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EFFECT OF SLOW RELEASE NITROGEN FERTILIZERS ON PRODUCTIVITY AND QUALITY OF POTATO (*Solanum tuberosum* L.).

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ABSTRACT

The present investigation was carried out at Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt (+ 7m altitude, 30^{o} 11^{-} latitude and 28^{o} 26^{-} longitude), during Nili seasons of 2007/08 and 2008/09, to study the effect of slow release-N (urea formaldehyde "UF"; Sulfur coated urea "SCU", and compost) as compared with soluble-N (ammonium nitrate "AN") fertilizer on productivity, and quality of potato cv. Cara. The most important finding could be summarized as follows:

- Compost $_{9\ ton\ fed^{-1}}$ plus SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ led to significant increase in all vegetative growth parameters of potato plants (plant height, leaf area/plant and dry weight/plant) in both seasons.
- Significant differences were detected in total tuber yield and yield components among various treatments in both seasons. Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ and SCU1 $_{135\ kg\ N\ fed^{-1}}$ had significant effect in this respect.
- Application of Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ significantly increased tuber dry matter (in both season), starch and specific gravity of tuber (1st season, only) and significantly decreased nitrate and nitrite content of tuber (both season), in comparison with other treatments.
- The NPK % of potato tubers in treatment amended with Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ was higher than with other treatments in two seasons. On the other hand, the greatest value of nitrogen use efficiency (NUE) was obtained by the application of SCU1 followed by UF2.
- The highest net return was obtained from potato receiving Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ in comparison with other treatments.

Generally, it could be concluded that, application of nitrogen fertilizer in the form of Compost at the rate of 9 ton fed^{-1} + SCU3 (67.5 kg N fed^{-1}) in potato fields was the most effective treatment for satisfactory improvements in productivity and quality yields with keeping the health and safety of human and environment.

Keywords: Potato, slow release N-fertilizers, soluble N-fertilizers, productivity, costs.

INTRODUCTION

Nitrogen is the most limiting nutrient for crop production in many of the world's agricultural areas and its efficient use is important for the economic sustainability of cropping systems. Furthermore, the dynamic nature of N and its tendency for losing from soil-plant systems creates a unique and challenging environment for its efficient management. Crop response to applied N and use efficiency are important criteria for evaluating crop N requirements for maximum economic yield. Recovery of N in crop plants is usually less than 50% worldwide. Low recovery of N in annual crop is associated with its loss by volatilization, leaching, surface runoff, denitrification, and plant canopy. Low recovery of N is not only responsible for higher cost of crop production, but also for environmental pollution. Hence, improving N use efficiency (NUE) is desirable to improve crop yields, reducing cost of production, and maintaining environmental quality (Fageria and Baligar, 2005).

Besides, the steady increase in population growth and food demand and the continuous reduction in cultivated land per capita induce steady intensification of fertilizer application worldwide. Despite improvements in the practices of nutrient application, the use efficiency (UE) of essential elements such as N is not satisfactory, resulting in an increase of environmental problems. The use of controlled-release fertilizers (CRFs) starts to evolve as a promising direction offering an excellent means to improve management of nutrient application and by this reducing significantly environmental threats while maintaining high crop yields of good quality. Low cost effectiveness and limited recognition of the potential benefits to be gained from the CRFs were so far the main reasons for their limited consumption. (Shaviv, 2001; Fageria and Baligar; 2005 and Chien *et al*., 2009).

Improved efficiency of N may be achieved with controlling the dissolution of applied nitrogen fertilizers, development of compounds with limited water solubility, altering soluble materials to retard their release to the soil solution and with mechanical additives to control fertilizer-soil microbial reactions (Chatzoudis and Valkanas, 1995).

From the view point of improving nutrient recovery by plants, three main advantages are cited for controlled-release fertilizers:

1-Reduction of nutrient loss via leaching and runoff, Reduction of chemical and biological immobilization reaction in soils which cause plant-unavailable form and for nitrogen, and Reduction of rapid nitrification and nitrogen loss through ammonia volatilization and denitrification (Fox *et al*., 1996).

In this respect, Allen (1984) mentioned that potential benefits from slow release fertilizers include: (i) more efficient use of nitrogen by the crop, (ii) less leaching of nitrogen, (iii) lower toxicity, (iv) longer lasting nitrogen supply, (v) reduced volatilization losses of nitrogen and (vi) lower application cost. Moreover, Liegel and Walsh (1976) reported that slow release SCU carriers produced higher yields and nitrogen recovery of potato than plants grown with urea or AN, because their dissolution reduced leaching losses of N. Also, they showed that frequent potato yield depressions with fast release N fertilizers, mainly due to N leaching. In another study, Waddell *et al.* (1999) reported that the use of unconventional N sources such as turkey manure and SCU are viable alternatives for potato production, SCU applied at the rate of 224 kg ha^{-1} N produced maximum tuber yield under either drip or sprinkler irrigation. In field trials for three years, Hutchinson and Simonne (2003) demonstrated that N rates can be reduced with a controlled-release fertilizer program compared to a soluble N fertilizer program (non-coated urea and/or ammonium nitrate) without reducing crop yield or quality. Also, Pack (2004) found that all six controlled release fertilizers (CRF) with the 168 kg N ha^{-1} rate, potatoes gave 3 to 14 % higher marketable yield than the AN at the rate of 224 kg N ha^{-1}. Also at the rate of 224 kg N ha^{-1}, five CRFs produced 7 to 36% higher marketable yield than with the AN. The objective of this study is to compare the slow release-N and traditional soluble-N fertilizers on productivity, quality, and economic costs of potato.

MATERIALS AND METHODS

Two field experiments were conducted in the Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt (+ 7m altitude, 30^o 11^- latitude and 28^o 26^- longitude), during Nili seasons of 2007/08 and 2008/09, to study the effect of slow release-N (urea formaldehyde "UF", Sulfur coated urea "SCU" and compost) and soluble-N (ammonium nitrate "AN") fertilizer on productivity, and quality of potato cv. Cara. Seed tubers were planted on 15^{th} of October in both seasons of study. Plot area was 11.25 m^2; consisted of 3 ridges; 5 m long; 75 cm wide, and 25 cm apart.

Some physical and chemical properties of the experimental soil at the depth of 0-30 cm were determined according to the standard procedures as described by Page (1982) (Table 1). The chemical analysis of the used compost was determined using standard methods described by AOAC (1990) (Table 2).

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

Some Physical properties	Values		Some Chemical Properties	Values	
	1^{st} season	2^{nd} season		1^{st} season	2^{nd} season
Sand (%)	27.8	28.0	pH value	8.1	7.9
Silt (%)	31.6	31.9	EC dSm^{-1}	0.9	0.8
Clay (%)	40.6	40.1	Total N (%)	0.03	0.04
Texture class	**Clay-loam**	**Clay-loam**	Available N (ppm) NH_4-N NO_2-N NO_3-N	 23.37 0.162 13.21	 23.00 0.126 13.12
$CaCO_3$ (%)	3.1	3.2	Available P (ppm)	12.3	12.1
Organic matter (%)	1.4	1.6	Available K (ppm)	304	295

A complete randomized blocks design with three replicates was used. The experiment included 14 treatments, which were as follows:

1. **Ammonium nitrate**, **AN** (33.5 % N); recommended full dose (RD) of N at the rate of **180** kg N fed^{-1} (Control).
2. **Compost**, (1.2 % N); at the rate of **18** ton fed^{-1}; as fresh weight (moisture =21.7%).
3. **Urea formaldehyde**, **UF1** (36.2 % N); at the rate of **135** kg N fed^{-1}.
4. **Urea formaldehyde**, **UF2** (36.2 % N); at the rate of **90** kg N fed^{-1}.
5. **Sulfur coated urea**, **SCU1** (32.0 % N); at the rate of **135** kg N fed^{-1}.
6. **Sulfur coated urea**, **SCU2** (32.0 % N); at the rate of **90** kg N fed^{-1}.
7. **AN** (**90** kg N fed^{-1}) + **UF3** (**67.5** kg N fed^{-1}).
8. **AN** (**90** kg N fed^{-1}) + **UF4** (**45** kg N fed^{-1}).
9. **AN** (**90** kg N fed^{-1}) + **SCU3** (**67.5** kg N fed^{-1}).
10. **AN** (**90** kg N fed^{-1}) + **SCU**4 (**45** kg N fed^{-1}).
11. **Compost** (**9** ton $fed.^{-1}$) + **UF3** (**67.5** kg N fed^{-1}).

12. **Compost** (**9** ton fed.$^{-1}$) + **UF4** (**45** kg N fed^{-1}).
13. **Compost** (**9** ton fed.$^{-1}$) + **SCU3** (**67.5** kg N fed^{-1}).
14. **Compost** (**9** ton fed.$^{-1}$) + **SCU4** (**45** kg N fed^{-1}).

Ammonium nitrate was used as a soluble N-fertilizer, while, compost, UF and SCU were used as a slow release N-fertilizers.

Table 2 : Some properties of compost used in experiments during 2007/08 and 2008/09 seasons.

Properties	Values		Properties	Values	
	1st season	2nd season		1st season	2nd season
N (%)	1.20	1.19	pH	6.80	6.75
P (%)	0.41	0.39	E.C. (dSm^{-1})	0.85	1.20
K (%)	1.67	1.70	Fe (ppm)	1822	1685
Organic carbon (%)	16.90	16.80	Mn (ppm)	274	286
C/N ratio	14.08	14.12	Zn (ppm)	190	210

The slow release-N (urea formaldehyde UF 1 & 2; Sulfur coated urea SCU 1 & 2, and compost) at the previously mentioned rates were added to experimental soil before planting. Ammonium nitrate (soluble form) was added at three equal doses, i. e. the first after emergence, and second and third doses were applied with 2nd and 3rd irrigation, respectively. Single superphosphate (15.5% P_2O_5) was applied with slow release N-fertilizers (before planting) at the rate of 75 kg P_2O_5 fed^{-1}. Potassium sulphate (48% K_2O) was used as a source of potassium at the rate of 96 kg K_2O fed^{-1} and was added in two equal doses with the 2nd and 3rd doses of ammonium nitrate (soluble form). Other agricultural practices were conducted according to recommendations. At 70 days after planting (DAP), a random sample of five plants was taken from each experimental unit to determine the growth parameters of potato plants (plant height, leaf area and dry weight/plant). At the harvesting time (130 DAP), the tuber yield fed^{-1} and yield grading plot^{-1}were recorded. A representative sample of 10 to 15 healthy tubers from each experimental plot was selected from the largest sizes to obtain quality data (dry matter, specific gravity, starch, and nitrate and nitrite content) according to the methods described by (AOAC, 1990). Nitrogen, phosphorus and potassium concentrations in plant leaves were determined at 50, 70 and 90 DAP using the methods described by Cottenie *et al*., (1982). The soil samples were taken out from plots for N, P and K determination at 60, 90 and 120 DAP according to Black (1965). N, P and K concentrations in the digested dry weight of tubers were determined according to the methods described by Olsen and Sommers (1982). For calculation of nitrogen use efficiency (NUE), total tuber yield (kg fed^{-1}) was divided by the amount of nitrogen in kg fed^{-1} (Aujla *et al.*, 1982). Economic evaluation, based on yield as an average of two seasons was estimated. Data obtained were subjected to statistical analysis by the technique of analysis of variance (ANOVA) according to Snedecor and Cochran (1982). The treatments mean were compared using the last significant differences (LSD) at 5 % level of probability as described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

1. Vegetative growth parameters:

Data presented in Table 3 demonstrate the effect of various treatments of slow release-N and soluble-N fertilizers on vegetative growth parameters of potato plants expressed as plant height, leaf area/plant and dry weight/plant. Significant effects on vegetative growth characters was obtained under the treatment where Compost $_{9\ ton\ fed^{-1}}$ plus SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ was applied in comparison with other treatments, in both seasons of study.

Table 3: Vegetative growth characters of potato as affected by slow and soluble N-fertilizers in 2007/08 and 2008/09 seasons.

Characters / Treatments	Plant height (cm)		Leaf area/plant (cm^2)		Dry weight/plant (g)	
	2007/2008	2008/2009	2007/2008	2008/2009	2007/2008	2008/2009
1- Ammonium nitrate (AN) (180 kg N fed.$^{-1}$), Control	54.67	55.00	4288	4212	28.95	29.15
2- Compost (18 ton fed.$^{-1}$)	56.00	57.00	4633	4835	31.27	32.73
3- Urea formaldehyde (UF1); 135 kg N fed.$^{-1}$	57.33	56.00	4521	4712	30.52	27.30
4- Urea formaldehyde (UF2); 90 kg N fed.$^{-1}$	52.00	52.33	4229	3918	28.55	27.16
5-Sulfur coated urea (SCU1); 135 kg N fed.$^{-1}$	58.67	56.33	5054	5118	34.12	33.76
6-Sulfur coated urea (SCU2); 90 kg N fed.$^{-1}$	52.33	54.67	4210	4280	28.42	26.70
7- AN $_{90\ kg\ N}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	49.67	44.67	3197	3120	21.58	22.20
8- AN $_{90\ kg\ N}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	49.33	43.33	3723	3681	25.13	25.76
9- AN $_{90\ kg\ N}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	47.33	42.67	3976	3824	26.84	24.34
10- AN $_{90\ kg\ N}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	43.00	40.00	3582	3426	24.18	23.42
11-Compost $_{9\ ton}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	54.66	54.00	4323	4180	29.18	28.70
12-Compost $_{9\ ton}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	50.33	48.33	4906	4980	33.12	32.00
13-Compost $_{9\ ton}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	60.67	58.00	5446	5423	36.76	34.84
14-Compost $_{9\ ton}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	47.00	46.00	4130	4286	27.88	26.00
LSD at 0.05 level	2.19	3.52	267.11	328.14	2.17	2.26

The best results obtaining from using SCU can be attributed to the slow release of nitrogen to meet potato plants requirement, where the coat of urea with sulfur can low the dissolution rate of urea than AN (soluble form), so reduce N loss from soil, gradually hydrolyzed in parallel with the plant demand, gives a chance for more nitrogen uptake by plant roots and gradual improvement in N-supply power for improving N efficiency of slow release as compared with soluble form (Waddell *et al.*, 1999; Allen, 1984 and Zvomuya *et al*., 2003). Also, the increases occurred in plant vegetative growth may be due to that SCU contain nitrogen and sulfur elements, and both elements are presented in the molecule of most amino acids and protein, in addition to the role of both elements in several biochemical processes that related to plant growth (Marschner, 1995). Sulfur may also decrease the soil pH, so resulting in increasing the available form of most nutrients, especially micro-elements. Besides, the beneficial effect of compost on vegetative growth may be related to improve physical conditions of the soil, provide energy for microorganism activity, increased nutrient supply and improve the efficiency of macro and micronutrients (Ezzat, 2001, and Mallory and Porter, 2007).

2. Yield and yield components:

The effect of various sources of slow release-N and soluble-N fertilizers on total tuber yield of potato and its different components are shown in Table 4. The results indicate that total tuber yield differed significantly with the different fertilizer management, in both seasons. Highest tuber yield (14.492 and 13.640 ton fed^{-1}, in both seasons, respectively) was obtained under the treatment received Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$. The second treatment regarding the increase in tuber yield was SCU1 (135 kg N fed^{-1}) without significant differences between 1st and 2nd treatments, respectively. The percentage increases over the control AN (soluble form) reached to 11.68, 11.73 % and 9.35, 8.79 % for both superiority treatments, in both seasons, respectively. On the other hand, the lowest tuber yield (9.150 and 7.520 ton fed^{-1}) was recorded under the treatment of AN $_{90\ kg\ N\ fed^{-1}}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$, in both seasons. Higher tuber yields for compost treatments were possibly due to extra N and other nutrients present in compost but not in other N sources (Waddell *et al.*, 1999; Ezzat, 2001 and Mallory and Porter, 2007). Nyiraneza and Snapp (2007) reported that potato tuber yield and N uptake in the integrated treatments of the organic fertilizer were 14 to 33 % higher than the inorganic fertilizer. On the other hand, the use of SCU may regulate N-nutrient release to be used more efficiently by plants, subsequently reducing-N leaching losses and providing a constant supply of nutrients to the roots according to growing pattern of potato plants (Lorenz *et al.*, 1974; Liegel and Walsh, 1976; Waddell *et al.*, 1999 and Pack, 2004).

Table 4: Total tuber yield and yield components of potato as affected by slow and soluble N-fertilizers in 2007/08 and 2008/09 seasons.

Characters / Treatments	Total tuber yield (Ton fed.$^{-1}$)		Tuber grading (Ton fed.$^{-1}$) Tuber weight > 60 mm		Tuber weight 30 : 60 mm		Tuber weight < 30 mm	
	2007/2008	2008/2009	2007/2008	2008/2009	2007/2008	2008/2009	2007/2008	2008/2009
1-Ammonium nitrate (AN) (180 kg N fed.$^{-1}$), Control	12.800	12.040	5.600	5.280	6.540	6.180	0.660	0.580
2- Compost (18 ton fed.$^{-1}$)	13.410	12.920	5.900	5.840	6.908	6.580	0.602	0.500
3- Urea formaldehyde (UF1); 135 kg N fed.$^{-1}$	12.920	13.400	5.600	6.120	6.780	6.760	0.540	0.520
4- Urea formaldehyde (UF2); 90 kg N fed.$^{-1}$	11.300	10.800	4.600	5.120	5.740	4.880	0.960	0.800
5-Sulfur coated urea (SCU1); 135 kg N fed.$^{-1}$	14.120	13.200	6.040	5.920	7.576	6.800	0.592	0.480
6-Sulfur coated urea (SCU2); 90 kg N fed.$^{-1}$	11.712	11.160	4.792	5.200	6.000	5.100	0.920	0.860
7- AN $_{90\ kg\ N}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	9.800	9.000	3.860	4.240	5.000	3.820	0.940	0.940
8- AN $_{90\ kg\ N}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	9.150	7.520	3.670	3.340	4.300	3.200	1.180	0.980
9- AN $_{90\ kg\ N}$ + SCU3 $_{67.5\ N\ kg\ fed.^{-1}}$	9.693	9.040	2.972	3.400	5.600	4.780	1.120	0.860
10- AN $_{90\ kg\ N}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	9.412	8.120	4.320	3.800	4.500	3.400	0.592	0.920
11-Compost $_{9\ ton}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	12.100	11.920	4.988	5.200	6.320	6.100	0.792	0.620
12-Compost $_{9\ ton}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	10.916	9.720	4.360	4.960	5.556	4.080	1.000	0.680
13-Compost $_{9\ ton}$+SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	14.492	13.640	6.340	6.480	7.692	6.760	0.460	0.400
14-Compost $_{9\ ton}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	10.568	10.240	4.408	4.640	5.100	4.920	1.060	0.680
LSD at 0.05 level	0.643	0.717	0.638	0.983	1.110	1.020	0.101	0.166

In this respect, Worthington *et al*. (2007) found that potato plants in controlled release fertilizer (CRF) treatments produced significantly higher marketable tuber yields in both years compared with plants in AN fertilizer treatments.

Regarding, the tuber grade-out and size grades (over 60 and 30: 60 mm) Table 4, it is obvious that it took the manner of total tuber yield as previously mentioned. Science, total yield increases were due to primarily the increase in tuber size in larger and medium grades and decrease of the small grades. In this respect, the treatment of Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ increased significantly weights of large (> 60 mm) and medium tubers (30: 60 mm) and decreased significantly small tuber weight (< 30 mm), in both seasons, respectively.

Similar observations were reported by Waddell *et al.* (1999), Tartoura *et al*. (2003) and Pack (2004); they associated the increase in tuber yield from slow release-N fertilizers with an increase in the number of tubers in the medium and large grades (marketable tubers) due to the increase in weight of tubers.

3. Tuber quality:

Data presented in Table 5 show that, there were significant differences in tuber quality parameters, and nitrate as well as nitrite content in potato tuber, in both seasons. Application of Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ significantly increased tuber dry matter (in both season), starch and specific gravity of tuber (1st season, only) and significantly decreased nitrate and nitrite content of tuber (both season), in comparison with other treatments.

It could be attributed that the compost and/or SCU fertilizers maintain the nutrients supply to the plants during growth period more than AN and its combinations. These increases in dry matter, starch and specific gravity may be attributed to the effect of organic and SCU fertilizers on increasing the availability of certain elements and their supply to plant (Table 6). These results were confirmed with those of Waddell *et al.* (1999) and Pack (2004).

Regarding, nitrate and nitrite content in tuber, the steady release of the nitrogen from compost + SCU may have resulted that nitrogen has been taken up mainly in the form of ammonium which probably caused low nitrate content of the tuber (Kolbe *et al.*, 1995). These results are similar to that reported by Govind *et al*. (1976) who showed that the effect of SCU on nitrate accumulation was minimal in cabbage and tomato.

4. NPK (tubers, 130 DAP) and NUE:

A significant differences between treatments occurred for tuber N, P and K concentration (Table 6). Among various treatments, the Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$ had the highest NPK %.

Also, data in Table 6 illustrate that the N, P and K % under compost and/or slow release treatments generally were increased significantly compared to AN (soluble form) in both seasons.

This may be attributed to the increase in growth characteristics (Table3) of the plant and linked this to nitrogen accumulation patterns (i.e., little N demand in very early, to heavy N demand during vegetative growth and bulking stages, to little N demand during maturation and senescence (Pack, 2004; Fig 1) which allow to increase P and K concentrations

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Table 6: Mineral content of potato tuber and NUE as affected by slow and soluble N-fertilizers in 2007/08 and 2008/09 seasons.

Characters / Treatments	N (%)		P (%)		K (%)		NUE Kg tuber per kg N	
	2007/2008	2008/2009	2007/2008	2008/2009	2007/2008	2008/2009	2007/2008	2008/2009
1- Ammonium nitrate (AN) (180 kg N fed^{-1}.), Control	1.43	1.48	0.26	0.28	3.66	3.52	71.11	66.89
2- Compost (18 ton fed.$^{-1}$)	1.68	1.62	0.30	0.32	3.78	3.78	74.50	71.78
3- Urea formaldehyde (UF1); 135 kg N fed.$^{-1}$	1.55	1.50	0.29	0.31	3.70	3.60	95.70	99.25
4- Urea formaldehyde (UF2); 90 kg N fed.$^{-1}$	1.51	1.51	0.21	0.24	3.56	3.52	125.56	120.00
5-Sulfur coated urea (SCU1); 135 kg N fed.$^{-1}$	1.68	1.60	0.32	0.34	3.87	3.63	104.59	97.78
6-Sulfur coated urea (SCU2); 90 kg N fed.$^{-1}$	1.74	1.64	0.22	0.26	3.60	3.50	130.13	124.00
7- AN $_{90\ kg}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	1.27	1.25	0.19	0.19	3.51	3.10	62.22	57.14
8- AN $_{90\ kg}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	1.23	1.22	0.18	0.17	3.36	3.28	69.72	60.15
9- AN $_{90\ kg}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	1.25	1.24	0.19	0.19	3.32	3.21	61.54	57.40
10- AN $_{90\ kg}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	1.21	1.22	0.18	0.17	3.26	3.26	67.78	55.70
11-Compost $_{9\ ton}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	1.51	1.50	0.24	0.26	3.64	3.51	76.82	75.68
12-Compost $_{9\ ton}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	1.43	1.38	0.20	0.21	3.54	3.50	80.86	72.00
13-Compost $_{9\ ton}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	1.78	1.70	0.34	0.36	3.90	3.88	92.01	86.60
14-Compost $_{9\ ton}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	1.50	1.56	0.20	0.21	3.61	3.60	78.28	75.85
LSD at 0.05 level	0.03	0.05	0.02	0.06	0.02	0.05	----	----

As regard to, nitrogen use efficiency (NUE), data presented in Table 6 indicate that the values of NUE ranged form 55.70 to 130.13. The greatest value of NUE was obtained by the application of SCU2 followed by UF2. Pack (2004) found that all controlled release fertilizers (CRF_s) can improve N-use efficiency. AN and its combinations with slow release fertilizers (UF or SCU) gave the lowest value, in this respect, and the obtained results may be due to that AN depressed the dry matter content (Table 5). On the other hand, the highest values of NUE were associated with dry weigh of plant (Table 3), higher values of nitrogen concentration (Table 6) and increasing non-nitrogenous compounds as indicated by Sullivan *et al*. (1974)

5. NPK (plant; 50, 70, and 90 DAP).

Figurers 1, 2 and 3 illustrate that the highest values of NK were at 70 DAP in potato plants, followed by 50 DAP and finally, 90 DAP, while P attained the highest values in early stage (50 DAP).

Also, the highest values of NPK (%) were obtained from potatoes receiving Compost $_{9\ ton\ fed^{-1}}$ + SCU3 $_{67.5\ kg\ N\ fed^{-1}}$. These results are confirmed with those of Pack (2004) who found that potato plants need little N demand in early stage, moderate to heavy N demand during vegetative growth and bulking stage, and little N demand in maturation.

Also, these results can be discussed according to compost and SCU acts as a slow release of nitrogen and other nutrients and the beneficial effect of it appears in later growth stage (Kolbe *et al.*, 1995).

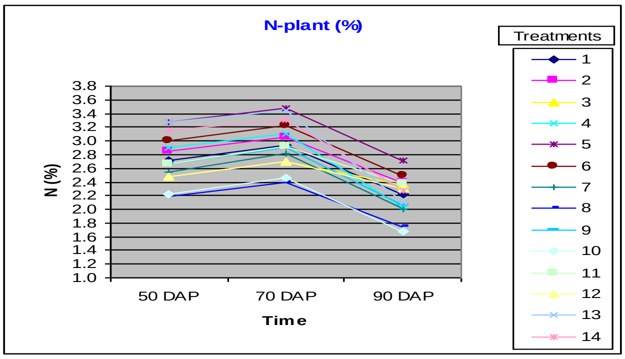

Fig 1: Nitrogen concentration in potato leaves at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

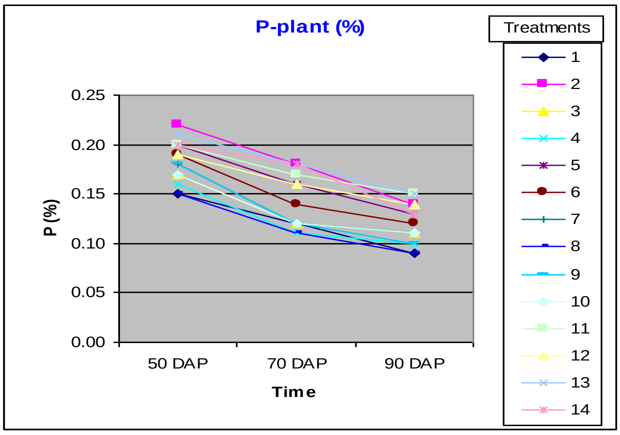

Fig 2: Phosphorus concentration in potato leaves at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

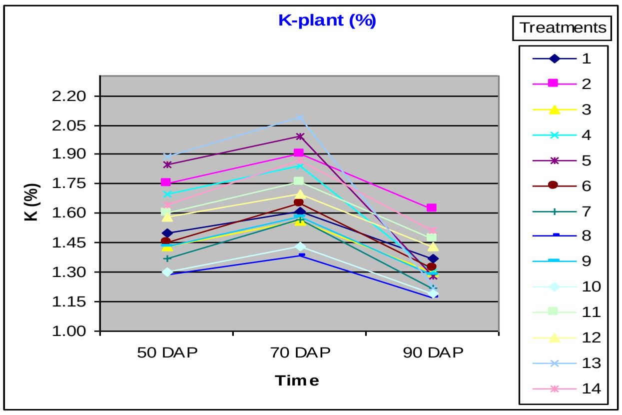

Fig 3: Potassium concentration in potato leaves at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

6. NPK (soil; 60, 90, and 120 DAP).

Concerning, NPK in soil samples at different stages, Figures 4, 5, and 6 shows that, the highest NPK concentration were attained in the treatment of Compost $_{18\ ton\ fed^{-1}}$ and all combinations of Compost plus SCU especially in later stage. Under the conditions of these treatments, the loss of NPK through leaching or volatilization is much minimized. Similar results were obtained by Matocha (1976). In this respect, Liegel and Walsh, (1976), in potato experiments, found that there was significantly more residual N in the soil for SCU treatments as compared to soluble form treatments. Also, it is noticed that the 1st stage (60 DAP) gave the highest values of NPK and decreased with growing stages. This is may be due to efficiency of recovery by potato plants and use efficiency of slow release fertilizers.

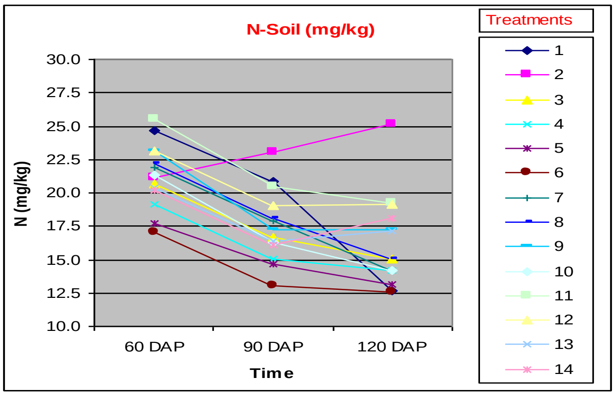

Fig 4: Nitrogen concentration in soil at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

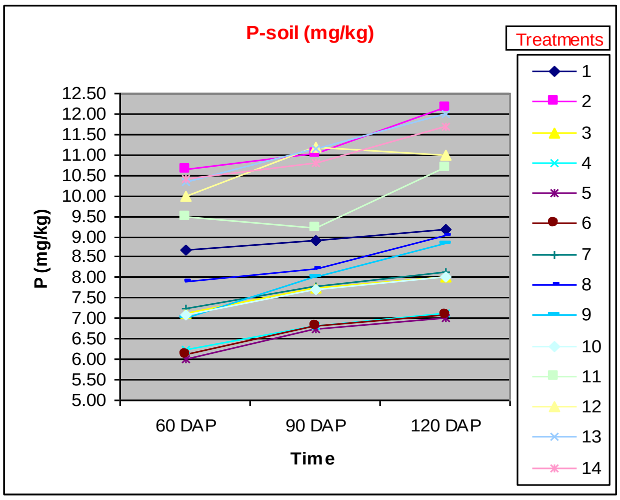

Fig 5: Phosphorus concentration in soil at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

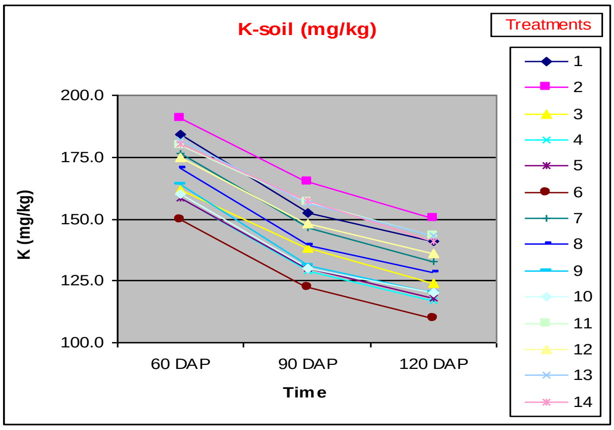

Fig 6: Potassium concentration in soil at different stages as affected by slow-N and soluble-N fertilizers (average two seasons).

7. Economic evaluation:

The data in Table 7 show that the highest net return (£.Є 10719 fed^{-1}) was obtained from potato receiving Compost $_{9\ ton\ fed}^{-1}$ + SCU3 $_{67.5\ kg\ N\ fed}^{-1}$, in comparison with other treatments. Thus, this treatment proved to be economical for potato production. As a support for the present results, Hutchinson and Simonne (2003) indicated that one possibility for lowering the cost of planting would be the use of controlled-release fertilizers.

Table 7: Estimate of additional net return of treatments.

Treatments	Tuber yield* (Ton fed^{-1})	Total costs** (£.Є fed^{-1})	Additional cost*** (£.Є fed^{-1})	Gross return (£.Є fed^{-1})	Net return (£.Є fed^{-1})	Order
1- Ammonium nitrate (AN) (180 kg N fed^{-1}.), Control	12.420	5880	880	14904	9024	5
2- Compost (18 ton fed^{-1}.)	13.165	5900	900	15798	9898	3
3- Urea formaldehyde (UF1); 135 kg N fed.$^{-1}$	13.160	6491	1491	15792	9797	4
4- Urea formaldehyde (UF2); 90 kg N fed.$^{-1}$	11.050	5995	995	13260	6769	8
5-Sulfur coated urea (SCU1); 135 kg N fed.$^{-1}$	13.660	6421	1421	16390	9969	2
6-Sulfur coated urea (SCU2); 90 kg N fed.$^{-1}$	11.436	5950	950	13723	7773	7
7- AN $_{90\ kg}$ + UF3 $_{67.5\ kg\ N\ fed.}^{-1}$	9.400	6185	1185	11280	5095	11
8- AN $_{90\ kg}$ + UF4 $_{45\ kg\ N\ fed.}^{-1}$	8.766	5937	937	10519	4582	13
9- AN $_{90\ kg}$ + SCU3 $_{67.5\ kg\ N\ fed.}^{-1}$	9.367	6150	1150	11240	5090	12
10- AN $_{90\ kg}$ + SCU4 $_{45\ kg\ N\ fed.}^{-1}$	8.335	5915	915	10002	4087	14
11-Compost $_{9\ ton}$ + UF3 $_{67.5\ kg\ N\ fed.}^{-1}$	12.010	6195	1195	14412	8217	6
12-Compost $_{9\ ton}$ + UF4 $_{45\ kg\ N\ fed.}^{-1}$	10.318	5947	947	12381	6434	10
13-Compost $_{9\ ton}$ + SCU3 $_{67.5\ kg\ N\ fed.}^{-1}$	14.066	6160	1160	16879	10719	1
14-Compost $_{9\ ton}$ + SCU4 $_{45\ kg\ N\ fed.}^{-1}$	10.404	5925	925	12484	6559	9

***Tuber yield as average of two seasons.**

****Total costs include leasehold, labor, PK fertilizers, pesticides, microelements and other cultural practices which equal nearly £.Є 5000, plus additional cost.**

*****Additional cost was calculated according to the following prices: Price of compost £.Є 50/ton; ammonium nitrate £.Є 1.60/kg; urea formaldehyde £.Є 4.00/kg; sulfur coated urea £.Є 4.00/kg, and finally, price of produce, £.Є 1200/ton**

Conclusion:

Under the conditions of this study, this investigation suggest that, application of nitrogen fertilizers in the form of compost (9 ton fed^{-1}) + sulfur coated urea (67.5 kg N fed^{-1}) in potato fields is indispensable to increase the vegetative characteristics, yield parameters and quality of tubers, in addition to lower concentrations in both nitrate and nitrite in tubers than the recommended rate of soluble form.

Moreover, the application of slow release fertilizers will save about 50% of the required amounts of N-fertilizer, and will also reduce the pollution of environment. On the other side, the use of slow release fertilizers will reduce potato production cost especially in the developing countries like Egypt, and give the highest net profit for farmers.

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تأثير الأسمدة النيتروجينية بطيئة الإمداد على الإنتاجية والجودة في البطاطس.

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يتواجد النيتروجين الصالح للنبات في صورتين هما أمونيومية NH_4^+ ونتراتية NO_3^- - ولأن النترات أنيون سالب الشحنة فهي لا تدمص علي أسطح حبيبات الطين ويحدث لها فقد مع ماء الري leaching – أما الأمونيوم فكاتيون موجب الشحنة يدمص علي أسطح حبيبات الطين، مما يقلل من فقده في التربة، الا أنه مع مضي الوقت يحدث أكسدة للأمونيوم إلي نترات بواسطة الأحياء الدقيقة (عملية: nitrification) ، ومن ثم تصبح أكثر عرضة للفقد .. وكذلك يحدث فقد للأمونيوم NH_4^+ بالتطاير في صورة NH_3^+ (عملية: volatilization)، وينشط الفقد علي هذه الصورة عندما تكون الأرض مرتفعة القلوية (pH أكبر من ٧.٥) أو تحتوي علي كمية كبيرة من كربونات الكالسيوم أو في الظروف الحارة الجافة – كذلك في الأراضي الرطبة حيث تسود الظروف اللاهوائية تنشط بعض الأحياء الدقيقة التي يمكنها أن تستخلص الأكسجين بسهولة من النترات والتي تختزل وتتحول إلي نيتروجين غازي أو أكسيد نيتروز (عملية: denitrification) ويصل الفقد في هذه الحالة إلي ٢٠%.

كذلك فأنه عند إضافة الأسمدة النيتروجينية سريعة الذوبان يأخذ النبات احتياجاته عند فترة الإضافة ولا يحصل النبات علي احتياجاته من العنصر عند مراحل نموه الفسيولوجية الأخرى والتي في حاجة ماسة عندها للنيتروجين، مع ملاحظة أن كفاءة استخدام النيتروجين بالأسمدة النيتروجينية المضافة أرضي يتراوح ما بين ٥٠ : ٦٠ % للأسمدة المعدنية سريعة الذوبان.

كل هذه العوامل تجعل من الضرورة رفع كفاءة استخدام الأسمدة النيتروجينية عن طريق استخدام الأسمدة النيتروجينية بطيئة الإمداد والتي يمكن من خلالها أعطاء النبات احتياجاته من عنصر النيتروجين طوال فترات نموه المختلفة بكفاءة عالية – حيث أن المحصول والجودة في البطاطس لا يتوقف فقط علي كمية الأزوت المضافة ولكن أيضا علي مدي صلاحية availability هذه الكمية من الأزوت خلال مراحل النمو المختلفة.

من أجل ما سبق أجريت تجربتان بحثيتان في مزرعة بحوث البساتين بالمنصورة في الموسميين الشتويين المتعاقبين ٢٠٠٨/٢٠٠٧ و ٢٠٠٩/٢٠٠٨ بهدف دراسة استجابة محصول البطاطس (صنف كارا) كصنف متأخر النضج للأسمدة بطيئة التيسر(يوريا فورمالدهيد أو اليوريا المغلفة بالكبريت أو الكمبوست) بصورة منفردة أو خليط مع الأسمدة سريعة الذوبان وتأثير ذلك علي النمو والمحصول وجودة الدرنات وكفاءة استخدام النيتروجين مع خفض تركيز النترات والنيتريت في درنات البطاطس بغرض الارتقاء بنوعية وجودة الدرنات وفي النهاية: عمل تقييم أقتصادي لتلك الأنواع المختلفة من الأسمدة.

ويمكن تلخيص أهم النتائج المتحصل عليها كما يلي:

١- أثرت الأسمدة بطيئة الإمداد سواء بصورة منفردة أو مختلطة معنويا علي جميع الصفات المدروسة.
٢- زادت معظم الصفات المدروسة باستخدام الأسمدة بطيئة الإمداد مقارنة بالصورة الذائبة.
٣- تفوقت معنويا المعاملة بأضافة الكمبوست (٩ طن/فدان) + اليوريا المغلفة بالكبريت (٦٧.٥ كجم/فدان) في الصفات الخضرية محل الدراسة (ارتفاع النبات، المساحة الورقية، الوزن الجاف) في كلا الموسمين.
٤- أحدثت المعاملة بسماد الكمبوست (٩ طن/فدان) + اليوريا المغلفة بالكبريت (٦٧.٥ كجم/فدان) زيادة معنوية في المحصول الكلي للدرنات، بالأضافة الي الدرنات الكبيرة والمتوسطة الحجم، بينما أدت نفس المعاملة الي نقص معنوي في الدرنات صغيرة الحجم في موسمي الدراسة.

٥- أدي استخدام سماد الكمبوست (٩ طن/فدان) + اليوريا المغلفة بالكبريت (٦٧.٥ كجم/فدان) إلي زيادة معنوية في نسبة المادة الجافة للدرنات في كلا الموسمين، وكذلك الكثافة النوعية ونسبة النشا (في الموسم الأول فقط).

٦- أثرت معنويا المعاملة باستخدام سماد الكمبوست (٩ طن/فدان) + اليوريا المغلفة بالكبريت (٦٧.٥ كجم/فدان) معنويا علي نسبة النيتروجين والفوسفور والبوتاسيوم في الدرنات في كلا الموسمين بالنسبة للمعاملات الأخري. بينما سجلت اعلي القيم في كفاءة استخدام النيتروجين للمعاملتين اليوريا المغلفة بالكبريت واليوريا فورمالدهيد بمعدل ٩٠ كجم للفدان لكلا المعاملتين.

٧- تم الحصول علي اعلي صافي ربح للفدان مع المعاملة التي استخدم فيها الكمبوست (٩ طن/فدان) + اليوريا المغلفة بالكبريت (٦٧.٥ كجم/فدان) مقارنة بباقي المعاملات.

تقترح هذه الدراسة أن استخدام الأسمدة بطيئة الإمداد (اليوريا المغلفة بالكبريت) بمعدل ٦٧.٥ كجم للفدان بالأضافة الي الكمبوست بمعدل ٩ طن للفدان هام لأنتاج مثالي في حقول البطاطس وأعطاء أعلي محصول وجودة للدرنات مع خفض تركيز النترات والنيتريت مع أعطاء أعلي صافي ربح للمزارعين مقارنة بالمعدل الموصي به من السماد الكيماوي.

قام بتحكيم البحث

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Table 5: Tuber qality of potato as affected by slow and soluble N-fertilizers in 2007/08 and 2008/09 seasons.

Characters / Treatments	Tuber dry matter (%)		Starch (%)		Specific gravity		Nitrate content (mg/kg F.W.)		Nitrite content (mg/kg F.W.)	
	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09
1- Ammonium nitrate (AN) (180 kg N fed.$^{-1}$), Control	20.862	20.213	14.65	14.30	1.0885	1.0798	65.30	68.23	0.62	0.58
2- Compost (18 ton fed.$^{-1}$)	21.400	21.196	15.38	15.23	1.0962	1.0842	34.71	24.86	0.24	0.28
3- Urea formaldehyde (UF1); 135 kg N fed.$^{-1}$	21.665	21.630	15.17	14.93	1.0918	1.0815	46.13	46.67	0.42	0.54
4- Urea formaldehyde (UF2); 90 kg N fed.$^{-1}$	20.793	19.981	14.13	14.63	1.0824	1.0823	51.74	49.23	0.48	0.46
5-Sulfur coated urea (SCU1); 135 kg N fed.$^{-1}$	22.520	21.180	15.73	15.10	1.0992	1.0833	50.00	48.13	0.50	0.43
6-Sulfur coated urea (SCU2); 90 kg N fed.$^{-1}$	21.800	20.840	14.41	14.82	1.0855	1.0730	49.25	40.81	0.40	0.48
7- AN $_{90\ kg}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	19.364	19.741	12.88	13.80	1.0713	1.0752	63.00	66.32	0.55	0.57
8- AN $_{90\ kg}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	19.382	19.801	13.64	12.87	1.0788	1.0740	62.18	65.20	0.53	0.53
9- AN $_{90\ kg}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	20.171	19.821	13.50	13.30	1.0800	1.0813	58.80	63.78	0.58	0.55
10- AN $_{90\ kg}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	19.442	19.630	12.94	12.65	1.0780	1.0718	54.30	62.37	0.51	0.51
11-Compost $_{9\ ton}$ + UF3 $_{67.5\ kg\ N\ fed.^{-1}}$	21.180	21.283	14.80	12.53	1.0894	1.0723	38.65	39.40	0.31	0.32
12-Compost $_{9\ ton}$ + UF4 $_{45\ kg\ N\ fed.^{-1}}$	20.940	20.418	14.02	13.80	1.0810	1.0800	35.70	38.78	0.38	0.40
13-Compost $_{9\ ton}$ + SCU3 $_{67.5\ kg\ N\ fed.^{-1}}$	21.840	21.374	15.91	15.33	1.0989	1.0935	24.80	25.13	0.27	0.30
14-Compost $_{9\ ton}$ + SCU4 $_{45\ kg\ N\ fed.^{-1}}$	20.833	19.878	13.66	13.61	1.0790	1.0732	30.18	32.22	0.30	0.38
LSD at 0.05 level	0.264	0.551	0.02	NS	0.0045	NS	2.05	5.02	0.02	0.05