Australian Journal of Basic and Applied Sciences, 2(4): 1092-1103, 2008
ISSN 1991-8178

Agroeconomic Evaluation of Conventional and Controlled Release Potassium Fertilizers for Potato Crop

[1]El-Sirafy Z.M., [2]Khadra A. Abbady, [1]A.M. El-Ghamry and [2]R.A. El-Dissoky

[1]Soil Dept, Faculty Agric., Mansoura Univ., Egypt.
[2]Soils, Water and Environment Res. Inst., Agric. Res. Center, Giza, Egypt.

Abstract: A field experiment was conducted in clay loam soil at Battra Village, Talkha District, Dakahlia Governorate, (clayey loam smectitic active, mesic xerofluvents) during the growing season of 2006/2007 to evaluate application of potassium sulfate fertilizer in conventional forms (powder and granules) and in controlled release ones (tablet and coated tablet) and economic return for each on the growth and production of potato crop (*Solanum tuberosum*, L.) cultivar Draga with levels of 0, 20, 40, 60 and 80 kg K/fed. Application of potassium in different forms and levels significantly affected average tuber weight, dry shoot yield, fresh tuber yield and agronomic use efficiency. Average tuber weight, dry shoot yield, tuber yield significantly increased with increasing potassium levels up to 60 kg K/fed. Also, the effect of interaction was significant. The highest fresh tuber yield was 16.758 t/fed with interaction between coated tablet form and 80 kg K/fed. Dry matter %, specific gravity and starch % in tubers were insignificantly affected by differed forms of potassium. The effect of applied K-levels was significant on dry matter % and protein % and insignificant on specific gravity and starch % in tubers. Also, the effect of interaction K-forms x K-levels was significant on dry matter% and protein%. Addition of K_2SO_4 fertilizer forms and levels significantly affected N, P and K % and their uptake in shoots and tubers. Also, their affection by interaction was significant. The effect of K-forms, K-levels and their interaction on EC of soil, available K, exchangeable K and water soluble K was significant. There was positively clear superiority for most studied parameters (plant and soil) of the controlled release forms to those of conventional ones. K-levels of 20 and 40 kg K/fed of tablet and coated tablet forms recorded the highest values for net return and investment factor.

Key words:

INTRODUCTION

Potassium is one of essential nutrients required for plant growth and reproduction. It is classified as a macronutrient as nitrogen and phosphorus. It plays a vital role in photosynthesis carbohydrate transport, protein formation, control of ionic balance, regulation of plant stomata and water use activation of plant enzymes and many other processes (Munson *et al.,* 1985).

For economic and environmental reasons, fertilizers technology in few past decades got a huge development by which series of products releasing their nutrients into root zone in slow action were become actual facts. One of them is controlled release formulation for soluble conventional fertilizers. In this paper, the controlled release tablet and coated tablet potassium fertilizers (K_2SO_4) were in use, their advantages are: (1) creating a sufficient continuous supply of nutrients in the soil without the risk of undesired increase in the soil solution concentration or losses due to leaching of nutrient, (2) allowing an accurate dosage of nutrients and reduces the unproductive fertilization beyond the reach of the root system, (3) saving in time and labor, and (4) securing a higher degree of nutrient utilization (Rui Liang, *et al.,* 2007).

The solanaceous vegetable crops (potato, tomato, eggplant, chilli and bell peppers) generally take up large amounts of nutrients. The amounts depend on the quantity of fruit and dry matter they produce, which in turn is influenced by a number of genetic and environmental variables. (Hewedy, 2000). Potato (*Solanum tuberasum L.*) as a number of the family solanaceae is one of the most important food crops all over the world including Egypt. It ranks the first export and the second vegetable crop in energy. Potato require high amounts of potassium fertilizer for optimum growth, production and tuber quality (Al-Moshileh and Errebi, 2004), but its

Corresponding Author: El-Sirafy Z.M., Soil Dept, Faculty Agric., Mansoura Univ., Egypt.

recovery of K is often quite low. The low efficiency is partly due to a shallow root system that is usually confined to the top 60 cm of soil, with 90 % of the root length in the surface 25 cm of the soil profile (Tanner *et al.,* 1982).

The main objective of the present study is to evaluate the effect of different forms of potassium sulphate fertilizer (conventional and controlled release) with different levels on potato yield, economic return and some soil properties.

MATERIALS AND METHODS

A field experiment was conducted in clay loam soil at Battra Village, Talkha District, Dakahlia Governorate, (clayey loam smectitic active, mesic xerofluvents) during growing season of 2006/2007 on potato (*Solanum tuberosum, L.*) cultivar Draga. The soil properties presented in Table (1) analysis were carried out according to (Jackson, 1967).

The experimental design was a split plot with three replicates. The Four forms of potassium sulfate fertilizer were the main plots and the five levels of K were the sub plots. Treatments were applied as follow:

- The four forms of potassium sulfate fertilizer (contain 41.5 % K) were applied as follows: (1) Powder form exported from Germaine; (2) granules form exported from United Europe; (3) tablet form prepared by Egyptian Fertilizer Development Center, Mansoura, Egypt from powder K_2SO_4 fertilizer form and (4) coated tablet form prepared by the same center, where tablet form (mentioned in 3) was coated with ureaformaldehyde polymer.
- The five levels of potassium fertilizers were applied as follows: K0 (control); K1 (20 kg K/fed); K2 (40 kg K/fed); K3 (60 kg K/fed) and K4 (80 kg K/fed).

Farmyard manure (FYM) was applied at rate 30 m^3/fed for all experiment soil before the last tillage then soil was irrigated and left for 17 days before planting. Calcium super-phosphate (6.76 % P) was applied before planting irrigation at the rate of recommended dose of 33 kg P/fed for all treatments. Ammonium nitrate fertilizer (33.5 % N) was applied at the rate of recommended dose (180 kg N/fed) in 2 doses, the 1st dose was added with the 1st irrigation and the 2nd dose with the 2nd after planting. Potassium fertilizers treatments (41.5 % K) were applied in one dose with the 2nd irrigation after planting. Potato plants were irrigated 7 irrigations after planting. Potato tuber pieces were planted in December 7th 2006 and harvested in April 7th 2007**.** Potato crop was harvested after 120 days from planting date and the following parameters were recorded**:** (1) Yield and Yield Components; average tuber weight (g/tuber), dry shoots yield (t/fed) and fresh tubers yield (t/fed). (2) Tuber quality parameters: dry matter %, specific gravity, starch % and protein (3) Chemical constituents; N, P and K % were determined in shoot and tuber dry matter according to Jackson, 1967. (4) The uptake of nutrients (N, P and K) was calculated by multiplying element concentration by dry weight of shoots and tubers yield. (5) Soil properties after harvest: EC was determined by measuring the electrical conductivity in the extract of soil 1:5 in dSm^{-1} ; (2) available potassium was determined by extracting soil with 1.0 N ammonium acetate at pH 7.0 ; (3) water soluble potassium were determined in the extract of soil 1:5 by using flame photometer and (4) exchangeable K were calculated by the difference between available potassium and water soluble potassium, as described by (Hesse, 1971).

The statistical analysis of the obtained data was done according to the methods described by (Gomez and Gomez, 1984) using LSD to compare the means of treatments values.

RESULTS AND DISCUSSION

This study are devoted to discuss the effect of conventional and controlled release potassium forms as potassium sulphate fertilizer on yield and its components, yield quality, concentration and uptake of N,P and K. Then estimation of their economic return and their effect on soil properties.

Yield and its Components:

The obtained data in Table (2) illustrate that average tuber weight was significantly affected by application of different forms. The superiority of average tuber weight was 159 g/tuber with tablet form. It is also obvious that the applied levels significantly increased average tuber weight. Their weights increased from 119 g/tuber (control) to 166 g/tuber with K3. Results in same table indicate that the effect of interaction on average tuber weight was significant. Their highest value was 239 g/tuber with interaction between granules form

Table 1: Some soil properties of the studied soil

Mechanical analysis				Physico properties					
Sand %	Silt %	Clay %	texture	SP %	BD gcm^{-3}	OM %	pH	EC dSm^{-1}	$CaCO_3$ %
41.55	30.20	28.25	Clay loam	60.00	1.30	1.78	7.84	1.85	3.10

Soluble cations (meq/L soil)				Soluble anions (meq/L soil)				Available nutrients (ppm)		
Ca^{++}	Mg^{++}	K^{+}	Na^{+}	CO_3^{-}	HC_3^{--}	Cl^{-}	SO_4^{--}	N	P	K
5.89	6.70	1.27	4.50	0.00	4.48	8.10	5.78	60.00	35.00	295

Table 2: Effect of K_2SO_4 forms, levels and their interaction on potato yield and tuber quality:

Treatments		average tuber weight (g)	Dry shoot Yield (t/fed)	Fresh Tuber yield (t/fed)	AUE [1] (kg tuber/ kg K)	Tuber quality parameters			
						Dry matter (%)	Specific Gravity[2]	Protein [3](%)	Starch [4](%)
K-forms effect									
Powder		131	0.532	11.144	56.850	21.21	1.087	12.08	15.14
Granules		159	0.619	12.523	94.950	21.16	1.085	11.60	14.71
Tablet		134	0.597	13.720	133.444	20.70	1.083	12.87	14.35
coated tablet		146	0.627	13.702	142.941	21.73	1.085	11.40	14.77
LSD at 5%		16	0.010	1.717	---------	ns	ns	0.197	ns
K-levels effect									
K0		119	0.511	8.865	0.000	23.48	1.083	10.15	14.43
K1		122	0.541	11.563	134.888	20.73	1.087	13.03	15.25
K2		150	0.635	13.466	115.031	20.99	1.086	12.93	15.05
K3		166	0.637	14.942	101.288	20.50	1.084	11.90	14.57
K4		156	0.643	15.023	76.978	20.31	1.083	11.92	14.42
LSD at 5%		19	0.024	0.726	---------	0.771	ns	0.199	ns
Interaction effect									
Powder	K0	101	0.444	8.865	0.000	23.58	1.088	10.46	15.40
	K1	112	0.503	9.810	47.250	20.26	1.088	12.29	15.46
	K2	131	0.515	11.565	67.500	21.21	1.090	12.02	15.79
	K3	185	0.554	12.654	63.150	20.35	1.082	13.13	14.27
	K4	126	0.578	12.825	49.500	20.67	1.085	12.48	14.80
Granules	K0	136	0.511	8.865	0.000	23.38	1.081	9.83	14.07
	K1	106	0.576	10.890	101.250	20.64	1.088	11.54	15.46
	K2	239	0.729	12.915	101.250	21.77	1.091	13.25	16.06
	K3	154	0.623	14.778	98.550	19.90	1.079	11.58	13.60
	K4	158	0.653	15.165	78.750	20.12	1.083	11.77	14.33
Tablet	K0	101	0.444	8.865	0.000	23.58	1.081	10.46	14.07
	K1	134	0.500	11.763	144.900	20.70	1.083	14.98	14.47
	K2	123	0.666	16.020	178.875	20.28	1.080	14.60	13.80
	K3	163	0.653	16.605	129.000	19.91	1.085	12.29	14.87
	K4	151	0.652	15.345	81.000	19.03	1.084	12.02	14.53
Coated	K0	138	0.511	8.865	0.000	23.38	1.082	9.85	14.20
tablet	K1	135	0.583	13.788	246.150	21.33	1.089	13.31	15.60
	K2	107	0.632	13.365	112.500	20.69	1.084	11.85	14.53
	K3	162	0.719	15.732	114.450	21.84	1.089	10.60	15.53
	K4	189	0.689	16.758	98.663	21.40	1.081	11.40	14.00
LSD at 5%		29	0.037	1.140	--------	1.210	ns	0.313	ns

[1] Agronomic use efficiency (AUE) $= \frac{\text{Yield of treatment(kg/fed)} - \text{Yiled of control (kg/fed)}}{\text{Quantity of K applied(kgK/fed)}}$

[2] $\text{Specific gravity (S.g.)} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$ (Smith, 1975).

[3] Protien (%) = Nitrogen (%) x 6.25 (Ranganna, 1977)

[4] $\text{Starch (\%)} = 17.546 + 199.07 \times (\text{S.g.} - 1.0988)$ (Burton, 1948)

x K2 (40 kg K/fed). This effect may be due to its role in plant growth which enhanced carbohydrate movement from the shoot to storage organs (tubers), (Hewedy, 2000). In this concern, (Anwar, 1998) reported that the number of tubers/plant significantly increased with increasing K fertilizer level.

As shown in Table (2) data appear that dry shoot yield was significantly affected by the different forms application. Their highest value was 0.627 t/fed with coated tablet form. Also, data reveal that the applied levels significantly increased dry shoot yield, however the differences between K3 and K4 were not significant. As will as the data show that the effect of interaction on dry shoot yield was significant.

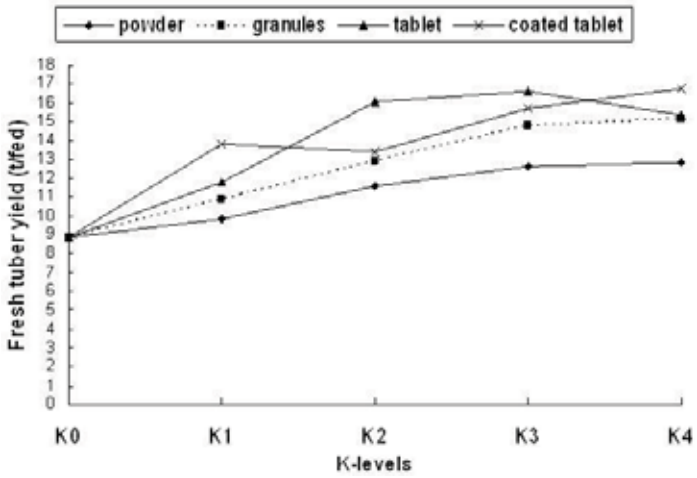

Fig. 1: Effect of forms and levels on fresh tuber yield.

Their maximum value was 0.780 t/fed with interaction of granular form x K2. This effect could be attributed to K function in plants which include cation transport across membranes water economy, energy metabolism and enzyme activation on exchange rate and nitrogen activity as well as enhanced carbohydrate movement from the shoot to storage organs, (Hewedy, 2000).

Data presented in Table (2) and Fig. (1) illustrate that effect of the applied forms on fresh tuber yield was significant. Their respective value was 13.720 t/fed for tablet. It is noticed that the effect of different forms on fresh tuber yield was as follow: tablet > coated tablet > granules > powder. It seems that the controlling release process for potassium encouraged the growth of tubers in turn which reflected on yield. Also, data indicate that the added K-levels significantly increased fresh tuber yield. It increased from 8.865 t/fed (control) to 15.023 t/fed with K4 level as will as the effect of interaction KF x KL on such yield was significant. Their maximum value (16.758 t/fed) was obtained from interaction of coated tablet form x K4.

To illustrate the importance of controlled release formulation the agronomic use efficiency (AUE) was calculated. AUE was increased by the application of the different forms. The highest value of AUE was 142.941 kg tubers/kg K as coated tablet form (Table 2). It is obvious that effect of the forms on fresh tuber yield was as follow: coated tablet > tablet > granules > powder. Here, it would be pointed out that simple modification for conventional potassium sulphate fertilizer truly performed huge difference where the yield of coated tablet form was two fold of that of powder one. Also, the added K-levels affected AUE. It decreased from 134.888 kg tuber/kg K with K1 to 76.978 kg tuber/kg K with K4. It could be concluded that AUE values decreased with increasing K-levels as will as the effect of interaction K-form x K-levels on AUE was significant. The highest value was 246.150 kg tuber/ kg K with interaction of coated tablet form x K1 (20 kg K/fed). i.e. use of controlled release form led to reducing potassium fertilization.

Tuber Quality:

Data presented in table (2) appear that dry matter % (DM) in tubers was insignificantly affected by application of the different forms. Generally, it decreased with addition of different forms as compared with control. However, it was significantly affected by addition of different K-levels. They were 23.48, 20.73, 20.99, 20.50 and 20.31 % with the applied K-levels 0, 20, 40, 60 and 80 kg K/fed, respectively. Also, it was significantly affected by interaction K-form x K-level which led to decreased it comparing with control. This effect may be due to dilution effect that associated with K-level increased. Similar observation are obtained by (Allison, *et al.,* 2001) and (Ali, 2006) who observed that K addition significantly decreased DM% of tuber yield.

The results presented in Table (2) appear that the different forms, different K-levels and interaction KF x KL insignificantly affected specific gravity. In this concern, (Davenport and Bentley, 2001) and (Abdel-Gadir, *et al.,* 2003) showed that specific gravity was not statistically affected by different levels of K. Conversely, (Ali, 2006) found that specific gravity of tubers yield decreased with increasing K addition.

As shown in Table (2), the effect of different forms on protein % was significant. Its highest value was 12.87 % with tablet form. Also, application of the different.

K-levels increased significantly protein %. The highest value was 13.03 % with K1 (20 kg K/fed). The effect of interaction KF x KL on protein % was significant.

Its highest value was 14.98 % with interaction tablet form x K1. Such effect increased protein %, however this increasing was not regular. This significant effect on protein % could be related to the vital role of K in plant that associated directly and indirectly with protein synthesis. Such effect of interaction is in agreement with results that obtained by (El-Sawy, *et al.,* 2000).

Data in Table (2) illustrate that starch % in potato tubers was insignificantly affected by application of different forms, added K-levels and also interaction K-form x K-level. The general trend recorded decrease for starch with increasing K-levels.

The obtained results are in agreement with (El-Sawy, et al., 2000) and (Ali, 2006) who observed that starch % decreased significantly with increasing K addition.

Chemical Constituents in Shoots and Tubers:

N, P and K % in Shoots:

Data presented in Table (3) reveal that application of the different forms significantly affected N %. Their values were 3.96, 3.66, 3.61 and 3.68 with addition powder, granules, tablet and coated tablet forms, respectively and that the added K-levels also significantly increased N %. The highest value was 3.91 % with K2-level. Also, data show that the effect of interaction on N % was significant. It is obvious that the interaction between K-form tablet or coated tablet and K-levels recorded the highest values of N %. The highest N % was 4.44 % with interaction of powder form x K4 (80 kg K/fed).

As shown in Table (3), the effect of applied forms and K-levels on P % was significant. The highest value of P % was 0.238 % for powder form and 0.230% for K1. Also, effect of interaction K-form x K-level on P % was significant. The highest P % was 0.261 % with interaction between powder form x K4.

The obtained data in table (4) reveal that K % increased significantly with addition of different forms as compared with control. The superiority of K % was 3.67% with powder form. It is clearly that effect of forms on K % was as follow:

Powder > granules > coated tablet > tablet as will as applied K-levels significantly increased K %. It increased from 2.75 % to 4.21 % with K0 and K4, respectively. Also, data in the same table appear that the effect of interaction on K % was significant. The highest value was 4.29 at the interaction between granules form x K4 (80 kg K/fed).

N, P and K % in Tubers:

The obtained results in table (3) show that application of different forms significantly affected N %. The highest value of N % was 2.06 % with tablet form. Also, data indicate that K- levels application significantly increased N % where it increased from1.62 % (control) to 2.09 % with K1. It is noticed that N % only increased at K1 level then the values declined with continuous increasing levels. Also,
the effect of interaction K-form x K-level on N % was significant. The highest value of N % were 2.40 and 2.34 % with interaction between tablet form, K1 and K2 levels, respectively.

Data illustrate that application of different forms significantly affected P %. The superior value of P % was 0.200 % with tablet form. It could be concluded that the effect of forms on P % was as follow: tablet > powder = granules > coated tablet.

Also, data indicate that P % significantly increased with added K-levels. The values of P % increased from 0.177 % to 0.187, 0.199, 0.196 and 0.199 % with K0, K1, K2, K3 and K4 levels, respectively as will as the effect of interaction on P % in tuber was significant. The highest value of P % was 0.217 % with interaction between tablet form x K2 (40 kg K/fed).

The obtained results in Table (3) illustrate that the addition of different forms insignificantly affected K %. It could be concluded that the effect of K-forms on K % was as follow: coated tablet > granules > powder > tablet. Data in the same table indicate that K % significantly affected by addition of different levels. K fertilization increased K % from 2.12 % with K0 to 2.62 % with K4.. Also, data indicate that the effect of interaction on K % was significant. The highest value was 2.72 % with interaction of granules form x K4.

N, P and K Uptake by Shoots and Tubers Yield:

N, P and K Uptake in Shoots:

Data presented in Table (4) reveal that N-uptake was significantly affected by application of different forms. Its superior value was 23.308 kg N/fed with coated tablet form. The effect of K-forms on N- uptake can be arranged as follow: coated tablet > granules > tablet > powder. Also, data appear that applied levels significantly increased N-uptake. Its values increased from 15.895 kg N/fed with K0 to 24.896 kg N/fed with

Table 3: Effect of K_2SO_4 forms, levels and their interaction on N, P and K % in potato:

Treatments		N %		P %		K %	
		in shoot	in tuber	In shoot	in tuber	In shoot	in tuber
K_2SO_4 forms effect							
Powder		3.96	1.93	0.238	0.192	3.67	2.36
Granules		3.66	1.86	0.217	0.192	3.59	2.38
Tablet		3.61	2.06	0.204	0.200	3.41	2.35
Coated tablet		3.68	1.82	0.219	0.182	3.53	2.39
LSD at 5%		0.05	0.03	0.005	0.003	0.103	ns
K levels effect							
K0		3.33	1.62	0.202	0.177	2.75	2.12
K1		3.64	2.09	0.230	0.187	2.98	2.24
K2		3.91	2.07	0.222	0.199	3.72	2.40
K3		3.91	1.90	0.219	0.196	4.09	2.47
K4		3.85	1.91	0.225	0.199	4.21	2.62
LSD at 5%		0.04	0.03	0.005	0.003	0.059	0.081
Interaction effect							
Powder	K0	3.41	1.67	0.195	0.188	2.75	2.12
	K1	3.67	1.97	0.249	0.194	3.57	2.26
	K2	4.15	1.92	0.237	0.192	3.93	2.39
	K3	4.23	2.10	0.246	0.193	4.02	2.45
	K4	4.32	2.00	0.261	0.191	4.09	2.57
Granules	K0	3.24	1.57	0.208	0.166	2.75	2.12
	K1	3.44	1.85	0.218	0.187	2.80	2.27
	K2	4.02	2.12	0.22	0.209	3.91	2.34
	K3	3.82	1.85	0.209	0.192	4.20	2.46
	K4	3.78	1.88	0.229	0.208	4.29	2.72
Tablet	K0	3.41	1.67	0.196	0.188	2.75	2.12
	K1	3.79	2.40	0.225	0.192	2.77	2.31
	K2	3.72	2.34	0.209	0.217	3.19	2.34
	K3	3.60	1.97	0.193	0.211	4.08	2.46
	K4	3.53	1.92	0.196	0.194	4.27	2.54
Coat	K0	3.24	1.58	0.209	0.167	2.75	2.12
tablet	K1	3.66	2.13	0.226	0.175	2.78	2.11
	K2	3.76	1.90	0.22	0.177	3.85	2.51
	K3	3.98	1.70	0.226	0.189	4.07	2.52
	K4	3.78	1.82	0.214	0.202	4.18	2.67
LSD at 5%		0.07	0.05	0.007	0.004	0.093	0.127

Table 4: Effect of K_2SO_4 forms, levels and their interaction on N, P and K uptake by potato:

Treatments		N-uptake (kg/fed)		P-uptake (kg/fed)		K-uptake (kg/fed)		KUE
		shoot	tuber	shoot	tuber	shoot	tuber	
K_2SO_4 forms effect								
Powder		20.720	45.518	1.247	4.546	19.681	56.119	41.29
Granules		22.879	49.281	1.351	5.158	22.629	63.466	67.17
Tablet		21.129	57.894	1.191	5.686	20.780	66.660	74.28
Coated tablet		23.308	54.695	1.380	5.504	22.542	71.515	91.30
LSD at 5%		0.698	8.600	0.051	0.834	0.710	8.140	----------
K levels effect								
K0		15.895	34.627	0.971	3.806	14.124	44.255	0
K1		19.702	50.240	1.243	4.500	16.075	53.791	57.43
K2		24.837	58.600	1.409	5.657	23.623	67.583	82.07
K3		24.896	57.837	1.395	6.045	26.107	76.076	73.01
K4		24.715	57.933	1.445	6.109	27.111	80.496	61.53
LSD at 5%		1.019	3.827	0.063	0.379	1.055	4.807	----------
Interaction effect								
Powder	K0	15.191	34.787	0.870	3.936	14.124	44.255	0.00
	K1	18.508	38.957	1.259	3.897	17.986	45.367	24.87
	K2	21.377	47.008	1.225	4.763	20.255	59.103	52.45
	K3	23.495	54.041	1.368	5.018	22.341	63.378	45.57
	K4	25.030	52.799	1.515	5.113	23.700	68.492	42.27
Granules	K0	16.599	33.751	1.068	3.618	14.124	44.255	0.00
	K1	19.907	41.448	1.265	4.219	16.202	51.023	44.23
	K2	29.339	59.497	1.614	5.913	28.586	66.116	90.81
	K3	23.826	54.187	1.309	5.662	26.212	72.694	67.54
	K4	24.724	57.522	1.501	6.377	28.023	83.242	66.11

Table 4: Continued

Tablet	K0	15.191	34.787	0.876	3.936	14.124	44.255	0.00
	K1	19.002	58.227	1.125	4.717	13.928	56.821	61.85
	K2	24.839	75.546	1.401	7.049	21.292	75.720	96.58
	K3	23.586	64.857	1.273	7.021	26.654	81.714	83.31
	K4	23.028	56.054	1.282	5.706	27.900	74.792	55.39
Coat	K0	16.599	35.181	1.072	3.735	14.124	44.255	0.00
tablet	K1	21.390	62.326	1.323	5.167	16.184	61.952	98.78
	K2	23.794	52.348	1.395	4.902	24.358	69.394	88.43
	K3	28.677	58.265	1.630	6.480	29.222	86.520	95.60
	K4	26.078	65.356	1.482	7.239	28.822	95.457	82.37
LSD at 5%		1.600	6.009	0.099	0.594	1.655	7.547	---------

$$\text{Potassium use efficiency (KUE)} = \frac{\text{K-uptake of treatment (kg/fed)} - \text{K-uptake of control (kg/fed)}}{\text{Qunatity of K applied(kg K/fed)}}$$

(Jagadeeswaran, *et. al.,* 2005)

K4 level as well as data show that the effect of interaction was significant. The maximum N-uptake was 29.339 kg N/fed as a result of interaction between granular form x K2. This effect on are in agreement with that obtained by (Ranganathan and Selvaseelan, 1997)

The obtained results in Table (4) appear that the different forms addition significantly increased P-uptake. It could be concluded that the highest value (1.380 kg P/fed) was recorded with coated tablet form. Also, data reveal that P-uptake significantly increased with the added levels. Its values increased from 0.971 with K0 to 1.445 kg P/fed with K4 as will as P-uptake significantly increased influenced by interaction where the highest P-uptake was 1.630 kg P/fed with interaction between coated tablet form x K3 (60 kg K/fed).

As shown in Table (4), K-forms significantly affected K-uptake. It is obvious that their effect on K-uptake was as follow: granules > coated tablet > tablet > powder

In addition to, data reveal that K-uptake significantly increased with different levels application whereas the values increased from 14.124 kg K/fed with K0 to 27.111 kg K/fed with K4. Also, the obtained results reveal that K-uptake increased significantly as affected by interaction. The highest value was 29.222 kg K/fed for interaction between coated tablet form x K3 (60 kg K/fed).

N, P and K Uptake in Tubers:

Data presented in table (4) show that the effect of the applied forms on N- uptake was significant. Its highest value was 57.894 kg N/fed with tablet form. Similarly, N-uptake was significantly increased with applied K-levels. It increased from 34.627 kg N/fed with K0 to 58.600 kg N/fed with K2 level. Also, the effect of interaction on N-uptake was significant. Such effect increased N-uptake as compared with control. This effect of K may be attributed to the vital role of potassium in physiological processes inside the plant, enzyme activities, water absorption and transpiration that reflected on N-uptake. These results are in accordance with those reported by (El-Kabbany, 1999)

Data presented in Table (4) reveal that the effect of the applied forms on P-uptake was significant. However, the superiority of P uptake was for tablet form. (5.686 kg P/fed). Also, the applied levels significantly increased P-uptake as compared with control. These values increased from 3.806 with K0 to 6.109 kg P/fed with K4.

As will as the effect of interaction K-form x K-levels on P-uptake was significant. The maximum P-uptake was 7.239 kg P/fed with interaction coated tablet form x 80 kg K/fed. These results may be due to acidic side effect of K_2SO_4 fertilizer on soil that increases the availability of P and consequently its uptake. Similar results are obtained by (El-Kabbany, 1999) and (Reis-Junior and Monnerat, 2001).

Data in Table (4) show that the effect of applied forms on K-uptake was significant. The highest mean of K-uptake was 71.515 kg K/fed with coated tablet form. The effect of K-forms on tuber K-uptake was as follow: coated tablet > tablet > granules > powder. Data in the same table illustrate that the values of K-uptake were significantly increased with K-levels addition.

The values of K-uptake increased from 44.255 kg K/fed with K0 to 80.496 kg K/fed with K4. Also, data reveal that the effect of interaction on K-uptake was significant. The highest value was 95.457 kg K/fed for interaction between coated tablet form x K4. This positive effect may be related to the main important role of K in plant. In this concern, Tawfik (2001) indicated that application of K-rates (60 and 120 kg K_2O/fed) increased leaf K- concentration. Also, Al-Moshileh and Errebi (2004) point out that tuber K-content increased significantly with K-rates (0, 150, 300, 450 and 600 kg K_2SO_4/ha).

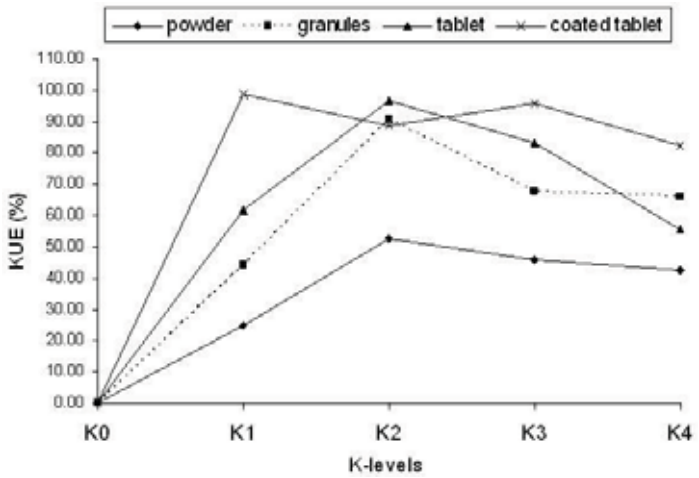

Fig. 2: Effect of forms and levels on Potassium use efficiency (KUE).

As for Potassium use efficiency (KUE), Data presented in Table (4) and Fig. (2) illustrate that it was varied with application of the different forms which their effect can be ranked as follow: coated tablet > tablet > granules > powder. Its highest value was 91.30 % with coated tablet. Also, KUE values were affected by the added K-levels. The highest value was 82.07 % with K2 as will as KUE was affected by interaction between forms and levels. The highest value was 98.78 with interaction of coated tablet form x K1 (20 kg K/fed).

Economic Evaluation:

Powder, granular, tablet and coated tablet forms of potassium sulphate used in this work implemented the concept of the controlled release formulation for conventional fertilizers. In spit of their promised agronomic results, their costs were considered somewhat higher. However, the experiments carried out on the slow release nitrogen fertilizer proved that they could give rational profitability (Abbady, *et al,* 2008).

As for the applied controlled release potassium fertilizers, the calculation of gain or loss would decisively determined their priority. In this study, it would be pointed out that the costs of other known agricultural processes were not included, therefore, the inputs were as follow:

- L.E. 3500 for powder potassium sulphate.
- L.E. 3500 for granular potassium sulphate
- L.E. 4000 for tablet potassium sulphate
- L.E. 4200 for coated tablet potassium sulphate
- L.E. 25 for labor/day
- The outputs were: L.E. 1300, the price for ton of potato.

Table (5) show calculation of costs, gross return, net return (NR) and investment factor (IF) for potato yield. Obviously, the treatments of forms positively affected NR and IF. Generally, all treatments fulfilled reasonable profitability where their IF values were more than 3. NR and IF values of tablet and coated tablet forms were superior to those of powder and granules forms. It is clear that the effect of forms on NR was as follow: tablet > coated tablet > granules > powder.

As for the effect of different levels of potassium on NR and IF, the Fig. (3) show that the values of NR increased with increasing the applied levels, on contrary, the IF increased up to third level (K3), then declined at fourth level (K4). It could be selected the K3, K3, K2 and K1 levels of powder, granules, tablet and coated tablet forms in the same order, to recommend with, because these levels fulfilled the highest IF. Also, it would be indicated that with application of the controlled release forms, the profitable applied levels got reduced. Although, the NR values were increased with increasing the applied levels, their IF values were decreased. This means that the highest yield does not necessarily mean the highest profitability. Fig. (4) illustrated the impact of the effect of different forms on the NR and IF. It is noticed that tablet and coated tablet forms gave approximated values for each of NR and IF. Therefore, it could be recommended with tablet form application because it is cheaper.

Table 5: Economic evaluation of different treatments for potato.

Treatments		yield increased (t/fed)	K_2SO_4 applied (kg/fed)	Cost of fertilizer (L.E.)	Cost of worker (L.E.)	total cost (L.E.)	gross return (L.E.)	Net Return (L.E.) (NR)	investment factor (IF)
Powder	K0	0.000	0.00	0.00	0	0.00	0.00	0.00	0.00
	K1	0.945	50	175	50	225	1229	1004	5.46
	K2	2.700	100	350	50	400	3510	3110	8.78
	K3	3.789	150	525	50	575	4926	4351	8.57
	K4	3.960	200	700	50	750	5148	4398	6.86
Mean of powder form								3216	7.42
Granules	K0	0.000	0.00	0.00	0	0.00	0.00	0.00	0.00
	K1	2.025	50	175	50	225	2633	2408	11.70
	K2	4.050	100	350	50	400	5265	4865	13.16
	K3	5.913	150	525	50	575	7687	7112	13.37
	K4	6.300	200	700	50	750	8190	7440	10.92
Mean of granular form								5456	12.29
Tablet	K0	0.000	0	0.00	0	0.00	0.00	0.00	0.00
	K1	2.898	50	200	50	250	3767	3517	15.07
	K2	7.155	100	400	50	450	9302	8852	20.67
	K3	7.740	150	600	50	650	10062	9412	15.48
	K4	6.480	200	800	50	850	8424	7574	9.91
Mean of tablet form								7339	15.28
Coat	K0	0.000	0.00	0.00	0	0.00	0.00	0.00	0.00
tablet	K1	4.923	50	210	50	260	6400	6140	24.62
	K2	4.500	100	420	50	470	5850	5380	12.45
	K3	6.867	150	630	50	680	8927	8247	13.13
	K4	7.893	200	840	50	890	10261	9371	11.53
Mean of coated tablet form								7284	15.43

yield increase = Yield of the treatment-Yield of control
Gross return=yield increase x price of potato
Net return = gross return - total cost
Investment factor= gross return (L.E.)/total cost

Table 6: Effect of K_2SO_4 forms, levels and their interaction on some chemical properties of the soil after harvesting:

Treatments		EC (dSm^{-1})	Available K (ppm)	Exchangeable K (ppm)	Water soluble K (mg/l)
K_2SO_4 forms effect					
Powder		1.515	536	403	26.65
Granules		1.895	697	542	30.92
Tablet		1.724	485	363	24.38
Coated tablet		1.560	700	565	26.94
LSD at 5%		0.128	8.54	15.72	2.48
K levels effect					
K0		1.193	397	327	14.04
K1		1.623	628	506	24.43
K2		1.882	672	524	29.59
K3		1.830	651	489	32.25
K4		1.839	675	496	35.81
LSD at 5%		0.182	3.81	13.81	2.68
Interaction effect					
Powder	K0	1.229	340	278	12.44
	K1	1.531	432	300	26.30
	K2	1.563	606	468	27.72
	K3	1.719	670	528	28.43
	K4	1.531	633	441	38.38
Granules	K0	1.156	446	368	15.64
	K1	1.99	811	670	28.08
	K2	2.083	736	576	31.99
	K3	2.038	729	537	38.38
	K4	2.208	763	561	40.52
Tablet	K0	1.229	354	292	12.44
	K1	1.734	523	415	21.68
	K2	1.821	596	460	27.37
	K3	1.656	453	309	28.79
	K4	2.177	496	338	31.63
Coated	K0	1.156	446	368	15.64
tablet	K1	1.235	747	639	21.68
	K2	2.063	749	592	31.28
	K3	1.906	750	583	33.41
	K4	1.438	809	645	32.70
LSD at 5%		0.286	5.99	21.68	4.21

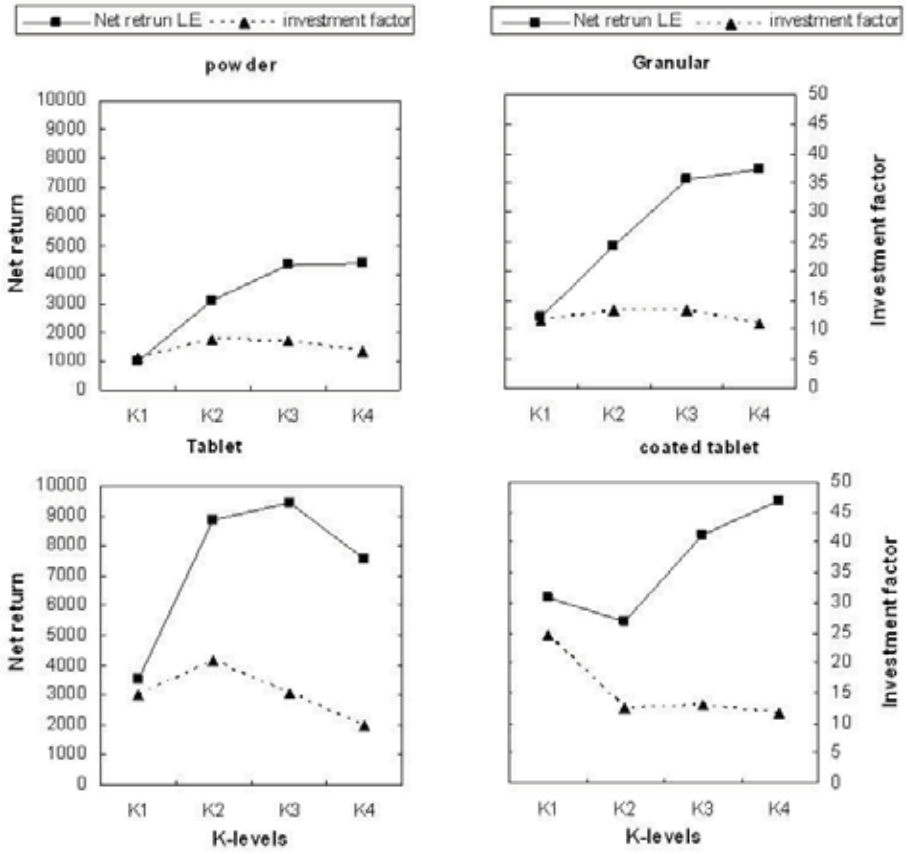

Fig. 3: Effect of K-levels on net return (NR) and investment factor (IF).

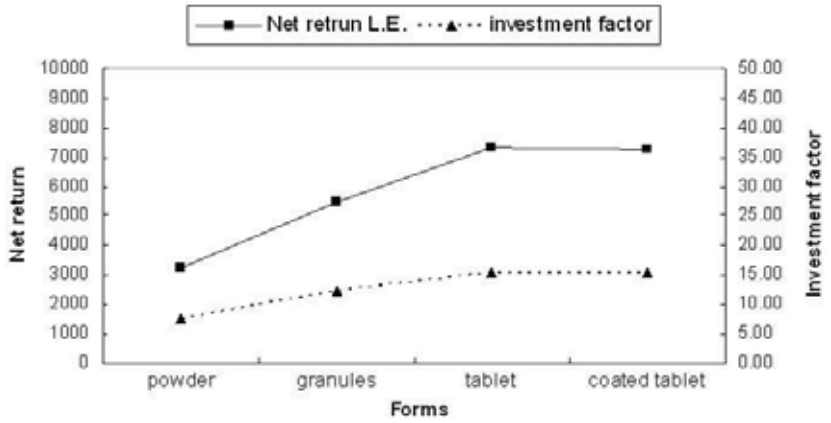

Fig. 4: Effect of K-forms on net return (NR) and investment factor (IF).

Some Chemical Properties of the Soil after Harvesting:

EC (dSm^{-1}):

The obtained data in Table (6) indicate that application K_2SO_4 fertilizer in different forms significantly affected EC of soil. It is observed the EC values were decreased with increasing control in released-potassium in turn which reflect on existed quantity of salts. This effect can rank as follow: granules > tablet > coated tablet > powder. EC value of powder form was low; this may be attributed to its speed loss.

Also, data show that the added levels significantly increased EC of soil. The values of EC increased from 1.193 dSm^{-1} with K0 to 1.623, 1.882, 1.830 and 1.839 dSm^{-1} with K1, K2, K3 and K4 levels, respectively.

Also, EC values were significantly increased with interaction between K-forms x K-levels whereas the highest value of EC was 2.208 dSm^{-1} recorded with interaction granules form x K4, and the lower one was recorded with interaction of coated tablet form x K1.

This effect of K-fertilization on EC of soil may be attributed to high solubility of K_2SO_4 fertilizer that affected concentration of soluble cations and anions and finally EC. Similar results are obtained by Gomaa (2007) who found that at alluvial soils, K_2SO_4 induced significant increases in EC values; however the controlled release action to some extent improved this effect.

Available -K (ppm):

Data in Table (6) appear that applied forms significantly affected the concentration of available K in soil. The values of available K were 536, 697, 485 and 700 ppm with powder, granules, tablet and coated tablet forms, respectively.

Data show that application of the different levels significantly increased available K in soil. It increased from 397 ppm with K0 to 628, 672, 651 and 675 ppm with K1, K2, K3 and K4, respectively. In this concern, Gomaa (2007) found that Available K was increased by increasing K fertilizer rate at calcareous soils.

Also, data reveal that the effect of interaction K-forms x K-levels on available K was significant. The values of available K were increased with interaction as compared with control. The superiority of available K was 809 ppm with interaction between coated tablet form x K4. From previous discussion, it is demonstrated that the delayed release of potassium offered continuous occurrence synchronized to no loss of potassium and prevent the soil from salting.

Exchangeable K (ppm):

As shown in Table (6), application of K_2SO_4 fertilizer in different forms significantly affected exchangeable K. However, the highest value was 565 ppm with coated tablet form. It seems that slowing release of potassium gave a good opportunity to exchange on soil colloids. Also, different K-levels application led to significant effect on exchangeable-K. The values of exchangeable K changed from 327 ppm with K0 to 524 ppm with K3 as will as the effect of interaction K-forms x K-levels on exchangeable K was significant.

Water Soluble K (ppm):

Results recorded in Table (6) illustrate that addition of K_2SO_4 fertilizer in different forms significantly affected water soluble K. They were 26.65, 30.92, 24.38 and 26.94 ppm with powder, granules, tablet and coated tablet forms, respectively. Also, they were significantly affected by applied K-levels. They increased from 14.04 ppm with K0 to 35.81 ppm with K4 as will as it was significantly affected by the interaction K-form x K-level. The maximum concentration of water soluble K was 40.52 with interaction of granular form x K4 (80 kg K/fed).

Conclusion:

The positive perspective of this study emphasized on the importance of potassium fertilization for potato especially, the controlled release potassium forms. It is obvious that tablet and coated tablet forms was more effective on fresh tuber yield and net return than conventional ones. The study could suggest the tablet form at level of 40 kg K/fed with recommended doses of N (180 kg N/fed) and P (33 kg P/fed) + 30 m^3 FYM/fed to reach optimum yield with maximum profitability.

REFERENCES

Abbady, A.Kh., Abd El-Aal, A.S.A. Abdel-Mawgoud and M.S. Awaad, 2008. Developed approach for grapevine fertilization. J. Agric. Sci. Mansoura Univ., 33(1): 871-886.

Abdel-Gadir, A.H., M.A. Errebhi, H.M. Al-Sarhan and M. Ibrahim, 2003. The effect of different levels of additional potassium on yield and industrial qualities of potato (*Solanum tuberosum L.*) in an irrigated arid region. Amer. J. of Potato Res., 80(3): 219-222.

Ali, A.A., 2006. Efficiency of potassium fertilizers on potatoes in a newly cultivated sandy soil . Ph. D. Thesis, Fac. Agric. Zagazig Univ.

Allison, M.F., J.H. Fowler and E.J. Allen, 2001. Responses of potato (*Solanum tubersum L.*) to potassium fertilizers. J. of Agric. Sci., 136(4): 407-426.

Al-Moshileh, A.M. and M.A. Errebi, 2004. Effect of various potassium sulfate rates on growth, yield and quality of potato grown under sandy soil and arid conditions. IPI regional workshop on Potassium and Fertigation development in West Asia and North Africa, Rabat, Morocco 24-28 November.

Anwar, R.S., 1998. Response of potato crop to phosphorus and potassium fertilization under sandy soil conditions. M. Sc. Thesis, Fac. Agric. Zagazig Univ.

Burton, W.G., 1948. "The Potato". Champan and Hall, London, pp: 319.

Davenport, J.R. and E.M. Bentley, 2001. Does potassium fertilizer form, source and time of application influence potato yield and quality in the Columbia Basin. Amer. Potato J., 78(4): 311-318.

El-Kabbany, E.A.Y., 1999. Effect of forms and levels of potassium fertilizer on yield and chemical composition of potato. J. Agric. Sci. Mansoura Univ., 24(11): 7039-7048.

El-Sawy, B.I., E.A. Radawan and N.A. Hassan, 2000. Growth and yield of potato as affected by soil and foliar potassium application. J. Agric. Sci. Mansoura Univ., 25(9): 5843-5850.

Gomaa, M.H., 2007. Response of tuber crops (potato) to potassium fertilization in some soils in Egypt. Ph. D. Thesis, Fac. Agric. Zagazig Univ.

Gomez, K.A. and A.A. Gomez, 1984. "Statistical Procedures for Agricultural Research". 2nd Ed. John Wiely and Sons, pp: 680.

Hesse, P.R., 1971. " A Text Book of Soil Chemical Analysis". Juan Murry (Publisher) Ltd, London.

Hewedy, A.M., 2000. Effect of methods and sources of potassium application on the productivity and fruit quality of some new tomato hybrids. Egyptian Journal of Agricultural Research, 78(1): 227-244.

Jagadeeswaran, R., V. Murugappan and M. Govindaswamy, 2005. Effect of slow release NPK fertilizer sources on the nutrient use efficiency in turmeric (*Curcuma longa L.*). World J. Agric. Sci., 1(1): 65-69.

Janardan - Singh, S.K. Bansal and J. Sing, 2000. Relative effect of two sources of potassium on yield and economics of potato production in an incept sol of Western U. P..J. of Potassium Research, 16(1-4): 52-54.

Lan Wu, Mingzhu Liu and R. Liang, 2008. Preparation and properties of a double-coated slow-release NPK compound fertilizer with super absorbent and water-retention. Bioresource Technology, 99: 547-554.

Munson, R., W.D. Bishop, W.L. Nelson, B.G. Ellis, E.C. Sample, D.A. Hot, M.E. Summer and L.S. Murphy, 1985. "Potassium in Agriculture", America. Soci. Agron., Crop Sci. Soc. America, Soil Sci. Soc. America, Madison, Wisconsin, USA.

Ranganathan, D.S. and D.A. Selvaseelan, 1997. Effect of mushroom spent compost in combination with fertilizer application on nutrient uptake by potato in an Ultic Tropudalf. J. Ind. Soc., Soil Sci., 45(3): 515-519.

Ranganna, S., 1977. "Manual of Analysis of Fruit and Vegetable Products". Central Food Technological Research Institute Mysore.

Reis-Junior, R.A. and P.H. Monnerat, 2001. Nutrient removal by potato tubers in response to potassium sulphate applications. Horticultura Brasileiea, 19(3): 360-364.

Rui Liang, Mingzhu Liu and Lan Wu, 2007. Controlled release NPK compound fertilizer with the function of water retention. Reactive & Functional Polymers, 67: 769-779.

Shahid, U. and Moinuddin, 2001. Effect of sources and rates of potassium application on potato yield and economic returns. Better Crops International, 15(1): 13-15.

Sharma, U.C. and B.R. Arora, 1987. Effect of nitrogen, phosphorus and potassium application on yield of potato tubers (*Solanum tuberosum L.*). J. Agric. Sci. Camb., 108: 321-329.

Smith, N.R., 1975. "Specific Gravity, Potato Processing". The AVI Publishing Comp. Inc., 43-66.

Tanner, C.B., G.G. Weis and D. Curwen, 1982. Russet Burbank rooting in sandy soils with pans following deep plowing. Am. Potato J.. 59: 107-112.

Tawfik, A.A., 2001. Potassium and calcium nutrition improves potato production in drip – irrigated sandy soil . Fifth Triennial Congress of the African Potato Association, 28 May-2June 2000, Kampala, Uganda. African Crop Sci. J., 9(1): 147-155.