). Nitrogen forms affect plant growth and yield. Most plants get their nitrogen (N) from the soil as either nitrate or ammonium, with some species showing a strong preference for one ionic

form over the other (Forde and Clarkson, 1999). Nevertheless, plant growth decreases under excessive nitrogen supply. The growth of potato (Cao and Tibbts, 1998) and bean (Sánchez et al., 2004), are significantly inhibited due to application of excessive nitrogen. In this regard Wei et al., 2009 reported that under high nitrogen levels, most plant species show reduced growth, smaller leaves and stunted root systems, and in severe cases can lead to death of the plant. High nitrate levels in soil or nutrient solution will cause osmotic stress, which can cause oxidative damage and induce reactive oxygen species (ROS). They are highly toxic and can damage many important cellular components, such as lipids, protein, DNA and RNA. Increased levels of ammonium could be highly toxic for plant cells (Pilbeam and Kirkby, 1992).

Usually plants are able to take up N as nitrate (NO₃⁻) and ammonium (NH₄⁺), but some may prefer one source or another depending on plant species (Marschner, 1995). N sources may affect plant growth via many processes within the soil plant system, and inside the plant (Wiesler, 1997). The use of different N sources may directly affect the nutrition status of plants due to changes in the rhizosphere, as a result of modification in the ionic balance in that soil fraction. The use of N-NH₄⁺ causes an increasing H⁺ excretion, leading to a decrease in soil pH, whereas the use of N-NO₃⁻ is associated with a decrease in H⁺ excretion and increasing rates of HCO₃⁻ or OH⁻ resulting in a pH rise, especially when in combination with Ca²⁺ (Marschner and Römheld, 1996). However, when plants are growing in a similar way and supplied with N-NO₃⁻ or N-NH₄⁺, they may differ in many aspects related to metabolic activity and ionic composition as a result of different physiological responses (Kandlbinder et al., 1997). The reduction of N-NO₃⁻ in plants consume great amount of reducing power. Considering the biochemical energy needed for NO₃⁻ reduction, one could suppose that plant supplied with N-NH₄ would grow better than that supplied with N-NO₃-source, however in most cases the opposite occurs even altering the plant architecture of fast growing plants (Beltrano et al., 1999). Some species show growth depression when supplied exclusively with N-NH₄⁺, but generally this causes a decrease in soil pH which may increase the availability of some mineral nutrients such as P, Fe, Mn, Cu, and Zn (Marschner, 1995).

Improving the soil/plant relationship is depending on soil conditions. N transfer from roots to leaves can occur in different manners and its incorporation in different amino acids, proteins, and other N compounds are differentiated for each plant species and development stage (Pate, 1973). The aim of this research was to study the effects of applying two different nitrogen sources AS and AN and their ratios on growth, yield marketable, nutrient uptake (N,P and K) and quality of potato (*Solanum tuberosum* L.).

MATERIALS AND METHODS

A field experiment was carried out at the Experimental Res. Farm of El-Kassasin Horticultural Research Station, Ismailia Governorate, (Around 30°.26' N 31°59' E) on 15th of October during two successive seasons;

2009/2010 and 2010/2011 to study the effects of applying two different nitrogen sources AS and AN and their ratios on growth, yield marketable, quality and nutrient uptake (N, P, and K) of potato (*Solanum tuberosum* L.; CV. Nicola); grown under sprinkler irrigation. Some Physical and chemical characteristics for the soil under study were conducted according to (Page et al., 1982) and (Klute, 1986). The results are shown in table 1

Table 1: Some physical and chemical properties of the studied soil.

Particle size distribution (%)				Textural class	Ca CO ₃ (%)	O.M (%)
Coarse sand	Fine sand	Silt	Clay			
2.38	67.42	18.2	12.00	Sandy loam	2.1	0.85

pH	EC dS m ⁻¹	%SP	Ion concentration in paste extract (meqL ⁻¹)							Available (mg kg ⁻¹)			
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁼	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	N	P	K
8.2	0.87	29	3.90	2.70	1.85	0.55	0.00	1.30	4.55	3.15	25.4	10.50	180.51

The experiment was laid out in factorial design based on complete randomized block design with three replications. Experimental factors included two N sources ammonium sulfate (AS); NH₄ (SO₄)₂ having 20.6% N, and ammonium nitrate (AN), (NH₄NO₃) having (33.5% N). The two N sources were applied at the same amount of N namely 140 N kg/fed. Five (AS) / (AN) ratio were used: 100/0, 0/100, 75/25, 50/50 and 25/75. The experimental treatments were as follow:-

100% N as Ammonium Sulphate (AS).

100% N as Ammonium Nitrate (AN).

75% AS + 25% AN.

50% AS + 50% AN.

25% AS + 75% AN.

The tested nitrogenous fertilizers and their ratios were split into four doses and added at four stages namely; 20% before planting, 20% at plant establishment, 30% at tuber initiation and 30% at tuber bulking.

Phosphorus fertilizer was added at the recommended dose, 75 kg P₂O₅ per fed. However, 50% of the amount was applied to the soil in the form of calcium superphosphate (15.5% P₂O₅) during soil preparation and the rest was fertigated in the form of phosphoric acid (62% P₂O₅) split into equally dose during growth stages.

Potassium fertilizer was fertigated at a rate of 120 kg K₂O in the form of Potassium sulfate (50%K₂O) split into 5 equal doses, one at soil preparation and the rest at 35, 45, 55 and 65 days after planting.

At 75 days after planting four plants were taken randomly from each plot to determine plant height (cm) and number of main stems/plant.

Total tuber yield (kg.fed⁻¹), and tuber weight/plant were determined at harvesting (120 days after planting).

N, P and K were determined in the leaves at 75 days of planting and in tubers at harvesting time. Total nitrogen was determined in dry leaves and

tubers using micro-kjeldahl methods as described by Ling (1963), while P was determined calorimetrically and potassium was determined by using a flame photometer as described by Jackson (1967).

Tuber Quality was appraised through testing some parameters namely; dry matter (%), starch content, carbohydrate fractions and specific gravity of tubers besides grading their size.

Starch content was determined according to A. O. A. C. (1990). Tuber dry matter (%) was determined by drying the tuber slices at 65°C for 72 hours according to the method of A. O. A. C. (1990). Carbohydrate fractions were determined in tuber according to the method described by Miller (1959). Specific gravity; SG of tuber was estimated using following formula outlined by Murphy and Goven (1959);
 $SG = (\text{tuber weight in the air}) / ((\text{tuber weight in the air}) - (\text{tuber weight in the water}))$

Tubers were graded according their size to large size >55, medium size; 35-55 and small size; < 35mm in diameter (Fattahalla, 1997). All collected data were statistically analyzed according to the procedure described by Snedecor and Cochran (1980). The statistical analysis was conducted for all yield parameters of the two seasons i.e. combined analysis.

RESULTS AND DISCUSSION

Effects of N-Sources and their ratios on the growth of potatoes plants:

Data in Table 2 show the effect of using different sources of nitrogen and various ratios of them on plant height and number of stems per plant ; average means of both seasons. Data elucidate that plant height was significantly elevated as the plants received 25%AS+75%AN compared with the other treatments.

The shorter plant height (49.2 cm) was recorded when 100% (AS) was administered and no significant difference was observed in the plant height recorded for such treatment and that of 75% AS+25%AN. Nevertheless, the longest plant height (64.5 cm) was recorded with the application of 25% AS+75% AN.

Table 2: Effects of N-Sources and their ratio on the growth of potatoes plants. (average means of both seasons.)

N Sources and their ratios	Plant height cm	Mean No. of stems/plant
100% Ammonium Sulphate (AS)	49.2 d	2.75
100% Ammonium Nitrate (AN)	52.9 c	2.75
75%AS+25%AN	50.9 d	2.80
50%AS+50%AN	55.9 b	3.20
25%AS+75%AN	64.5 a	3.70
LSD 0.05	1.99	N.S

AS=Ammonium Sulphate

AN=Ammonium Nitrate

The data reveal that the lowest number of stems per plant (2.75 cm) was assigned for the plants received sole nitrogen source while plants received 25%AS+75% AN gave the highest number of stems per plant (3.7). This parameter is of great importance because it is directly related to the total production of tubers. The more is the number of stems/plant the more is the number of tubers per plant. Number of stems per plant is also important for tuber size. (Marschner, 1986) pointed out that the increase in plant height may be attributed to the beneficial effects of N on stimulating the meristmatic activity for producing more tissues and organs and N plays major roles in structural proteins and other several macromolecules related with growth plants. Walch-Liu et al., (2000) reported that excessive NH₄⁺ is harmful to tobacco plants and could result in hormonal imbalance and a strong decline of cytokinins in the xylem sap, which could then hamper growth and reduce yield.

The diverse response of plant to N-NO₃ and N-NH₄ was interpreted by some researchers. Romero et al., (2006) explained that applying N-NO₃ may increase the plant highest, the acid-base balance that was broken, in which NO₃⁻ increased the pH around the roots due to the efflux of HCO₃⁻ or OH⁻, and NH₄⁺ decrease the pH due to the efflux of H⁺

Effect of AS/AN ratio on nutrients content in leaves and tubers

Table 3 displays the effect of using different sources of N-fertilizers on N, P and K contents in leaves and tubers of potato. Nitrogen content in the leaves of potato exhibited remarkable difference due to diverse source of nitrogen and/or their combination. Application of 25% AS+75% AN gave the highest N% in the leaves (5.33%). As the % of added ammonium sulfate (AS) was increased N content of the leaves significantly decreased. It is worth mentioning that the lowest % of N content was recorded in leaves of potato fertilized solely with AS (3.6%). Interestingly similar trend was generally noticed in the case of P and k content in the leaves.

Higher concentration of P, and K were recorded in treatments received 25%AS+75%AN of nitrogen, which in turn resulted in higher concentration of P, and K in leaves. The highest percent of P (0.54) and K (4.09) were recorded with the application of nitrogen at 25%AS+75% AN. These effects of N forms on tissue mineral composition were consistent with (Cao and Tibbts, 1993).

Table 3: Effects of N-Sources on N, P and K content in potato plant. (average means of both seasons.)

Treatments	Nutrients content in leaves after 75 day			Nutrients content in Tubers at harvest			Total uptake at harvest kg/fed.		
	% N	% P	% K	% N	% P	% K	N	P	K
100% Ammonium Sulphate (AS)	3.6 e	0.34 d	3.45 c	1.8 b	0.28 d	1.74 d	207.9 b	32.6 d	198.4 d
100% Ammonium Nitrate (AN)	4.68 c	0.46 b	3.61 b	1.7 b	0.39 b	1.85 b	214.1 b	47.13 b	220.8 c
75%AS+25%AN	4.14 d	0.39 c	3.68 b	1.58 c	0.33 c	1.78 c	190.5 c	39.7 c	218.4 c
50%AS+50%AN	4.99 b	0.49 b	4.05 a	1.7 b	0.42 b	1.93 a	209.7 b	50.75 b	234.8 b
25%AS+75%AN	5.33 a	0.54 a	4.09 a	2.05 a	0.45 a	1.97 a	283.6 a	61.6 a	271.1 a
LSD 0.05	0.185	0.042	0.12	0.097	0.035	0.046	9.57	4.35	6.92

Effect of AS and AN ratio on Yield and marketable yield of potatoes:

Different AS and AN ratios significantly affected the size distribution of potatoes (Table 4). Regarding the size of potato the data clearly indicated that the source of N played indispensable role in obtaining desired marketable size. Applying 25 AS+ 75% AN gave significantly bigger sizes; medium and large, compared with those obtained due to sole application of 100% AS and/or 100% AN. The opposite was true regarding the small size. The maximum yield of 13,766 kg fed.⁻¹ was obtained in the treatment 25%AS+75%AN followed by those receiving 75%AS+25%AN (12,219 kg fed.⁻¹ and 50%AS+50%AN (12,169 kg-fed).

Table 4: The effects of N-Sources on Tuber marketable yield and size distribution (average means of both seasons.)

Treatments	Yield kg fed ⁻¹ Small size *	% Yield Small size	Yield kg fed ⁻¹ Medium size **	% Medium Yield	Yield kg fed ⁻¹ Large size ***	% Yield Large size	% Marketable size	Total Yield kg fed ⁻¹	Total Yield kg/plant
100% Ammonium Sulphate (AS)	2023 a	17.8	9175 e	80.2	225 d	2.0	82.2	11423 d	0.887 c
100% Ammonium Nitrate (AN)	1912 b	16.0	9787 c	81.7	281 c	2.4	84.1	11981 c	0.958 b
75%AS+25%AN	2065 a	17.4	9431 d	80.0	723 b	2.5	82.5	12219 b	0.943 b
50%AS+50%AN	1900 b	14.6	10161 b	82.2	108 e	3.2	85.2	12169 b	0.953 b
25%AS+75%AN	1803 c	14.1	11203 a	83.5	750 a	3.1	86.6	13766 a	1.055 a
LSD 0.05	54.4		66.87		16.11			105.9	0.052

* small size; < 35mm, **medium size; 35-55, *** large size; >55, Marketable; large +medium size

The yield was lowest (11.423 kg fed.⁻¹) in the treatment receiving 100% (AS). Usage of combination of 25%AS+75%AN achieved 17% and 11% increment of the total yield compared to 100% of AS application and 100% AN, respectively. But, it was only 9% with 75% AS+25% AN and 8% with 50% AS+50% AN. It is worthy to note that differences arise from diversity of the fertilizer prices of the studied N sources have no impact on the production cost of potato. The present results are in harmony with those reported by (Wang et al., 2009) who stressed the usage of mixed nitrogen sources for obtaining higher yield. Moreover, Cao and Tibbitts 1993 demonstrated that dry weights of shoots, tubers, and whole plant at the harvest were increased significantly with all mixed nitrogen treatments as compared with single NH₄⁺ or NO₃⁻ form. The enhanced growth with mixed nitrogen was greatest at 8% to 20% NH₄⁺-N. Also, the concentrations and accumulation of total N in the shoots and roots were greater with mixed nitrogen than with separate NH₄⁺ or NO₃⁻ nutrition.

On the contrary (Ge, 2002; and Wang et al., 2005) reported that the highest yield of plant was produced at 0:100 of AS to AN.

In the current study higher sulphur content, present in the fertilizer applied seems to have a detrimental effect on the growth of potato. In this concern, many workers reported that although sulphur plays substantial role in potato production through its role in better partitioning of the photosynthates in the shoots and tubers, yet heavy application of sulphur can result in yield

reduction (Sud and Sharma2002 and Lalitha et al. 2002). Their findings are in consonance with Nasreen et al. (2007) on onion.

Effect of nitrogen sources and their ratios on tubers quality of potato

Table 5 summarizes the results of the some quality tests done on potatoes grown under different treatments (average means of both seasons).

Table 5: The effects of N-Sources and their ratios on qualitative characters of potato (average means of both seasons).

Treatments	% NS Sugar	% Total Sugar	%D.M	specific gravity	%Starch
100% Ammonium Sulphate (AS)	34.81 c	37.25 e	17.54 d	1.052 e	14.62 e
100% Ammonium Nitrate (AN)	33.22 d	35.68 d	22.35 b	1.057 d	15.93 d
75%AS+25%AN	36.08 c	38.5 c	19.87 c	1.064 c	17.18 c
50%AS+50%AN	37.18 b	39.69 b	22.14 b	1.073 b	18.84 b
25%AS+75%AN	40.82 a	43.50 a	24.14 a	1.082 a	20.75 a
LSD 0.05	0.72	0.74	1.04	0.0019	0.92

Tubers quality, such as starch, specific gravity, D.M soluble sugar, non-soluble sugar and total sugar % were significantly ($P \leq 0.05$) affected by AS and AN ratio. Starch, specific gravity, D.M. and total sugar % differed significantly due to the studied N fertilization management. Regardless the effect of 100% of ammonium nitrate on the dry matter the assigned higher value recorded for these parameters followed the order: 25%AS+75%AN >50%AS+50%AN >75%AS+25%AN >100% (AN) >100% (AS).

The obtained results concerning the effects of AS and AN ratio on Tubers quality of potato was in accordance with Dong et al. (2004) who reported that increasing the ratio of AS/AN (25, 50 and 75%) in the treatments led to a significant decrease in Starch, and D.M content.

The specific gravity is a measure of quality in potato tuber which is related to the dry matter contents in the tubers. The specific gravity is also associated with starch content, total solids and mealiness of potato tubers (Teich and Menzres 1964). They also reported a reduction in specific gravity due to fertilizer treatment and its influence on crop quality. The higher is the specific gravity the better is the quantity of dry matter and greater is the yield of produce. Potatoes with high specific gravity are preferred for manufactured processes.

(Lalitha et al, 2002) explained that sulphur being a component of sulphur containing amino acid as well as involved in sulpho-hydral bonds in polypeptides, also component of protein enzyme involved in chlorophyll, starch and protein synthesis. Involvement of sulphur in these biochemical processes in plant metabolism may be the cause for increased starch synthesis and production of large size tubers.

Based on the above mentioned information it may be concluded that application of 25%AS+75%AN gave the best quality under experimental trails.

CONCLUSIONS

Different AS and AN ratios in treatments not only affected plant growth, but also affected yield marketable and tubers quality of potato. The maximum yield and quality of potato was obtained as 25% of N was added in the form of ammonium sulphate and the other 75% in the form of ammonium nitrate. Nonetheless, the lowest yield and quality was recorded as potato was fertilized with 100% Ammonium sulphate. This research drew the attention to the usage appropriate ratio of ammonium sulphate to ammonium nitrate for potato fertilization grown in Egypt rather than relying on sole source of them. Besides extra care should be given to higher content of sulphate in fertilization management of potato as higher content of such element could reduce its yield. More researches are needed to be carried out concerning such topic.

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تأثير إضافة مصدرين للنيتروجين بنسب مختلفة على النمو والمحصول والجودة في نبات البطاطس

أحمد ابو الوفا خليل

معهد بحوث الاراضي والمياه والبيئة - مركز البحوث الزراعية - جيزة- مصر

اجريت تجربة حقلية في محطة بحوث القصاصين - محافظة الاسماعيلية خلال موسمي الزراعة 2010/2009 و 2010/2011 على نبات البطاطس صنف (نيكولا) لدراسة تأثير نسب مختلفة من مصادر الاسمدة النتروجينية (سلفات الامونيوم و نترات الامونيوم) وأضيفت بمعدل ثابت 140 كجم/ف على صفات النمو الخضري والمحصول القابل للتسويق وامتصاص النيتروجين والفوسفور والبوتاسيوم وجودة الدرنات ، صممت التجربة في قطاعات كاملة العشوائية بثلاث مكررات. اشتملت التجربة على 5 معاملات كالآتي :

100% كبريتات الامونيوم.

75% نترات الامونيوم.

75% كبريتات الامونيوم + 25% نترات الامونيوم.

50% كبريتات الامونيوم + 50% نترات الامونيوم.

25% كبريتات الامونيوم + 75% نترات الامونيوم.

أخذت عينات نباتية ممثلة بعد 75 يوم، و تم حصاد المحصول عند 120 يوم من الزراعة.

اوضحت النتائج أن تسميد النباتات بمخلوط الاسمدة النتروجينية ادى إلى زيادة معنوية في وزن الدرنات والمحصول مقارنة بالنباتات التي سمدت بمصدر واحد من النيتروجين .

وقد أعطى تسميد النباتات بالمعدل 25% كبريتات امونيوم + 75% نترات امونيوم أعلى مادة جافة

24.2% ، ومحصول كلي (13.77 كجم/ف) وامتصاص للنيتروجين والفوسفور والبوتاسيوم، و أعلى محصول قابل للتسوق بنسبة (86.6%) ومحتوي الدرنات من النشا (20.75%) ومحتوى النيتروجين في الورقة (2.05%) تليه المعاملة بـ 50% كبريتات امونيوم + 50% نترات امونيوم ، مقارنة بالتسميد بمصدر نيتروجيني واحد. تبين أن التسميد النيتروجيني بمعدل 140 كجم للفدان وبمخلوط يحتوي على 25% سلفات امونيوم مع 75% نترات امونيوم حقق زيادة في المحصول الكلي وصلت الى 17% ، و 11% مقارنة بـ 100% سلفات امونيوم ، و 100% نترات امونيوم على التوالي.

وجهت الدراسة النظر إلى الاهتمام بانتقاء نوعية مصادر التسميد النيتروجيني ونسب خلطها لمحصول البطاطس النامي في أراضي رملية.