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Mixed and Conventional Nitrogen Fertilizers Impacts on Yield, Quality and Nutrient Uptake by Potato

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SELECTING the appropriate form of nitrogen fertilizer is one of the important limitation factors for potato yield and quality, which depends primarily on the availability and cost of fertilizers. The aim of this study was to compare the effect of conventional N-fertilizer forms (urea "U", ammonium nitrate "AN" and ammonium sulphate "AS') with mixed fertilizers (six MF: as a mixture percent's of AS with U or AN of the added N) on growth, yield, quality, nutrients uptake, N use efficiency (NUE) and profitability of potatoes grown in clayey loam soils. Two field experiments were carried out at Batra, Talkha, Dakahlia Governorate, Egypt during successive seasons on two potato varieties (i.e., Spunta and Diamant). Treatments were arranged in Complete Randomized Blocks Design with three replicates. The obtained results showed that mixed nitrogen fertilizers treatments enhanced plant growth, tuber yield, quality, nutrient uptake and NUE compared to sole application of conventional forms, with superiority of MF: 75%AN+25%AS, 50%AN+50%AS and 50%U+50%AS. The highest yield of dry matter and starch was obtained by adding MF of 50%AN+50%AS. However, the accumulation of NO_3^- in tuber is inversely proportional to dry matter; the highest content obtained with 100%Uea, but the lowest content obtained with MF of 25%AN+75%AS. The greatest percentage of NUE was obtained with MF of 50%AN+50%AS in both experiments. These results referred to the importance of AS application along with AN or U as a mixed fertilizer to maximize potato yield and quality, NUE and profitability.

Keywords: Nitrogen Fertilizer forms; N use efficiency; Potato varieties; Dry matter& nitrate relationship; Profitability.

Introduction

Potato (*Solanum tuberosum* L.) is one of the important economically crops that widely grown for local consumption and exportation in Egypt. It occupies more than 17% of the cultivated land (27.000 ha) with an average of production 360.000 tons per year (FAO 2015). Good Management of nitrogen-fertilizer (N) is the major limitation factors for potato yield and quality. Determining the optimum N-fertilizer rate and selection fertilizer forms are considering the most important decisions for growers (Güler 2009 and Zebarth et al. 2015).

Availability and cost are the most important factors to consider in choosing a fertilizer formulation today. The most common Nitrogen fertilizers in Egypt are: urea "U" (contributes 57.58% of total N-fertilizers), ammonium nitrate "AN" (10.52%) and ammonium sulfate (AS: 2.24%) (El-Gabaly 2015). In addition, U is the most widely used in the world (contributes 59.34% of total N-fertilizers production), whereas AN and AS contribute 7.69% and 3.96%, respectively (IFA 2014). Therefore, U contributes the most production of nitrogen-fertilizers, whereas AN-fertilizer is the most preferable one for potatoes grown in old and newly soils in Egypt (Ahmed et al., 2009 and Khalil, 2014). However, AN is not available at all time of season, and high expensive. On contrast, U is usually less expensive than AN, and more available at all time of season. So, growers resort to U for its availability and economic considerations more than the other sources. On the other hand, AS isn't

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common as U and AN, as well as it isn't known for some growers in Egypt, however it is the most popular fertilizer in many countries (Sharma and Bali, 2018).

Plant takes up N in two forms: NO_3^--N and NH_4^+-N, but some plant species prefer one ion over the other. Under normal aerated conditions in soils, nitrate is the main source of nitrogen; and readily mobile in plants and can be stored in vacuoles (Marschner, 1995 and Barker & Pilbeam, 2007). The excessive application of N-fertilizers resulted in a higher nitrate status in the plant tissues and in underground water (Ismail and Abu-Zinada, 2009). Nitrate contents in vegetables depend largely on the level of NO_3^- nutrition; high rates of NO_3^- application (300 to 400 kg N ha^{-1}) result in high levels of NO_3^- in the plant material (Mengel and Kirkby, 2001). In addition, increasing the accumulation of nitrate in fruits had a bad effect on its quality and is dangerous on the common health, where it is believed to be carcinogenic (Wong and Li, 2004).

Also, high NO_3^--N levels in soil or nutrient solution will cause oxidative damage and induce reactive oxygen species, and at highly toxic level can damage many important cellular components as lipids, protein, DNA and RNA. On the other hand, increasing level of NH_4^+-N could be highly toxic for plant cells (Pilbeam and Kirkby, 1992). So, the good management of application N-Fertilizer has important effects on quality of potato yield too (Laboski & Kelling, 2007 and Zebarth et al., 2015).

Optimizing N fertilization requires matching the supply of N to the crop N demand in space and time. Potato varieties differ in the relationship between growth and N uptakes as well as it differed in tuber yield response to N-fertilizer (Zebarh et al., 2004). The rapid plant uptake of N occurs during tuber initiation and set (from about 50 to 70 days after planting), and is reduced during tuber bulking (from about 70-90 days after planting) (Zebarth and Rosen, 2007). The varieties vary in their requirements of N-fertilizer that ranged from 120 to 180 kg N fed^{-1} (fed= 0.42ha), according to variety and soil type (MALR, 2014).

Growth, yield, quality and the nutrient uptake of potato plant are affected by nitrogen fertilizer forms. Karadogan (1995) indicated that the greatest growth of potato plants resulted by supplying N as NO_3^- followed by both NO_3^- and NH_4^+ and the least with NH_4^+. However, Westermann and Sojka (1996) showed that vegetative growth characters were higher by using ammonium sulfate (AS) fertilizer rather than ammonium nitrate (AN). In the same trend, Soliman et al. (2000) found that N sources had significant effects on plant growth and tuber yield of potato with superiority of AS when compared with AN or urea.

On the other hand, Ahmed et al. (2009) found that using N fertilizers as AN (at a rate of 230 Kg N fed^{-1}) recorded the highest values of tuber yield, number of tubers $plant^{-1}$ and marketable tuber percentage, whereas using the same source of N at a rate of 130 Kg N fed^{-1} gave the highest values of quality; specific gravity, starch, dry matter, P and K in tubers. In the same trend Ahmed et al. (2015) reported that vegetative growth characters of potato plants, tuber yield and quality were better with using AN rather than U-fertilizer under the ecological conditions of clay loam soil. However, the differences among the impacts of N-sources; AN, U, NP and NPK fertilizers on the plant growth, yield and quality of tuber did not reveal significant differences in clayey soil (Marouani et al., 2015).

In addition, Dua (2018) reported that ammonium sulphate (21% N) is the most preferred one of N-sources for potato production, due to its content of sulfur (24% S), followed by calcium ammonium nitrate (25% N), whereas urea (46% N) being cost effective, and it is most commonly used. Also, Sharma and Bali (2018) demonstrated that AS is considered an excellent source of N and S, it tends to decrease soil pH as a side effect, which makes it a preferable option at high soil pH and when additional S is also required for sufficient crop growth and health. Accordingly, achieving to successful fertilizer form that gained top yields that have high quality and maximizing returns of fertilizer investment is considering the greatest goal in planning a fertilizer program for potatoes (Forde and Clarkson, 1999).

So, the aim of this study was to compare the effect of conventional forms of nitrogen fertilizers with some mixture percent's of them as mixed fertilizers on growth, yield, quality, NPK-uptake and the use efficiency of added nitrogen for two potato varieties grown in clayey loam soil. Furthermore, assessment the economic return of each treatment.

Materials and Methods

Two field experiments were carried out in clayey loam soils at Batra Village, Talkha

District, Dakahlia Governorate, Egypt (30° 16' 72"N; 31° 46' 25.80"E) during the two successive grown seasons: 2015/2016 and 2016/2017. The 1st experiment was conducted on potato cultivar: Spunta (non-industrial cultivar), and the second experiment was on potato cultivar: Diamant (industrial cultivar; according to Potato Varieties Database- Online 2019).

Samples of soil surface (0-30 cm) were taken from each experiment before soil preparation for planting. The samples were air dried and prepared for laboratory analyses. Some physical and chemical properties of soil and initial soil status of available nutrients N, P, K, Ca, Mg, Fe, Mn and Zn were determined according to Hesse (1971) and Page (1982) as shown in Table 1(average of the two study seasons).

Each experiment included ten treatments; zero application (without application any nitrogen fertilizer), and nine treatments of nitrogen fertilizer formulas at the rate of 150 kg N fed^{-1}. Three of them as common or conventional N-fertilizers forms: urea (U: 46% N), ammonium nitrate (AN: 33.5% N) and ammonium sulphate (AS: 20.6% N+ 24% S); and six treatments as mixed fertilizers (MF) of AS with U or AN at different percentages of application N (150 kg N fed^{-1} "the recommended of N") as follows:-

T1: Zero application.
T2: 100% of the added N as U [$CO(NH_2)_2$].
T3: 100% of the added N as AN [NH_4NO_3].
T4: 100% of the added N as AS [$(NH_4)_2SO_4$].
T5: MF1: 75%U+25%AS.
T6: MF2: 50%U+50%AS.
T7: MF3: 25%U+75%AS.
T8: MF4: 75%AN+25%AS.
T9: MF5: 50%AN+50%AS.
T10: MF6: 25%AN+75%AS.

The treatments were arranged in Complete Randomized Blocks Design with three replicates. The area of each plot was 10.5 m^2 (3 lines * 5 m length * 0.70 m width). Potatoes were planted in the 1st season on 7th December 2015 and harvested in the last week of April 2016 for both experiments (Spunta and Diamant). In the 2nd season, potatoes in both experiments were planted on 13th December 2016 and harvested in the first week of May 2017.

Nitrogen fertilizer treatments were applied at two equal doses with first and second irrigation after planting. Phosphorus was added at the rate of 75 Kg P_2O_5 fed^{-1} as single super phosphate fertilizer (15% P_2O_5) with soil preparation. Potassium was added at the rate of 48 kg K_2O fed^{-1} as potassium sulphate fertilizer (48% K_2O) before planting. Each experiment received about 6

TABLE 1. Some physical and chemical properties of the experimental soils

Properties		Values 1st Experiment	Values 2nd Experiment	Properties		Values 1st Experiment	Values 2nd Experiment
Particle size distribution %	Sand	34.45	31.10	**EC (dSm^{-1})		2.04	1.41
	Silt	30.30	33.30	Soluble Cations ($mM\ L^{-1}$)	Ca^{++}	7.0	5.0
	Clay	35.25	35.60		Mg^{++}	5.0	4.0
Texture class		Clayey loam	Clayey loam		Na^{+}	7.1	4.2
Saturation percent		65.0	60.0		K^{+}	0.54	0.46
Organic matter %		0.93	1.10	Soluble anions ($mM\ L^{-1}$)	CO_3^{--}	***N.D.	N.D.
$CaCO_3$%		2.40	2.30		HCO_3^{-}	4.0	4.0
*pH		8.16	8.08		Cl^{-}	12.5	8.5
Bulk density (g cm^{-3})		1.25	1.20		SO_4^{--}	3.14	1.16
Available nutrient (mg kg^{-1})							
N		70	65	Mg		180	210
P		13.6	9.8	Fe		3.80	4.2
K		380	320	Mn		2.15	2.3
Ca		1100	980	Zn		0.75	1.0

*pH in soil : water suspension 1:2.5; ** EC in soil paste extract; ***N.D. (not detected).

irrigations; the first after 30-35 days form planting and then irrigation every 21 days, and every 15 days at bulking and maturity stages, respectively. Additionally, all recommended field practices for potato were performed for each experiment.

At harvest stage (after 135 days from planting approximately), 6 plant were taken from each plot to determine growth parameters as plant height (cm), leaf number per plant, fresh and dry weight of plant and dry straw weight (kg fed^{-1}). Additionally, unit area from each plot was harvested and collected to calculate total tuber yield per fed (fed= 0.42 ha). Samples of plant and tubers were randomly taken for chemical analyses. Parameters of tuber quality were carried out on fresh tubers as dry matter % and nitrate content. Dry matter % was calculated as percentage of dry weight of 100 gram fresh tuber weight was oven dried at 70 ℃ according to Dogras et al. (1991). Nitrates were determined according to Singh (1988) using spectrophotometer at wave length 540 nm.

Samples were dried then wet digested using mixture of sulphoric and percolreic acids (1:1) for chemical analyses of NPK concentrations in plant and tuber. Nitrogen was determined using micro Kjeldahl method. Phosphorus was determined by ammonium molybedate method using spectrophotometer at wave length 640 nm. Potassium was determined using flame photometer**.** Starch % was calculated as {17.457+ 0.891×(dry matter% -24.182)} according to Burton (1948). Total carbohydrates and reducing sugars were determined using spectrophotometer at wave length 420 nm according to A.O.A.C. (1990). Nitrogen agronomic efficiency (NAE) is known as the ability of use N to produce biomass (Mengel and Kirkby 2001). NAE was calculated as «kg yield/ kg N-applied».

Nitrogen use efficiency (NUE) known as N-removal to N-applied ratio (EU Nitrogen Expert Panel 2015 and Evans et al., 2016), also it is known by apparent nitrogen recovery (Mengel and Kirkby, 2001). Hence, NUE% was calculated according to the following equation:

$$NUE\% = \frac{(N\ uptake\ of\ treatment - N\ uptake\ of\ control)}{N\ applied\ as\ fertilizer} x100$$

Also, study included economic evaluation of potato yield per fed (fed= 0.42ha) for each treatment of nitrogen fertilizer according to the total cost and the total gross return in Egyptian Pound (L.E). The total cost included the cost of nitrogen fertilizer as a variable beside the other constant cost of phosphorus, potassium and other fertilizers, seeds, pesticides, labors and other field practices. The total gross return was calculated as (tuber yield by kg fed^{-1} X price in L.E kg^{-1}). Generally, prices were the average for the two seasons.

The statistical analysis was done according to Gomez and Gomez (1984) as a combined analysis of the two seasons, and the means of treatments were compared against Least Significant Differences Test (L.S.D) at level 5% and Duncan's Multiple Comparisons Test.

Results and Discussion

Soil characteristics of experiments

Data in Table 1 illustrate the initial status of studied soils before planting both experiments of potato varieties; Spunta and Diamant. It is clear from results that soils were moderately texture (clayey loam); slight alkaline, non-saline and low in content of organic matter. Also, it was moderate in available N, P, K and Mg; high in available Ca and low in available Fe, Mn and Zn**.**

Plant growth

It is obvious from results in Table 2 that plant height, fresh and dry weight of plant, leaf No. $plant^{-1}$ and dry straw weight (kg fed^{-1}) were significantly affected by variation in N-fertilizer forms at both experiments; Spunta and Diamant. Application of N as Mixed fertilizer (MF) of AS $[(NH_4)_2SO_4]$ at 25 or 50% of the added N with AN (NH_4NO_3) or U $[CO(NH_2)_2]$ significantly increased growth of plant than sole application of each form for both potato varieties. The superiority in plant growth was recorded with treatments of MF: 75%AN+25%AS (T_8) followed by 50%AN+50%AS (T_9), without significant differences between them. Also, MF of AS with U as 75%U+25%AS, 50%U+50%AS and 25%U+75%AS enhanced growth of plant (plant height, leaf No. $plant^{-1}$ and dry weight of plant) as compared with sole application of U, AN or AS. For comparison among conventional N-fertilizer forms, AS gave higher values of dry weight per plant and per fed than AN and U, but U had higher values of plant fresh weight.

The superiority of vegetative growth of plants that obtained with application of AN (33.5% N) rather than U (46% N) may be attributed to plants take up N as either NO_3^- N or NH_4-N. However, urea contains neither NO_3-N nor NH_4-N; when

U [$CO(NH_2)_2$] applied is converted into NH_4-N by the enzyme urease, since these reactions take some days may be lengthen or shorten based on several factors such as soil moisture, soil texture, soil temperature and organic matter (Barker and Pilbeam, 2007).

In this admiration, Westermann (1993) and Karadogan (1995) reported that the greatest growth of potato plants resulted from supplying N as NO_3-N followed by NO_3+NH_4 then with NH_4-N. Also, Khalil (2014) indicated that the application of N-demand at 25%AS and 75%AN enhanced growth of potato grown in sandy soil more superior than relying on sole source of them followed by the application as 50%AS and 50%AN then the application as 100%AN. Furthermore, Dua (2018) and Sharma and Bali (2018) reported that ammonium sulphate (21% N) is the most preferred one of N-sources for potato production, due to its content of sulfur (24% S).

Tuber yield and its components

Data in Table 3 illustrate that tuber yield, average weight of tuber as well as dry matter and starch yields were significantly affected by varying in N-fertilizer forms in both experiments; Spunta and Diamant. Mixed N fertilizer treatments had the greatest effect on potato yield and its components as compared with conventional forms of N-fertilizer for both varieties.

Spunta experiment

The highest yields of tubers (20.457 t. fed^{-1}), dry matter (3861 Kg fed^{-1}) and starch were obtained by treatment of MF 50%AN+50%AS, but these yields were insignificant with that obtained by MF 75%AN+25%AS. Also, the highest average of tuber weight (226 g) was obtained with MF of 75%AN+25%AS. In general, MF treatments of 50%AN+50%AS and 75%AN+25%AS had higher values of NAE and higher percentages of relative increase (RI) of dry matter and starch yields followed by those of MF 50%U+50%AS.

Diamant experiment

The highest tuber yield (18.930 t. fed^{-1}) was gained at the treatment of MF 75%AN+25%AS, but this yield insignificantly differed with that obtained by treatments of MF; 50%U+50%AS (18.519 t. fed^{-1}) and 50%AN+50%AS (18.466 t. fed^{-1}). Also, MF of 50%AN+50%AS had the highest yields of dry matter and starch (4145 and 2956 Kg fed^{-1}, respectively), but these values were insignificantly differed with that of MF: 75%AN+25%AS and 50%U+50%AS. Concerning conventional forms, AN had superior effect on yield of tuber, dry matter and starch followed by AS-fertilizer then urea for both varieties. The highest NAE (kg yield/kg N-applied) was gained with MF of 50%AN+50%AS.

It is obvious from previous mentioned results that MF treatments maximized the values of tuber yield, average weight of tuber, dry matter and starch yields, and it had high RI as compared with traditional fertilization as a sole application in both experiments. The superiority was the greatest with treatments of MF: 75%AN+25%AS (T_8), 50%AN+50%AS (T_9) and 50%U+50%AS (T_6). These results are confirmed by Khalil (2014), who indicated that the usage of appropriate ratio of AS to AN for potato fertilization grown in sandy soil was more superior than relying on sole source of them. The superiority of AN-fertilizer is attributed to its content of the two forms NO_3^- and NH_4^+ which is considered preferable for plant than contain NH_4^+ only (Westermann 1993 a nd Karadogan 1995).

However, the lowest yield of tuber, dry matter and starch was obtained with 100%U. In this respect, Ahmed et al. (2015) found that tuber yield was better with using nitrogen fertilizer in the form of ammonium nitrate rather than urea fertilizer. The poor performance of urea has been found to be related to its adverse effect on plant emergence by increasing the osmotic pressure particularly at higher doses. Therefore, it is recommended that half of N be applied at planting through calcium ammonium nitrate and remaining at earthling up at about 25-30 days after planting through urea (Dua, 2018).

NPK-uptake and NUE

Nitrogen uptake and NUE

The presented results in Table 4 show that potato uptake of N was significantly affected by variation in N-fertilizer forms. Application of N-requirements as mixed fertilizer (MF) of AS with AN or lower rates of U (treatments of T_6 to T_{10}) enhanced the plant N-uptake and the use efficiency of application N (NUE) than sole application as conventional forms i.e. U, AN or AS for both varieties.

The greatest uptake of N was obtained by treatments of MF 50%AN+50%AS (T_9), without significant differences with N-uptake with MF treatments of 75%AN+25%AS (Fig. 1). Also, the highest NUE was obtained with N fertilization as MF of 50%AN+50%AS (T_9), but the lowest percentage of NUE was recorded with the application as 100%U (Fig. 2). Furthermore, MF treatments of 50%U+50%AS and 25%AN+75%AS

TABLE 2. Effect of conventional forms of nitrogen fertilizers and some mixture percent's of them as mixed fertilizer on plant growth

Parameters→ Treatments↓	Plant height (cm)	Leaf No./plant	Plant fresh weight (g)	Plant dry weight (g)	Dry straw weight (kg/fed)
Spunta cv. Experiment					
T_1: Control	23.3^{g}	10.7^{f}	39.8^{f}	9.27^{f}	312^{f}
T_2: 100% U	31.2^{f}	15.8^{e}	135.7^{c}	14.42^{e}	486^{e}
T_3: 100% AN	34.4^{cd}	19.5^{bc}	116.2^{de}	15.46^{de}	521^{d}
T_4: 100% AS	32.8^{de}	17.5^{d}	110.7^{de}	17.26^{c}	582^{c}
T_5: 75%U+25AS	35.2^{bc}	17.5^{d}	121.5^{d}	16.28^{cd}	549^{cd}
T_6: 50%U+50%AS	32.6^{ef}	19.3^{c}	106.5^{e}	18.68^{b}	630^{b}
T_7:25%U+75%AS	33.5^{de}	18.2^{d}	163.5^{b}	18.70^{b}	630^{b}
T_8: 75%AN+25%AS	36.2^{ab}	21.8^{a}	177.3^{a}	21.82^{a}	735^{a}
T_9: 50%AN+50%AS	36.9^{a}	22.3^{a}	168.8^{ab}	21.41^{a}	722^{a}
T_{10}:25%AN+75%AS	34.3^{cd}	20.5^{b}	113.2^{de}	18.40^{b}	620^{b}
L.S.D. at 5%	1.63	1.10	11.03	1.04	35.04
Diamant cv. Experiment					
T_1: Control	26.7^{e}	17.3^{f}	65.4^{f}	13.08^{g}	441^{g}
T_2: 100% U	36.3^{bc}	23.3^{cd}	104.4^{e}	20.14^{f}	679^{f}
T_3: 100% AN	35.7^{bcd}	20.7^{de}	124.3^{d}	20.88^{f}	704^{f}
T_4: 100% AS	36.7^{bc}	25.0^{abc}	124.7^{d}	22.49^{e}	758^{e}
T_5: 75%U+25AS	35.3^{cd}	22.3^{cde}	137.2^{bc}	24.87^{cd}	838^{cd}
T_6: 50%U+50%AS	35.0^{cd}	24.0^{bc}	134.7^{c}	26.30^{bc}	886^{bc}
T_7:25%U+75%AS	33.3^{d}	20.3^{e}	135.6^{c}	24.60^{d}	829^{d}
T_8: 75%AN+25%AS	40.0^{a}	27.7^{a}	156.5^{a}	28.09^{a}	947^{a}
T_9: 50%AN+50%AS	38.3^{ab}	27.0^{a}	151.3^{a}	27.22^{ab}	917^{ab}
T_{10}:25%AN+75%AS	35.0^{cd}	26.3^{ab}	143.0^{b}	25.83^{bcd}	870^{bcd}
L.S.D. at 5%	2.97	2.69	6.87	1.55	52.4

U (urea 46%N); AN (ammonium nitrate 33.5%N); AS (ammonium sulphate 20.6%N).

maximize plant uptake of N as compared with other treatments, whereas the differences among them were insignificant. In this admiration, Ahmed et al. (2009) found that the highest NPK-uptake in tuber was found with applying N-fertilizer as AN followed by that of U then AS.

The above mentioned results demonstrated that application of N-requirements as mixed fertilizer of AS [$(NH_4)_2SO_4$] along with U [$CO(NH_2)_2$] or AN (NH_4NO_3) improved the use efficiency of application N, where it increased the uptake of N (Table 5 and Fig. 1 & 2) as compared individual application of each form. The greatest percentages of NUE in both experiments were attained with treatments of MF: 50%AN+50%AS, 75%AN+25%AS and 50%U+50%AS, respectively.

These results may be attributed to that forms of MF gave plant the optimum chance to take up N at two forms NH_4^+-N and NO_3^--N along with S as SO_4^{2+}, that had positive relationship between them (N and S); the uptake and assimilation of N and S by plants are strongly interrelated and dependent upon each other (Mengel and Kirkby 2001; Barker and Pilbeam 2007). Application of N as MF of 50%AN+50%AS supply plant with N as 25% NO_3^--N + 75% NH_4^+-N along with SO_4^{2+} (at 90 kg S), whereas MF of 75%AN+25%AS supply plant with N as 37.5% NO_3^--N + 62.5% NH_4^+-N along with SO_4^{2+} (at 45 kg S). However, the application of N as MF of 50%U+50%AS supply plant with N as 50% NH_2-N (rapidly converted to NH_4^+-N after application)+ 50% NH_4^+-N along with SO_4^{2+} (at 90 kg S).

Furthermore, the plant uptake of N and NUE could be returned to relationship between forms of fertilizer and its behavior in soil; fertilizers that contain N as NH_4^+-N (AS) carries a positive charge and is adsorbed onto soil particles and is resistant to leaching too, so it had high percentage of NUE. However, fertilizers that contain N as NO_3^--N (calcium nitrate and AN) carries a negative charge and is not adsorbed onto soil particles, moves freely in the soil solution, so it is free to be leached from the soil which reflect by negative on NUE. On other hand, urea-fertilizer (U) is readily available to plants at the application to soil; it rapidly changes to NH_4^+-N, but significant quantities of NH_4^+-N may be lost through volatilization, especially when it is surface applied at high soil pH (Das and Mandal, 2015). Moreover, it is worth mentioning that there are numerous processes affect N turnover in the soil; i.e. nitrification, denitrification and ammonification. Generally, ammonium fertilizers tend to be converted to nitrate by nitrification process in soil. Therefore, soils usually contain higher levels of nitrate than ammonium (Mengel and Kirkby, 2001). Therefore, application of N as MF of two forms (AS+U or AS+AN) reduced the loss of applied N and maximize the plant uptake of NH_4^+-N and NO_3^--N along with and SO_4^{2-}. These results are in accordance with Westermann (1993), Karadogan (1995) and Khalil (2014) who reported that the ideal nitrogen program is one that employs both NO_3^- and NH_4^+ sources, which provides a steady and adequate supply of N to the plant over the season.

TABLE 3. Effect of conventional forms of nitrogen fertilizers and some mixture percent's of them as mixed fertilizer on potatoes yield and its components

Parameters→ / Treatments↓	Tuber yield (t. fed^{-1})	*NAE (kg tuber/ kg N)	Average weight of tuber (g)	Dry matter yield (kg fed^{-1})	**RI %	Starch yield (kg fed^{-1})	RI %
Spunta cv. Experiment							
T_1: Control	9.217^e	0.00	111^f	1593^h	0.00	1043^g	0.00
T_2: 100% U	15.058^d	38.9	165^e	2576^g	61.71	1679^f	60.98
T_3: 100% AN	18.188^b	59.8	198^{bc}	3220^d	102.13	2126^d	103.84
T_4: 100% AS	16.973^c	51.7	185^{cd}	3051^e	91.53	2025^d	94.15
T_5: 75%U+25AS	16.500^c	48.6	208^b	2903^f	82.23	1912^e	83.32
T_6: 50%U+50%AS	18.553^b	62.2	193^{bcd}	3419^c	114.63	2288^c	119.37
T_7:25%U+75%AS	17.013^c	52.0	178de	3157de	98.18	2117^d	102.97
T_8: 75%AN+25%AS	20.020^a	72.0	226^a	3747^{ab}	135.22	2520^{ab}	141.61
T_9: 50%AN+50%AS	20.457^a	74.9	201^b	3861^a	142.37	2604^a	149.66
T_{10}:25%AN+75%AS	18.340^b	60.8	179de	3621^b	127.31	2476^b	137.39
L.S.D. at 5%	0.546	--	15.4	137.3	--	103.5	--
Diamant cv. Experiment							
T_1: Control	10.184^e	0.00	81^e	2158^g	0.00	1516^g	0.00
T_2: 100% U	15.465^d	0.0	97^d	3170^f	46.88	2206^f	45.54
T_3: 100% AN	16.808^c	35.2	100^d	3569^{cd}	65.39	2508^{cd}	65.48
T_4: 100% AS	16.194^c	44.2	131^b	3392^e	57.19	2375^e	56.70
T_5: 75%U+25AS	16.272^c	40.1	119^c	3469de	60.73	2440de	60.99
T_6: 50%U+50%AS	18.519^a	40.6	127^{bc}	4048^{ab}	87.56	2866^{ab}	89.10
T_7:25%U+75%AS	16.763^c	55.6	129^b	3692^c	71.09	2620^c	72.84
T_8: 75%AN+25%AS	18.930^a	43.9	125^{bc}	4093^a	89.68	2891^a	90.69
T_9: 50%AN+50%AS	18.466^a	58.3	130^b	4145^a	92.10	2956^a	94.99
T_{10}:25%AN+75%AS	17.606^b	55.2	139^a	3899^b	80.66	2770^b	82.74
L.S.D. at 5%	0.711	--	7.67	165.5	--	119.6	--

*NAE (nitrogen agronomic efficiency) **RI (relative increase %).

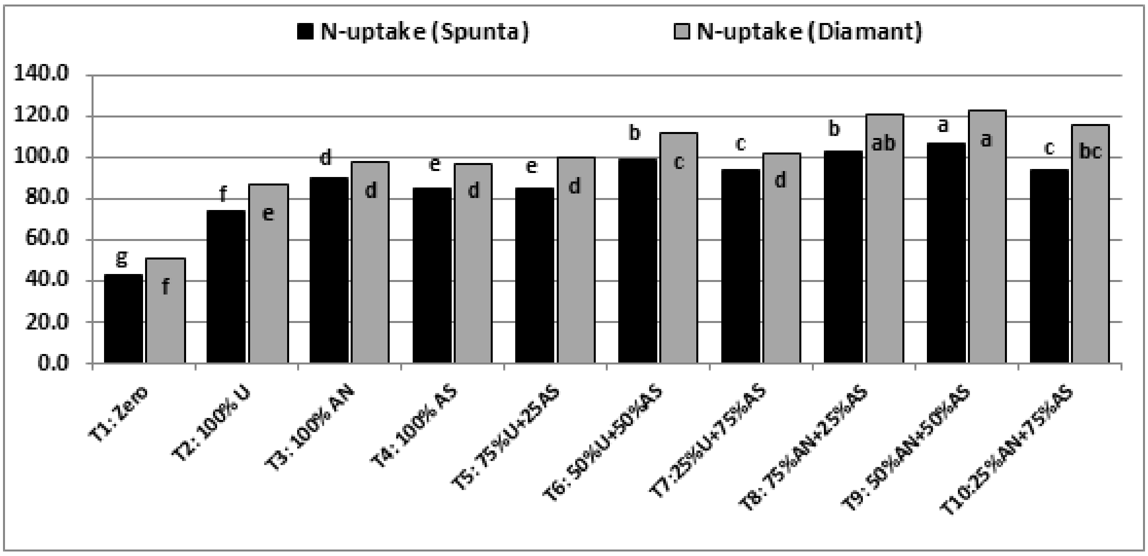

Fig. 1. Total N-uptake (kg fed-1) as affected by treatments

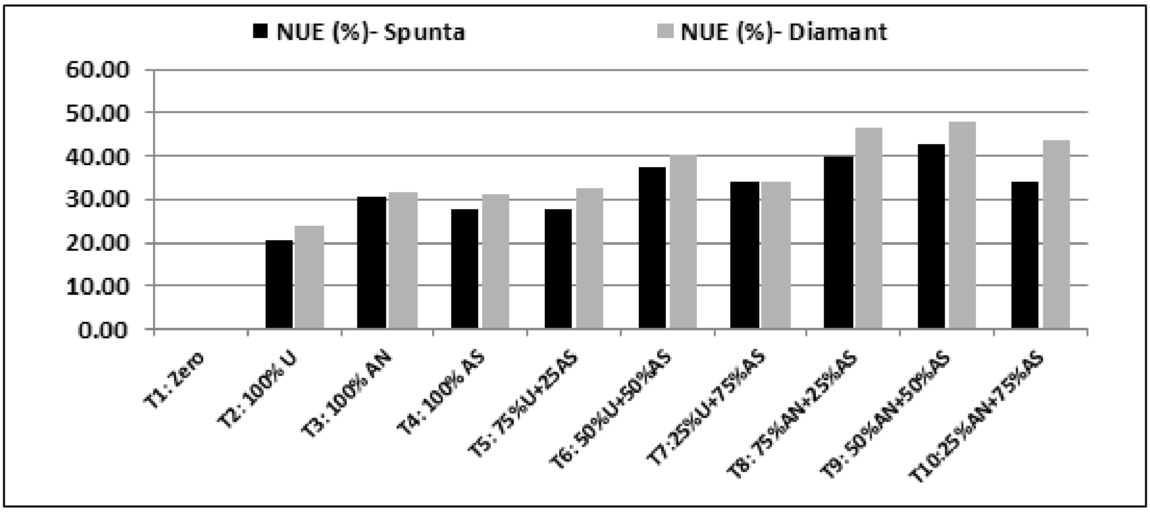

Fig. 2. Nitrogen use efficiency (NUE%) as affected by treatments

Phosphorus uptake

Also, data presented in Table 5 illustrate that the plant uptakes of P was significantly affected by variation in N-fertilizer forms. Application of N as MF boosting the uptake of P more than solely added as conventional forms (T_2, T_3 and T_4) in both experiments of potato: Spunta and Diamant. The highest uptake of P was obtained with treatment of MF 75%AN+25%AS (T_8), but it was insignificant with that uptake at treatment of MF 50%AN+50%AS (T_9) in both experiments. Furthermore, MF of AS with U maximizes the uptake of P more than individual application of 100%U (T_2) in favor of MF 50%U+50%AS (T_6). However, the plant uptake of P was higher with 100%AN rather than 100%AS or 100%U (Fig. 3).

These results may be return to synergistic relationship between P and N, optimum supply of N ensures optimum uptake of P (Barker and Pilbeam 2007). However, the differences among treatments may be attributed to side effect of every treatment of N-fertilizer form. 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 (Wei et al., 2009). The use of NH4$^+$-N (as AS) causes an increasing hydrogen ionic (H^+) excretion, leading to a decrease in soil pH. On the other hand, the use of NO_3^--N is associated with a decrease in H^+ excretion and increasing rates of HCO_3^- or OH^- ionics resulting in rise pH, especially when in combination with Ca^{+2} (Marschner & Römheld 1996 and Mengel & Kirkby, 2001). This side effect had a positive or negative effect on the release of P and its uptake; positive at a decreased in soil pH and negative at raise pH.

Potassium-uptake

Also, plant uptake of K significantly affected by forms of N-fertilizer whether conventional forms or as mixed fertilizers for both varieties (Table 5). The highest plant uptake of K was obtained with N-fertilization as MF of 75%AN+25%AS, but without significant differences with that uptake at MF of 50%AN+50%AS. Also, MF treatment of 50%U+50%AS enhanced the plant uptake of K as compared with sole application of urea. However, the uptake of K was higher with AN than AS and U (Fig. 4).

Application of N as mixed fertilizer as treatments of T6, T8, T9 and T10 improved the plant uptake of K as compared other treatments. These results may be attributed to positive relationship between yields of tuber and starch and the uptake of K that had the same trend (Tables 3 and 4). The enzyme of starch synthetase is strongly activated by K^+, therefore tuber content of starch is correlated by the uptake of K and vice versa. In addition, the greatest uptake of K with AN and MF of AN with AS rather other treatments forms may be return to role of K in NO_3^- mobilization; K^+ acting as a counter ion for $N0_3^-$ transport in the xylem from the root to the shoot for reduction and assimilation; and after NO_3^- reduction as amino acids and organic anions, K+ again acts as counter ion from shoot to root (Mengel and Kirkby, 2001).

Quality of tuber yield

Quality of tuber yield is the main factor that determined price of yield and suitability for local consumption and export, as well as the suitability for processing. Dry matter % (DM), starch %, carbohydrate %, reducing sugar % and nitrate contents are considering the most important factors of tuber quality, especially DM and starch for processing potato cultivars (as Diamant). Results in Table 5 show that quality of tuber was significantly affected by forms of N-fertilizer (as traditional or MF) in both experiments of potato: Spunta and Diamant. Application N-requirements as mixed fertilizer of two N forms enhanced quality of tuber as compared with sole application of conventional N-fertilizer forms.

In Spunta variety; the highest tuber contents of DM (19.74%), starch (13.50%) and carbohydrates were obtained by treatment of MF: 25%AN+75%AS. However, in Diamant variety the highest tuber content of DM (22.45 %) and

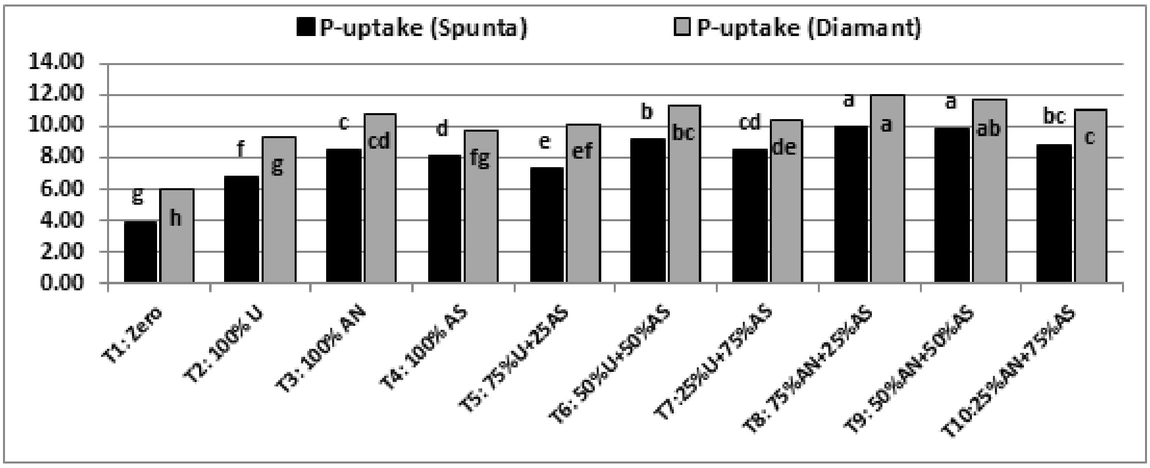

Fig. 3. Total P-uptake (kg fed-1) as affected by treatments

starch (16.01) was gained with N fertilization as MF of 50%AN+50%AS. Furthermore, mixed fertilizers of T_8, T_9 and T_{10} enhanced quality of tuber (increased the content of DM, starch and carbohydrates) rather than conventional sole application of 100%U, 100%AN and 100%AS, with significant differences in both varieties. These results may be attributed to positive relationship between yields of tuber and starch, the uptake of K and tuber content of dry matter and carbohydrates that had the same trend (Tables 3, 4 and 5).

On the other hand, tuber content of reducing sugar and nitrate decreased with MF treatments as compared with sole application of one fertilizer form (where decreasing the tuber content of these two components are considering in quality). The lowest tuber content of nitrate and reducing sugar was obtained with treatment of MF: 25%U+75%AS and 25%AN+75%AS, but the highest content was gained at treatment of 100%U (T_2). However, 100%AS and 100%AN had better effect on quality of tuber than 100%U, without significant differences between AS and AN. In this admiration**,** Ahmed et al. (2009) found that values of tuber quality (starch, dry matter and protein content) were the highest with application of N-fertilizer in the form of AN rather than the others (U and AS).

Relationship between DM and NO3-

Results shown in Fig. 5 illustrate tuber content of DM, NO_3^- and the relationship between them as regression. It is obvious from the trend line the negative relationship between them, when the production of DM increased the accumulation of NO_3^- decreased for both potato experiments. Furthermore, data analysis as correlation showed significant correlation between them, where the correlation coefficient (r) values were -0.59* and -0.822** for both varieties: Spunta and Diamant, respectively.

In general, tuber content of NO_3^- was lower than the critical level according to Mengel and Kirkby (2001**)**, who reported that the critical level of NO_3^- is 2 mg per g (2000 mg kg^{-1}) dry matter in vegetables and particularly in spinach; however in forage crops contents of up to 4 mg NO_3^- per g (4000 mg kg^{-1}) dry matter are acceptable. Moreover, The other values of quality are suitable (good) for processing potato especially of Diamant variety, where these values are in accordance with quality requirements of potato for chip processing; *i.e.* 20-25% dry matter and 15-18% starch **(**Dua, 2018**)**.

The previous mentioned results demonstrate that potato supply of N demand as a mixed fertilizer of two formulas; ammonium sulfate (AS)+ urea (U), or AS+ ammonium nitrate (AN) provides and enhancing potato yield and its quality as compared with sole application of every N-fertilizer alone. These results may be attributed to sulfur in AS-fertilizer that boosting N utilization efficiency and mobilization processing of N. Where under conditions of S deficiency, the utilization of N will be reduced, and consequently nonprotein N compounds, including nitrate accumulation

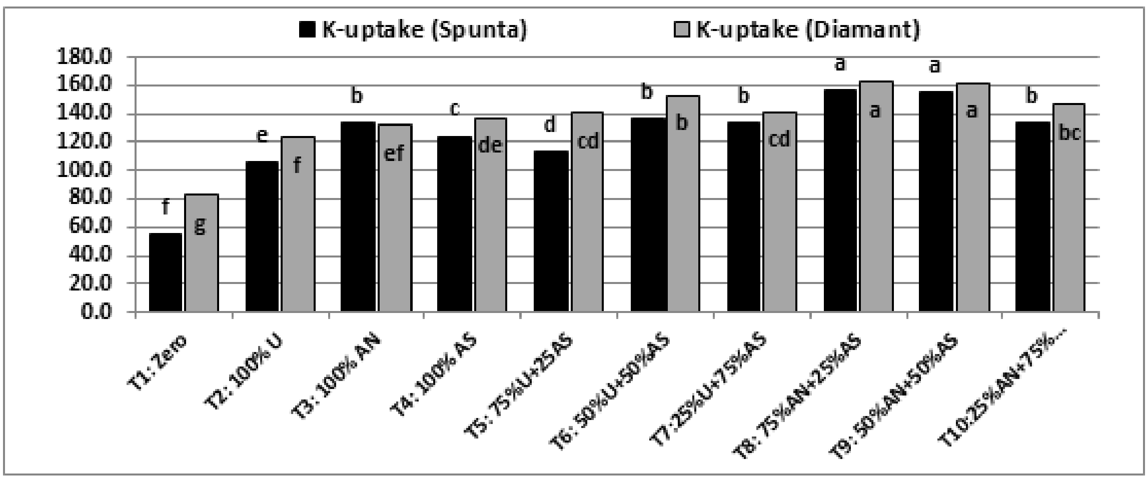

Fig. 4. Total K-uptake (kg fed-1) as affected by treatments

TABLE 4. Effect of conventional forms of nitrogen fertilizers and some mixture percent's of them as mixed fertilizer on NPK-uptake (kg fed-1)

Parameters→ Treatments↓	N-uptake		P-uptake		K-uptake	
	Tuber	Straw	Tuber	Straw	Tuber	Straw
Spunta c.v. Experiment						
T_1: Control	32.5^{g}	10.6^{e}	3.15^{f}	0.807^{e}	40.9^{f}	14.7^{g}
T_2: 100% U	56.4^{f}	17.7^{d}	5.54^{e}	1.192^{d}	81.3^{e}	24.1^{f}
T_3: 100% AN	69.6^{d}	19.8^{c}	7.38^{bc}	1.185^{d}	106.9^{b}	26.8^{e}
T_4: 100% AS	63.0^{e}	21.8^{b}	6.78^{d}	1.380^{c}	94.7^{c}	29.4^{d}
T_5: 75%U+25AS	64.4^{e}	20.4^{b}	5.96^{e}	1.341^{c}	88.9^{d}	24.9^{f}
T_6: 50%U+50%AS	77.0^{bc}	22.0^{b}	7.65^{b}	1.546^{b}	106.4^{b}	29.5^{d}
T_7:25%U+75%AS	71.6^{d}	22.4^{c}	7.14^{cd}	1.384^{c}	102.8^{b}	31.3^{c}
T_8: 75%AN+25%AS	77.7^{b}	25.0^{a}	8.23^{a}	1.760^{a}	117.0^{a}	39.7^{a}
T_9: 50%AN+50%AS	82.2^{a}	24.8^{a}	8.27^{a}	1.528^{b}	118.7^{a}	37.0^{b}
T_{10}:25%AN+75%AS	72.7^{cd}	21.1^{bc}	7.49^{bc}	1.342^{c}	103.1^{b}	30.8^{cd}
L.S.D. at 5%	4.33	1.32	0.436	0.120	4.81	1.69
Diamant cv. Experiment						
T_1: Control	37.2^{e}	13.3^{e}	4.98^{g}	0.97^{e}	61.9^{g}	20.8^{f}
T_2: 100% U	62.2^{d}	24.2^{d}	7.71^{f}	1.65^{d}	87.5^{f}	35.6^{d}
T_3: 100% AN	74.6^{c}	23.1^{d}	9.06^{abc}	1.73^{d}	100.3^{de}	31.1^{e}
T_4: 100% AS	70.4^{c}	26.7^{c}	7.91^{ef}	1.85^{cd}	94.2^{e}	42.8^{b}
T_5: 75%U+25AS	71.9^{c}	27.4^{c}	8.12^{ef}	2.04^{c}	101.7^{d}	38.8^{cd}
T_6: 50%U+50%AS	81.2^{b}	30.1^{b}	8.94^{bc}	2.36^{ab}	112.8^{b}	40.1^{bc}
T_7: 25%U+75%AS	74.0^{c}	27.9^{c}	8.29^{de}	2.10^{bc}	99.6^{de}	41.4^{bc}
T_8: 75%AN+25%AS	88.2^{a}	32.3^{a}	9.48^{a}	2.43^{a}	109.3^{bc}	52.9^{a}
T_9: 50%AN+50%AS	92.1^{a}	30.4^{ab}	9.13^{ab}	2.56^{a}	121.1^{a}	40.5^{bc}
T_{10}:25%AN+75%AS	88.1^{a}	27.7^{c}	8.67^{cd}	2.37^{a}	104.5^{cd}	41.8^{bc}
L.S.D. at 5%	5.43	2.04	0.447	0.266	6.58	3.53

U (urea 46%N); AN (ammonium nitrate 33.5%N);AS (ammonium sulphate 20.6%N).

in plant tissue (Barker and Pilbeam, 2007). These results agreed with Soliman et al. (2000), Khalil (2014) and Dua (2018), who reported the importance of ammonium sulphate fertilizer for potato production.

Economic evaluation

Data in Table 6 show comparison study among the treatments of N-fertilizer forms as economic assessment of potato yield. The inputs were; 290 L.E/50 kg urea fertilizer, 250 L.E/50 kg ammonium nitrate fertilizer and 200 L.E/ 50 kg ammonium sulphate fertilizer. Furthermore, 23600 L.E fed^{-1} other constant costs (400 L.E tillage, 350 L.E super phosphate fertilizer, 7150 L.E potato seeds, 900 L.E cost of planting, 600 L.E potassium sulphate fertilizer, 1200 L.E labors, 1500 L.E pesticides, 1500 L.E harvest and 10000 L.E rental value of land area "fed= 4200 m^2"). The outputs were; gross return per feddan that calculated as "tuber yield*price of potato", where price of potato range from 2.7 L.E (Spunta) to 3 L.E (Diamant) per kg of tuber (as 2700 to 3000 L.E t^{-1}). The net return was calculated as "Gross return fed^{-1}−Total cost fed^{-1}". Investment factor (IF) was calculated as "Gross return/Total cost".

Spunta experiment

Data in Table 6 illustrate that application of N as 100%AS (T_4) had the highest cost of N-fertilizer (2700 L.E); whereas the treatment of 100% U had the lowest cost (1885 L.E). For gross return per

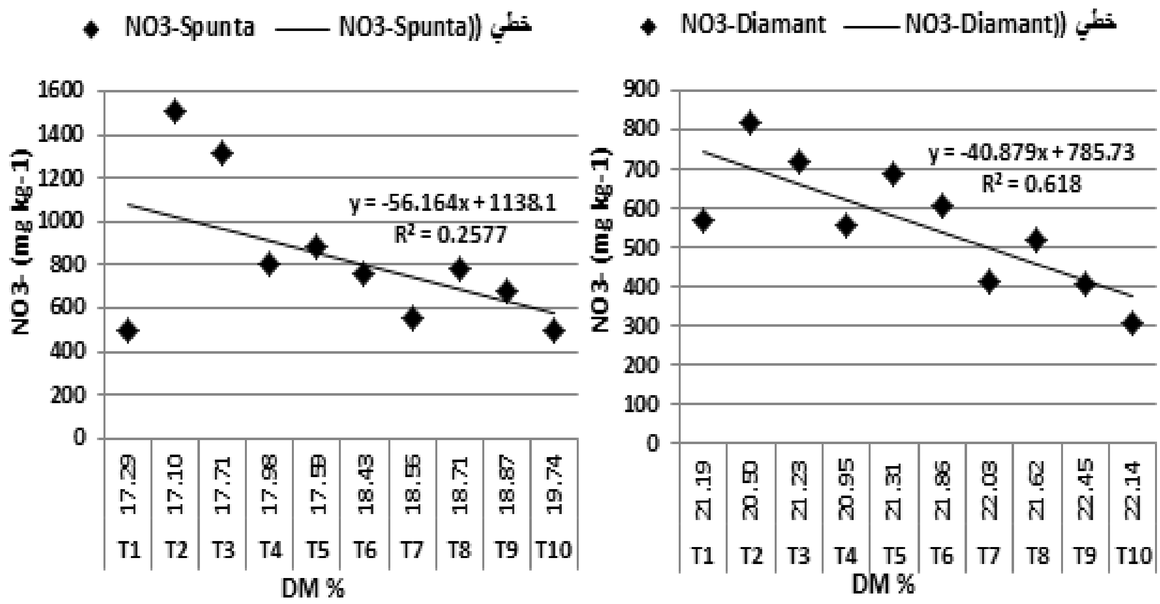

Fig. 5. Tuber content of DM (%) and NO3- (mg kg-1) as affected by treatments, and the relationship between them

feddan, N fertilization as MF of 75%AN+25%AS recorded the highest gross return, followed by that of MF 50%AN+50%AS then 50%U+50%AS. Also, treatment of MF 75%AN+25%AS had the highest net return followed by 50%AN+50%AS, but the lowest net return was obtained with treatment of 100%U. However, the treatment of MF 50%AN+50%AS had the highest investment factor (2.12).

Diamant experiment

Also, N fertilization as MF of 75%AN+25%AS was gained the highest gross return and the highest net return per feddan followed by MF treatments 50%U+50%AS then 50%AN+50%AS, with high values of IF; 2.19, 2.15 and 2.12, respectively.

In general, the previous results illustrated that application of potato N-demands as mixed fertilizer (MF) of 50%AN+50%AS, 75%AN+25%AS or 50%U+50%AS were the best treatments (as respectively) for yield, quality, nutrients uptake and N utilization efficiency than individual application as conventional forms of 100%AN, 100%AS or 100%U. Furthermore, applications of N as these forms of MF maximize profitability of yield in the both experiments (Spunta and Diamant). In addition, application of N as these pervious mentioned MF could be declined the load or request on AN-fertilizer, as well as enhancing the use efficiency of applied N-fertilizers, and consequently could reduce the added rate of N. Therefore, application of AS-fertilizer along with AN or U as mixed fertilizer has become very important.

Conclusion

Under the ecological conditions of clayey loam soils (Dakahlia Governorate, Egypt), it can be concluded that application of potato N-demands as mixed fertilizer of 50%AN+50%AS or 75%AN +25%AS or 50%U+50%AS; are the best N-fertilizer forms for optimize tuber yield and its quality and profitability, whether from the two potato varieties; non industrial (Spunta) or industrial (Diamant).

TABLE 5. Effect of conventional forms of nitrogen fertilizers and some mixture percent's of them as mixed fertilizeron quality of tuber yield

Parameters→ Treatments↓	D M %	Starch %	Carbohydrates %	Reducing sugar %	NO_3^- (mg kg^{-1})
Spunta cv. Experiment					
T_1: Control	17.29[ef]	11.32[ef]	53.52[f]	30.00[c]	502[f]
T_2: 100% U	17.10[f]	11.15[f]	57.38[f]	39.83[a]	1504[a]
T_3: 100% AN	17.71[d]	11.69[d]	65.50[e]	36.83[ab]	1312[b]
T_4: 100% AS	17.98[d]	11.93[d]	73.17[cd]	33.83[b]	806[cd]
T_5: 75%U+25AS	17.59[de]	11.59[de]	79.33[ab]	27.17[c]	884[c]
T_6: 50%U+50%AS	18.43[c]	12.33[c]	69.17[de]	27.67[c]	762[de]
T_7:25%U+75%AS	18.56[bc]	12.44[bc]	74.83[bc]	28.00[c]	555[f]
T_8: 75%AN+25%AS	18.71[bc]	12.58[bc]	74.33[ab]	27.33[c]	785[cde]
T_9: 50%AN+50%AS	18.87[b]	12.73[b]	65.00[e]	23.00[d]	681[e]
T_{10}:25%AN+75%AS	19.74[a]	13.50[a]	80.50[a]	30.00[c]	502[f]
L.S.D. at 5%	0.397	0.355	4.63	3.23	113.8
Diamant cv. Experiment					
T_1: Control	21.19[e]	14.88[e]	63.50[f]	16.50[b]	567[de]
T_2: 100% U	20.50[g]	14.27[g]	74.17[e]	23.17[a]	822[a]
T_3: 100% AN	21.23[e]	14.92[e]	81.83[abc]	15.17[bcd]	719[b]
T_4: 100% AS	20.95[f]	14.67[f]	80.00[bcd]	12.50[e]	555[de]
T_5: 75%U+25AS	21.31[e]	15.00[e]	77.83[d]	16.00[bc]	690[bc]
T_6: 50%U+50%AS	21.86[c]	15.48[c]	79.33[cd]	13.17[de]	608[cd]
T_7:25%U+75%AS	22.03[b]	15.63[b]	78.33[d]	9.17[f]	415[f]
T_8: 75%AN+25%AS	21.62[d]	15.27[d]	81.17[abc]	14.50[bcde]	517[e]
T_9: 50%AN+50%AS	22.45[a]	16.01[a]	82.17[ab]	13.83[cde]	410[f]
T_{10}:25%AN+75%AS	22.14[b]	15.73[b]	82.83[a]	10.00[f]	306[g]
L.S.D. at 5%	0.156	0.141	2.69	2.48	90.8

U (urea 46%N); AN (ammonium nitrate 33.5%N); AS (ammonium sulphate 20.6%N).

TABLE 6. Economic evaluation of tuber yield as affected by treatments of N fertilizer

Variables → Treatments ↓	Cost of N-fertilizer (L.E)	Total costs (L.E)	Tuber yield (t.fed^{-1})	Gross return (L.E)	Net return (L.E)	IF*
1st Experiment (Spunta c.v.):						
T_1: Control	0	23600	9.217	24887	1287	1.05
T_2: 100% U	1891	25491	15.058	40656	15165	1.59
T_3: 100% AN	2240	25840	18.188	49106	23266	1.90
T_4: 100% AS	2700	26300	16.973	45826	19526	1.74
T_5: 75%U+25AS	2098	25698	16.500	44551	18853	1.73
T_6: 50%U+50%AS	2295	25895	18.553	50094	24199	1.93
T_7:25%U+75%AS	2502	26102	17.013	45936	19834	1.76
T_8: 75%AN+25%AS	2357	25957	20.020	54053	28096	2.08
T_9: 50%AN+50%AS	2470	26070	20.457	55233	29163	2.12
T_{10}:25%AN+75%AS	2587	26187	18.340	49519	23332	1.89
2nd Experiment (Diamant c.v.):						
T_1: Control	0	23600	10.184	30552	6952	1.29
T_2: 100% U	1891	25491	15.465	46395	20904	1.82
T_3: 100% AN	2240	25840	16.808	50424	24584	1.95
T_4: 100% AS	2700	26300	16.194	48582	22282	1.85
T_5: 75%U+25AS	2098	25698	16.272	48816	23118	1.90
T_6: 50%U+50%AS	2295	25895	18.519	55557	29662	2.15
T_7:25%U+75%AS	2502	26102	16.763	50289	24187	1.93
T_8: 75%AN+25%AS	2357	25957	18.930	56790	30833	2.19
T_9: 50%AN+50%AS	2470	26070	18.466	55398	29328	2.12
T_{10}:25%AN+75%AS	2587	26187	17.606	52818	26631	2.02

IF* (investment factor); U (urea); AN (ammonium nitrate); AS (ammonium sulphate).

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تأثير الأسمدة النيتروجينية التقليدية والمخلوطة على محصول البطاطس وجودته وامتصاص العناصر الغذائية

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يعد اختيار الصورة المناسبة أو الملاءمة من الأسمدة النيتروجينية أحد أهم العوامل المحددة لإنتاج البطاطس وجودتها، والتي تعتمد في المقام الأول على المتاح من الأسمدة وتكاليفها (أسعارها)؛ تهدف هذه الدراسة لمقارنة تأثير الأسمدة النيتروجينية التقليدية (اليوريا، نترات الأمونيوم وسلفات الأمونيوم) والأسمدة المخلوطة منها (فى صورة نسب مخلوطة من سلفات الأمونيوم مع اليوريا أونترات الأمونيوم من النتروجين المضاف) وذلك على نمو النبات والمحصول والجودة وامتصاص العناصر الغذائية وكفاءة استخدام النيتروجين وكذلك ربحية المحصول للبطاطس المنزرعة في الأراضى الطينية الطميية؛ تم إجراء تجربتين حقليتين بقرية بطرة- مركز طلخا-محافظة الدقهلية خلال موسمي زراعة متتالين على صنفين من البطاطس (أسبونتا ودايمونتا)؛ هذا وقد وزعت المعاملات في تصميم قطاعات تامة العشوائية فى ثلاث مكررات. أظهرت النتائج المتحصل عليها تحسن كلا من نمو النبات، محصول الدرنات، الجودة، امتصاص العناصر الغذائيه وكفاءة استخدام النيتروجين مع معاملات إضافة الأسمدة النتروجينية المخلوطة بالمقارنة مع إضافة الأسمدة التقليدية فى صورة منفردة، ومع تفوق معاملات الأسمدة المخلوطة من ٧٥٪نترات الأمونيوم+٢٥٪سلفات الأمونيوم، ٥٠٪نترات الأمونيوم+٥٠٪سلفات الأمونيوم و ٥٠٪يوريا+٥٠٪سلفات الأمونيوم؛ كما سجل أعلى محصول من المادة الجافة والنشا مع إضافة معاملة السماد المخلوط من ٥٠٪ نترات الأمونيوم+٥٠٪ سلفات الأمونيوم؛ وعلى الرغم من ذلك فإن تراكم النترات في الدرنات تناسب عكسيا مع إنتاج المادة الجافة حيث سجل أعلى محتوى من النترات مع معاملة التسميد فى صورة ١٠٠٪يوريا، ولكن أقل محتوى تم الحصول عليه مع معاملة السماد المخلوط من ٢٥٪ نترات الأمونيوم+٧٥٪ سلفات الأمونيوم. هذا وقد زادت كفاءة استخدام النتروجين مع معاملات السماد المخلوطة وسجلت أكبر نسبة منها مع السماد المخلوط بنسبة ٥٠٪ نترات الأمونيوم+٥٠٪ سلفات الأمونيوم في كلتا التجربتين؛ هذا وتشير النتائج إلى أهمية إضافة سماد سلفات الأمونيوم إلى جانب نترات الأمونيوم أو اليوريا كسماد مخلوط لزيادة إنتاجية محصول البطاطس وجودته وكفاءة استخدام النيتروجين والربحية إلى أقصى حد.