Effect of Mineral and Organic Potassium Fertilization on Sweet Potato Crop Grown in The Newly Reclaimed Land

Hala A. Abd El-Aal[1] Nashwa I. Abo El-Fadl[2] and Sameh A.M. Moussa[2]

ABSTRACT

Two field experiments were carried out during the two successive summer seasons of 2008 and 2009 at a newly reclaimed area, at Sadat city, of the Environmental Studies and Research Institute Farm, Minufiya University, Minufiya Governorate, Egypt. This study was conducted in order to assess the effects of different levels of both potassium sulphate fertilizer (0.0; 50; 100; 150 and 200 Kg/fed.) and potassium humate foliar applications (11% K_2O) rates, i. e. 0.0, 0.5, 1.0 and 1.5%; as well as their interactions on the vegetative growth, yield and its components, tuber characteristics and tuber quality attributes of sweet potato crop. Potassium sulphate fertilizer affected significantly most studied traits. Generally, the increased potassium sulphate fertilization levels, from zero up to 200 Kg/fed., enhanced vegetative growth and, gradually, increased tuber root yield. The obtained results indicated that 200 Kg potassium sulphate fertilizer/fed. was the best level to increase total tuber yield. A similar trend was reached by spraying K-humate levels. Increasing potassium humate concentration from 0.0% to 1.5% increased most of the studied characters. The combined application of K_2SO_4 fertilizer levels and K-humate sprays reflected clear interaction effects. Tuber root yield reflected an increase of 10% - 15% by adding 200 Kg K_2SO_4/fed. combined with 1.5% K-humate compared with the control treatment (200 Kg K_2SO_4/ fed. only) in the first and the second seasons of the study, respectively. Generally, this study recommended spraying sweet potato fields, fertilized with 150 Kg K_2SO_4, with potassium humate to produce the highest tuber yield with the best quality.

Key words: potassium humate, potassium sulphate, sweet potato, *Ipomoea batatas, L.*mineral fertilizer and organic fertilizer.

INTRODUCTION

Sweet potato (*Ipomoea batatas, L.)* is a popular vegetable crop in Egypt. It is cultivated for both human food consumption and starch production. Moreover, the foliage is used for animal feeding. As a root crop, sandy soil is the most suitable one for its production, however, low levels of nutrients, such as potassium, are considered as of the major production constrains of this type of soil. Hassan *et. al. (2007*) stated that starch crops; like potatoes, cassava and sweet potato; have particularly high k needs. It was reported that k application had a positive influence on the quality parameters of tuber roots (Mohan Kumar *et. al.*, 1998; Attalla *et. al.*, 2001; SRI., 2003 and Sherif *et al.*, 2003) .The same trend was reported by El- Gamal (1980) and Barakat (1987) on potato tubers.

Sharfuddin and Voican (1984) stated that both the sugars and starch contents in sweet potato tubers roots were increased by elevating k rate from 62 to 186 kg/ ha. Wanas (1987) indicated that increasing k fertilizer levels led to increments on reducing, non-reducing and total sugars contents of sweet potato roots.

Potassium humate can be used as an organic potash fertilizer to supply the plants with high levels of soluble potassium in a readily available form. Combined with humic acid, potassium can be rapidly absorbed and incorporated into plants, whether via soil or foliar application methods. Enhancement of plant growth through using potassium humate had been attributed to the increased uptake of many minerals such as N, Ca, P, K, Mg, Fe, Zn and Cu (David et. al., 1994 and Adani, *et .al.*, 1998). Meanwhile, potassium humate increases photosynthesis, chlorophyll density and plant root respiration which resulted in greater plant growth and yield (sladky, 1959; Smidova, 1960 and Chen and Aviad, 1990).

Application of potassium humate in the field increased root system, tuber yield, and tuber number per plant in potato as reported by Asadi *et al*. (2010). However, the gradual increase in using fertilizers, especially potassium fertilizers, and the consequent increases in production costs in the recent years require giving more attention from producers to reduce total production cost. Such a reduction can be achieved by selecting the proper form and amount of fertilizers that are suitable for the soil type and plant species, in addition to using foliar spray of the beneficial organic fertilizers to realize a real increase in crop yield and high produced quality, reflecting a high economic income. Accordingly, the present study was carried out to achieve the following goals**:**

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[1]Environmental Studies and Researches Institute, Minufiya University, Sadat Branch, Egypt.
[2]Sabaheya Hort. Res., Horticultural Research Institute, Agriculture Research Center, Egypt.
[1]E-mail addresses for correspondence: halahala1997@yahoo.com samehmoussa@yahoo.com
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1-Determination of the suitable rates of k fertilizer under different concentrations of potassium humate to obtain high yield with good root quality.

2-Minimizing the added potassium sulphate fertilization rates and, thereby, lowering the total production cost under our newly reclaimed land conditions.

MATERIALS AND METHODS

The present investigation was carried out during the two successive summer seasons of 2008 and 2009 at a newly reclaimed area, at Sadat city, of the Environmental Studies and Researches Institute Farm, Minufiya University, Minufiya Governorate, Egypt; using the sweet potato cv. Minufiya 66. Planting was on the first of June in both seasons. Stem cuttings of 25 cm length were planted in rows, 0.75 m apart, and at spacing of 0.50 m within rows; under a drip irrigation system.

Treatments:

Each experiment contained twenty treatments, which represented all possible combinations of four levels of potassium sulphate fertilizer (48% K_2O); i.e. 0.00, 50, 100, 150 and 200 Kg K_2SO_4/fed. (The recommended dose of potassium fertilizer of the Ministry of Agriculture of Egypt); with four potassium humate sprays (11% K_2O) rates; i.e. 0.0, 0.5, 1.0, and 1.5 %. The mineral potassium sulphate fertilizer levels were randomly distributed in the main plots; whereas, the potassium humate rates were randomly assigned in the sub-plots. Each sub-plot consisted of three rows, 10.0 m long and 0.75 m wide, with a sub-plot area of 22.5 m^2. Potassium sulphate fertilizer was applied through a drip irrigation system and splited into four equal doses, starting at two weeks after planting and then at two weeks intervals. Potassium humate (11% K_2O) was dissolved thoroughly with water and was sprayed on the vegetative growth of the grown plants. The spraying rates were applied four times on the dates of potassium sulphate fertilizer applications.

The potassium humate used in this study was produced in China Rep., having a physical data as follows: appearance (black powders), pH (9-10) and water solubility (> 98%). The guaranteed analyses were as follows: humic acid (80%), potassium, K_2O, (10-12%), and zinc, iron and manganese etc., (100 ppm).

Agricultural operations were as follows: At soil preparation time, full dose of P_2O_5 (300 Kg/fed), as mono calcium phosphate (15.5 % P_2O_5), plus 5 tons/fed of compost; produced by El-Salam Compost Co., El-Minofiya Governorate, Egypt; were added. The nitrogen fertilizer was added to the soil throughout the drip irrigation system in the form of ammonium nitrate (33%) in four equal doses, as potassium sulphate fertilizer was applied. The nitrate fertilizer dose was 150 Kg N/fed. The physical and chemical analyses of the soil, of the used experimental cite, are presented in Table (1). All the agricultural practices used for commercial sweet potato production were carried out in both experiments**.**

Measurements:

Vegetative growth and yield parameters: Five whole plant samples per sub-plot were randomly used, 80 days after planting, for the determination of the vegetative growth (plant height (m), number of branches and plant fresh weight (kg)). Another five random plants were used for determining plant tuber root yield (kg). Tuber root yield was determined in weight and number of all tuber roots per plant.

Chlorophyll density: The non-destructive chlorophyll content was determined in plant leaves; using the handheld chlorophyll content meter (CCm-200), produced by Opti-Sicences, Inc. 8 Winn Avenue Hudson, NH 03051, U.S.A.

Physical characteristics: Random samples 0f 10 tuber roots per treatment were randomly used to measure the physical characteristics of the tubers; tuber length and diameter were measured to calculate the tuber shape index by dividing the former by the latter.

Tuber root quality:

1- Tuber dry matter (%) was carried out by weighing a certain weight of fresh tubers and then dried.

$$\text{Dry matter \%} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Table 1. Physical properties and chemical analyses of the experimental soil

Mechanical analysis			Texture	pH	EC. dS/m	$CaCo_3$%	O.M.%
Sand%	Silt%	Clay%					
90	5	5	sandy	7.26	6.00	5.5	0.80

Chemical analysis

Cations (meq/L)						Anions (meq/L)			
N^+	P^+	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^-	HCO_3^-	CL^-	SO_4^{--}
Traces	0.40	53.75	23.75	17.1	2.16	Zero	8.0	68.0	20.76

2-Determination of reducing and non-reducing sugars content (%): A known mass (5 g) of fresh tuber root was taken to determine reducing and non-reducing sugars, using sulphuric acid and phenol (5%); then they were colourimetrically determined, according to the method of **Dubios *et. al*. (1956).**

3- Determination of starch: Tuber root starch content (%) was determined using a sample of 1 g of fresh tuber, according to the method described in **A.O.A.C. (1970).**

4-Determination of carotene content: Carotene content was determined as β carotene, using the method described by **Nakdimon and Gabelman (1971).** A Milton Roy, spectrophotometer-601 at 440 nm, was used

Experimental design and statistical analysis:

The used experimental layout was arranged as a split-plot in a randomized complete blocks design (R.C.B.D), with three replicates. Five treatments of potassium sulphate fertilizer levels (0, 50, 100, 150, and 200 kg/fed., where 200 Kg/fed. was the control treatment) were considered as main plots, and four sub-treatments of potassium humate rates (0, 0.5, 1, and 1.5 %) were randomly distributed in the sub plots in the three replicates. Collected data of the experiments were statistically analyzed, using the analysis of variance method. Single and multiple linear regressions were applied to fit the data using CoStat-Software program of analysis (2004). Comparisons among the means of different treatments were done, using Duncan's multiple range test procedure at p = 0.05 level of significance, as illustrated by Snedecor and Cochran (1980).

RESULTS AND DISCUSSIONS

1-Effects of mineral potassium levels on the studied characters:

1-1-Vegetative growth and leaf chlorophyll content:

Data, presented in Table (2), show that potassium sulfate fertilizer rates had significant effects on most studied characters during the two used seasons of this study. The results, generally, indicated that lowering the percentage of potassium sulphate fertilizer, gradually from 100% (200 kg/fed.)down to zero percentage, decreased gradually and significantly the studied vegetative characters (No. of branches/plant, plant length and foliage fresh weight) and leaf chlorophyll content; whereas, plant length gave a different response in this respect. Similar findings were obtained by Tong and Change (2002) on sweet potato. Recently, in Egypt, similar K promoting effects on cassava vegetative growth were described by Attalla *et. al*. (2001) and Hassan *et. al*. (2007).

The positive effect of the high rate of K fertilizer on tuber root characters might be attributed to the improved efficiency of utilizing soil minerals, mainly N fertilizer, and, subsequently, other applied fertilizers (Ardjasa *et. al*. 2002).

1-2- Tubers root yield, yield components and tuber shape index:

The results, reported in Table (3), indicate that increasing K fertilization rates had significant positive effects on tuber No. ⁄ plant, average tuber weight⁄ plant, yield⁄ plant and yield ton/fed. in both seasons. It was obvious that the highest yield, in the two seasons (25.09 and 26.19 ton/fed.), obtained by applying 100% K_2SO_4 (200 Kg potassium sulphate/fed.), with significant differences from the other applied rates. The same trend was also explored for tuber number/ plant and tuber weight traits. On the other hand, the lowest yielding (13.91 and 11.51 ton/fed.) was traced by applying 0.00% K_2SO_4 fertilization, as shown in Table (3). The distinct superiority of fertilizing with the high and moderate K fertilization levels (200 and 150 Kg/fed); regarding tuber yield, in comparison with the low levels (100, 50 and zero Kg/fed.); might be related to the role of potassium in the translocation of carbohydrates, produced in the leaves through photosynthesis, to the various plant organs (Norman *et. al.*, 1984). The obtained results appeared to be in a general matching with those reported by Lu *et. al.* (2001) and Mansour *et. al.* (2002), on sweet potato; and Hassan *et. al. (2007*) on cassava plants.

The tuber yield (Y) was found to be correlated with the used potassium sulphate fertilizer rate (X) (as shown in Fig. 1). The regression equations for this relationship in the first and second seasons could be represented as follows:

The first season (2008): $Y_1 = 14.569 + 0.052X$ $R^2 = 0.965$ $(P<0.01)$

The second season (2009): $Y_2 = 10.396 + 0.069X$ $R^2 = 0.829$ $(P<0.01)$

The presented data indicated that sweet potato tuber yield was strongly and positively affected by the applied potassium sulphate rate; where, determination coefficients (R^2) of 0.965 and 0.829; in the two seasons, respectively; under the experimental conditions of the present study. The results in Table (3) demonstrated also that tuber root shape index was significantly affected with potassium sulphate applications; but, only in the second season of the study.

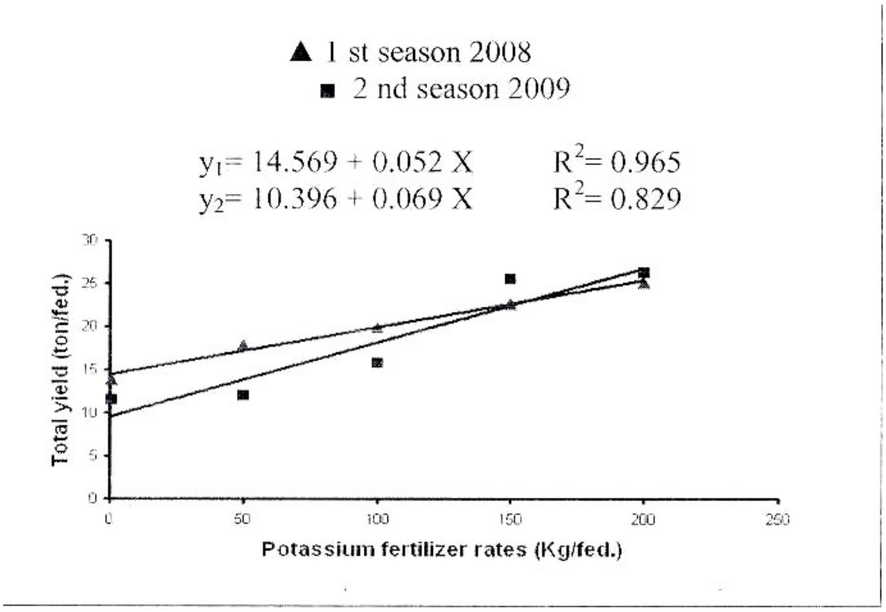

Fig. 1. The relationship between sweet potato total yield (ton/fed.) and potassium sulphate fertilizer rates during the two used seasons

1-3- Quality attributes of tubers root characters:

As shown in Table (4), the tuber quality characteristics under study (tuber dry matter, carotene content, reducing and non-reducing sugars and starch percentages) were positively influenced by potassium sulphate fertilizer levels in both growing seasons, with the exception of carotene content in the first season. Adding the highest level (100 %) of K_2SO_4 fertilizer (200 kg/ fed.) surpassed the other k fertilizer levels and resulted in the highest percentages of the chemical components of tuber roots. Similar trends of such results were reported by Lu *et. al.* (2001) and Georg *et. al.* (2002) on sweet potato, and Mohan Kumer *et. al.* (1998), Olasantan (2003) and Hassan *et. al.* (2007) on cassava. The positive effect of the high rate of potassium sulphate fertilizer on tuber quality characteristics might be attributed to the role of K in assimilation and translocation of carbohydrates, as well as, in their conversion into starch (Nelson, 1970).

2 – Effects of potassium humate concentrations on the studied characters:

2-1- Vegetative growth and leaf chlorophyll content:

The relationships between potassium humate rates and respective vegetative characters, Table (2), reflected significant effects on the various vegetative characteristics (No. of branches/ plant, in the first year only and foliage fresh weight/ plant); while, leaf chlorophyll content was significantly affected only in the second year. The results presented herein appeared to be in accordance with those found by Hassanpannah *et. al.* (2007) on potato crop. These results might be explained on the basis that potassium humate increased photosynthesis, chlorophyll density and plant root respiration, which resulted in greater plant growth and yield (Sladky, 1959; Smidova, 1960; and Chen and Aviad, 1990).

2-2- Tuber root yield, yield components and tuber shape index:

As shown in Table (3), sweet potato yield/ plant, tuber yield (ton/fed.) and average tuber weight / plant characters appeared to be significantly affected with the used potassium humate rates in both seasons; whereas, No. of tubers/plant was significantly affected only in the first year. Tuber shape index reflected significant effects for potassium humate in the second season only. Generally, tuber yield/plant showed gradual decrement with the decreasing of k-humate rates. Similar results were also reported by Asadi *et al.* (2010), and Mahmoud and Hafez (2010) in their researches on potato crop. These results might be attributed to the effects of potassium humate on increasing plant growth attributes (No. of branches/plant, foliage fresh weight/plant and leaves chlorophyll content), as shown previously in table (2); which, by turn, resulted in greater yield characteristics. The obtained results are also in harmony with those of Sladky, (1959), Smidova (1960), and Chen and Aviad (1990).

The tuber yield (Y) was regressed against the potassium humate rates (X) (Fig. 2). The regression equations for this relationship were:

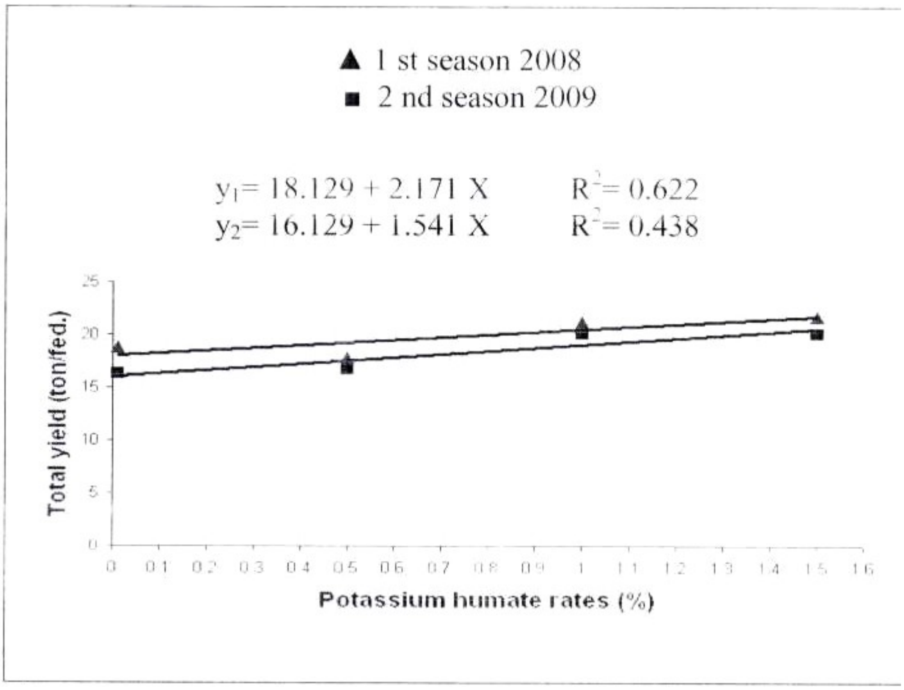

Fig. 2. The relationship between sweet potato total yield (ton/fed.) and potassium humate spraying rates during both summer seasons of 2008 and 2009

The first season (2008): $Y_1 = 18.129 + 2.171X$

$R^2 = 0.622$ ($P<0.01$)

The second season (2009): $Y_2 = 16.129 + 1.541X$

$R^2 = 0.438$ ($P<0.05$)

These data indicated that sweet potato tuber yield was positively affected by potassium sulphate application with a high determination coefficient (R^2= 0.622) in the first season (2008); while, it was somewhat affected with potassium humate rates during the second season (2009) with a low determination coefficient (R^2= 0.438).

2-3- Quality attributes of tuber root characters:

Data in Table(4) illustrated that the tuber root quality characteristics were significantly affected with potassium humate sprays, regarding non-reducing sugars and starch percentages. Both Tuber dry matter and reducing sugars reflected significant effects only in the first year of the study; whereas, tuber dry matter percentage was positively correlated with K-humate rates, as demonstrated in Table (4). The highest starch percentage was obtained with 1.5% k-humate rate, in both trials, with insignificant differences from both 1.0% and 0.5% k-humate rates. Such a stimulation effect of starch content percentage was probably due to the supplemental effect of K-humate of soluble potassium in a readily available form which might aid the translocation of carbohydrates produced by photosynthesis (sladky, 1959; Smidova, 1960; and Chen and Aviad, 1990). On the other side, carotene content did not seem to be affected with k-humate rates.

3-Influence of the interactions between potassium fertilization and k- humate rates

3-1-Vegetative growth and leaf chlorophyll content:

Data presented in Table (2) indicated that the foliage fresh weight character was significantly affected with the interaction between potassium sulphate fertilizer and potassium humate sprays (AxB interaction) in both years; whereas, No. of branches/ plant, plant length, leaves chlorophyll content characters reflected significant AxB interaction effects only in one season of the study. It was clear that the highest values for both foliage fresh weight and leaf chlorophyll traits were obtained by applying 200 Kg/fed. of K_2SO_4 combined with 1.5 % K-humate in both seasons of the study. On the other hand, the lowest values of the vegetative traits were achieved when the plants were neither fertilized with potassium sulphate (0.00%) nor sprayed with K-humate. These results indicate clearly that potassium has an important role in enhancement photosynthesis, resulting in greater plant growth and yield. These responses are in accordance with these obtained by (Sladky, 1959; Smidova, 1960 and Chen and Aviad, 1990).

Table 2. Mean performances of the studied vegetative characteristics of sweet potato during both summer seasons of 2008 and 2009

seasons		1 st 2008				2 nd 2009			
Treatments		No. of branches/ plant	Plant length (m)	Foliage fresh weight (Kg)	Leaf chlorophyll content	No. of branches/ plant	Plant length (m)	Foliage fresh weight (Kg)	Leaf chlorophyll content
Potassium sulphate fertilizer									
200 Kg K_2SO_4		8. 77a	1. 19 b	1. 11 a	23. 17a	7. 67 a	1. 32 a	1. 37 a	21.15 a
150 Kg K_2SO_4		8. 33 a	1. 20 b	0. 99 b	21. 21 b	8. 86 a	1. 30 a	1. 29 a	19. 32 b
100 KG K_2SO_4		6. 36 b	1. 28 ab	0. 80 c	19. 14 c	9. 22 a	1. 18 ab	1. 10 b	19. 01 c
50 Kg K_2SO_4		6. 75 b	1. 31a	0. 77 c	17. 29 d	7. 61 ab	1. 01 c	0. 78 c	16. 87d
Zero K_2SO_4		5. 44 c	1. 02 c	0. 62 d	15. 89 e	6. 58 b	1. 07 bc	0. 74 c	16. 62 e
K-humate fertilizer									
1.5 % K humate		8. 57 a	1. 17 c	0. 99 a	20. 75 a	8. 55 a	1. 20 a	1. 09 ab	18. 64 a
1.0 % K humate		7. 47 b	1. 17 c	0. 88 b	18. 99 b	8. 07 a	1. 19 a	1. 08 b	18. 49 a
0.5 % K humate		6. 22 c	1. 21 b	0. 76 d	19. 19 b	8. 40 a	1. 19 a	1. 10 a	18. 66 a
0.0 % K humate		5.66 d	1. 24 a	0. 78 c	18. 42 b	7. 71 a	1. 11 a	0. 95 c	18. 49 a
Potassium sulphate X K-humate interaction									
200 Kg K_2SO_4	1.5 % K humate	8. 33 bc	1. 18 a	1. 24 a	28. 32 a	9. 41 a	1. 35 a	1. 40 a	21. 81 a
	1.0 %K humate	8. 44 bc	1. 25 a	1. 15 ab	23. 04 b	9. 33 a	1. 33 a	1. 35 a	21. 37 a
	0.5 % K humate	9. 0 bc	1. 21 a	1. 10 abc	20. 34 cd	8. 11 a	1. 29 abc	1. 39 a	20. 71 a
	0.0 % K humate	9. 3 b	1. 13 a	0. 95 cde	20. 96 bcd	7. 67 a	1. 30 ab	1. 35 a	20. 71 a
150 Kg K_2SO_4	1.5 % K humate	11. 99 a	1. 06 a	1. 15 ab	22. 08 bc	8. 00 a	1. 33 a	1. 37 a	20. 04 a
	1.0 % K humate	8. 89 bc	1. 07 a	0. 97 bcde	21. 47 bcd	10. 11 a	1. 35 a	1. 31 a	19. 13 a
	0.5 % K humate	6. 00 fg	1. 17 a	0. 61g	19. 68 cde	9. 67 a	1. 31 a	1. 10 bc	18. 90 a
	0.0 % K humate	6. 11 fg	1. 30 a	0. 89 de	19. 61cde	8. 44 a	1. 30 ab	1. 25 ab	19. 17 a
100 Kg K_2SO_4	1.5 % K humate	8. 00 cd	1. 30 a	0. 94 cde	20. 06 cd	10. 67 a	1. 33 a	1. 30 a	19. 16 a
	1.0 % K humate	6. 78 ef	1. 33 a	0. 81cf	17. 57 efg	8. 22 a	1. 15 abcde	1. 07 c	18. 91 a
	0.5 % K humate	6. 00 fg	1. 17 a	0. 61g	19. 68 cde	9. 67 a	1. 31 a	1. 10 bc	18. 90 a
	0.0 % K humate	4. 67 h	1. 31 a	0. 83 ef	19. 24 def	8. 33 a	0. 92 f	0. 92 cd	18. 61 a
50 Kg K_2SO_4	1.5 % K humate	7. 89cde	1. 37 a	1. 03 bcd	17. 02 fgh	8. 56 a	0. 93 ef	0. 80 de	16. 71 a
	1.0 %K humate	7. 11def	1. 29 a	0. 87 def	16. 56 gh	6. 89 a	1. 05 cdef	0. 93 cd	16. 80 a
	0.5 % K humate	4. 78 h	1. 28 a	0. 55 g	19. 16 def	8. 33 a	1. 05 cdef	0. 73 ef	17. 48 a
	0.0 % K humate	4. 20 h	1. 28 a	0. 63 g	16. 40 gh	6. 67 a	1. 00 def	0. 65 ef	16. 48 a
Zero K_2SO_4	1.5 % K humate	6. 66 f	0. 95 a	0. 60 g	16. 25 gh	6. 11 a	1. 08 cdef	0. 60 f	16. 59 a
	1.0 %K humate	6. 11 fg	0. 93 a	0. 61 g	16. 31 gh	5. 78 a	1. 05 cdef	0. 73 ef	16. 88 a
	0.5 % K humate	5. 0 gh	1. 02 a	0. 69 fg	15. 07 h	7. 00 a	1. 10 bcdef	1. 03 c	16. 63 a
	0.0 % K humate	4. 00 h	1. 18 a	0. 58 g	15. 91 gh	7. 44 a	1. 03 def	0. 58 f	16. 38 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance.

Table 3. Mean performances of tuber root yield, yield components and tuber shape index of sweet potato during both summer seasons of 2008 and 2009

seasons		1 st 2008					2 nd 2009				
treatments		No. of tubers/ plant	Average tuber weight/ plant (Kg)	Tuber yield/ plant (Kg)	Tuber yield (ton/fed.)	Tuber shape index	No. of tubers/ plant	Average tuber weight/ plant (Kg)	Tuber yield/ plant (Kg)	Tuber yield (ton/fed.)	Tuber shape index
Potassium sulphate fertilizer											
200 Kg K_2SO_4		7.63 b	0.29 a	2.23 a	23.76a	1.62a	9.57a	0.24 a	2.31a	26.19a	2.12a
150 Kg K_2SO_4		8.33 a	0.26bc	1.99 b	21.17b	2.00a	8.42 a	0.25 a	2.07 b	23.51b	1.69a
100 KG K_2SO_4		7.25 b	0.25 c	1.75 c	18.61c	1.63a	8.58 a	0.16 c	1.38 c	15.73c	1.78a
50 Kg K_2SO_4		5.89 c	0.27 b	1.57 d	16.72d	1.73a	6.92 b	0.15 c	1.05 d	11.97d	2.19a
Zero K_2SO_4		5.50 c	0.23 d	1.22 e	13.01e	1.42a	5.33 c	0.20 b	1.01 d	11.51d	2.26a
K-humate fertilizer											
1.5 % K humate		7.44 a	0.25 b	1.91a	20.40a	2.16 a	8.13a	0.21a	1.77 a	20.08a	1.99a
1.0 % K humate		6.75 b	0.29 a	1.87 a	19.90a	1.78ab	7.91a	0.20 b	1.58 b	18.01b	1.90a
0.5 % K humate		6.49 b	0.28 a	1.57 c	16.79c	1.63bc	7.60a	0.19 c	1.46c	16.69c	2.08a
0.0 % K humate		7.00ab	0.23 c	1.64 b	17.54b	1.31 c	7.42a	0.19 c	1.44c	16.34c	2.06a
Potassium sulphate X K-humate interaction											
200 Kg K_2SO_4	1.5% K humate	7.97 a	0.29 c	2.31 a	24.64 a	2.09 a	10.20 a	0.25 abc	2.55 a	29.07 a	1.87 a
	1.0%K humate	7.77 abc	0.29 c	2.25 ab	24.00 ab	1.72 a	10.00 a	0.25 abc	2.52 a	28.73 a	1.83 a
	0.5% K humate	7.11 bcde	0.31 b	2.21 ab	23.57 ab	1.88 a	8.87 abcde	0.22 de	1.95 cd	22.23 cd	2.37 a
	0.0% K humate	7.66 abc	0.28 d	2.14 b	22.83 b	1.59 a	9.22 abc	0.24 bcd	2.21 bc	24.71 bc	2.41 a
150 Kg K_2SO_4	1.5% K humate	8.67 a	0.25 f	2.16 b	23.04 b	2.66 a	9.78 ab	0.23 cd	2.25 b	25.27 b	1.88 a
	1.0% K humate	8.67 a	0.33 a	2.15 b	22.93 b	2.56 a	8.56 bcde	0.23 cd	1.97 bcd	22.46 bcd	1.53 a
	0.5% K humate	8.66 a	0.21 i	1.80 c	19.20 c	1.43 a	7.78 defg	0.26 ab	2.02 bc	23.03 bc	1.79 a
	0.0%K humate	7.33 bcd	0.25 f	1.83 c	19.52 c	1.36 a	7.55 efg	0.27 a	2.04 bc	23.27 bc	1.57 a
100 Kg K_2SO_4	1.5% K humate	7.55 abc	0.25 f	1.86 c	19.84 c	2.29 a	9.00 abcd	0.19 fg	1.71 d	19.49 d	2.15 a
	1.0% K humate	6.88 bcde	0.27 e	1.88 c	20.05 c	1.80 a	9.00 Abcd	0.15 hi	1.35 e	15.39 e	1.37 a
	0.5% K humate	6.66 cdef	0.22 h	1.41 e	15.04 e	1.37 a	8.33 cdef	0.17 gh	1.42 e	16.19 c	1.68 a
	0.0%K humate	7.89 ab	0.24 g	1.83 c	19.52 c	1.07 a	8.00 cdefg	0.13 i	1.04 f	11.86 f	1.91 a
50 Kg K_2SO_4	1.5% K humate	7.22 bcde	0.25 f	1.78 cd	18.99 cd	1.83 a	6.67 gh	0.20 ef	1.33 e	15.16 e	2.42 a
	1.0%K humate	5.33 g	0.31 b	1.67 d	17.81 d	1.47 a	7.00 fgh	0.15 hi	1.05 f	11.97 f	2.05 a
	0.5% K humate	5.00 g	0.27 c	1.37 e	14.61 e	2.37 a	7.00 fgh	0.13 i	0.91 f	10.37 f	1.74 a
	0.0% K humate	6.00 efg	0.24 g	1.45 e	15.47 e	1.24 a	7.00 fgh	0.13 i	0.91 f	10.37 f	2.54 a
Zero K_2SO_4	1.5% K humate	5.78 fg	0.25 f	1.45 e	15.47 e	1.93 a	5.00 I	0.20 ef	1.00 f	11.40 f	1.65 a
	1.0% K humate	5.11 g	0.27 e	1.38 e	14.72 e	1.34 a	5.00 I	0.22 de	1.01 f	11.51 f	2.70 a
	0.5% K humate	5.00 g	0.22 h	1.08 f	11.52 f	1.12 a	6.00 Hi	0.17 gh	1.02 f	11.63 f	2.82 a
	0.0% K humate	6.11 defg	0.16 j	0.97 f	10.35 f	1.28 a	5.33 i	0.19 fg	1.01 f	11.51 f	1.87 a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance

Table 4. Mean performances of tuber root quality attributes of sweet potato during both summer seasons of 2008 and 2009

seasons		1 st 2008					2 nd 2009				
treatments		Tuber dry matter (%)	Carotene content (mg/100 g)	Reducing sugars (%)	Non-reducing sugars (%)	Starch (%)	Tuber dry matter (%)	Carotene content (mg/100 g)	Reducing sugars (%)	Non-reducing sugars (%)	Starch (%)
Potassium sulphate fertilizer											
200 Kg K_2SO_4		31. 00a	4. 28 a	1. 91a	0. 86 a	22. 68a	27. 83a	3. 39 b	4. 50a	2. 40 a	17. 26 a
150 Kg K_2SO_4		30. 03b	4. 22 a	1. 78a	0. 75 b	20. 39b	27. 83a	3. 03 b	4. 37a	2. 07 b	15. 85 b
100 KG K_2SO_4		28. 56c	4. 40 a	1. 52ab	0. 72 b	19. 73c	26. 08b	3. 15 b	3. 27b	1. 53 c	14. 84 c
50 Kg K_2SO_4		27. 76d	4. 84 a	1. 13bc	0. 64 c	18. 41d	25. 45bc	3. 99 a	2. 63c	1. 34 c	14. 41 d
Zero K_2SO_4		27. 08d	4. 01 a	1. 03c	0. 53 d	16. 47e	24. 85c	3. 93 a	2. 38d	1. 07 d	13. 93 e
K-humate fertilizer											
1. 5% K humate		29. 42a	4. 29 a	1. 58 a	0. 71 a	20. 27a	26.69 a	3.54 a	3. 48 a	1. 73b	15. 70 a
1. 0% K humate		29.22ab	4. 44 a	1. 47 a	0. 73 a	19. 67b	26. 45 a	3. 49 a	3. 47 a	1. 72b	15. 46 a
0. 5% K humate		28.59bc	4. 18 a	1. 26 b	0. 68 b	19. 31c	26. 49 a	3. 54 a	3. 41 a	1. 71b	15. 07 b
0.0% K humate		28. 34c	4. 48 a	1. 58 a	0. 68 b	18. 89d	25. 99 a	3. 41 a	3. 35 a	3. 35a	14. 83 b
Potassium sulphate X K-humate interaction											
200 Kg K_2SO_4	1. 5%K humate	31.84 a	3. 58 a	1. 93 bc	0. 90 a	25. 00 a	28.40 a	3.05 a	4.27 a	2. 47a	17. 87a
	1. 0% K humate	31. 29a	3. 92 a	2. 00 b	0. 96 a	23. 20 b	28.14 a	3. 00a	4. 60a	2. 50a	17. 50a
	0. 5%K humate	30. 28a	4. 73 a	1. 00 ij	0. 81 a	22. 00 c	27.45 a	4. 31a	4. 70a	2. 52a	17. 00a
	0.0%K humate	30. 60a	4. 89 a	2. 70 a	0. 77 a	20. 53 e	27.34 a	3. 21a	4. 43a	2. 10a	16 .67a
150 Kg K_2SO_4	1. 5%K humate	30. 38a	4. 38 a	2. 00 b	0. 76 a	21. 30 d	28.32 a	2. 94a	4. 60a	2. 10a	16 .67a
	1. 0% K humate	30. 67a	4. 91 a	1.70bcde	0. 78 a	20. 10f	28. 27a	3. 15a	4. 40a	2. 13a	16. 03a
	0. 5% K humate	29. 22a	3. 80 a	1. 83bcd	0. 74 a	20. 17 f	27. 85a	3. 00a	4. 10a	2. 17a	15. 53a
	0.0% K humate	29. 85a	3. 77 a	1. 60bcdef	0. 73 a	20. 00 fg	26. 87a	3. 01a	4. 37a	1. 87a	15. 17a
100 Kg K_2SO_4	1. 5% K humate	28. 92a	4. 85 a	1. 70bcde	0. 74 a	19. 63 gh	27. 10a	3. 67a	3. 47a	1. 63a	15. 20a
	1. 0% K humate	28. 92a	4. 89 a	1. 53cdefg	0. 73 a	19. 93 fg	26. 00a	3. 08a	3. 33a	1. 47a	15. 10a
	0. 5% K humate	28. 59a	3. 54 a	1. 37efghi	0. 71 a	19. 83fgh	25. 71a	2. 73a	3. 20a	1. 50a	14. 73a
	0.0% K humate	27. 91a	4. 30 a	1.47defgh	0. 71 a	19. 53 h	25. 49a	3. 10a	3. 07a	1. 53a	14. 33a
50 Kg K_2SO_4	1. 5% K humate	28. 16a	4. 67 a	1. 17ghij	0. 64 a	18. 63 i	25. 59a	4. 32a	2. 63a	1. 37a	14. 83a
	1. 0% K humate	27. 98a	5. 07 a	1. 20fghij	0. 61 a	18. 53 i	25. 69a	3. 91a	2. 63a	1. 37a	14. 76a
	0. 5% K humate	27. 87a	4. 81 a	1. 01ij	0. 62 a	18. 30 ij	25. 62a	3. 69a	2. 63a	1. 33a	14. 07a
	0.0% K humate	27. 02a	4. 82 a	1. 13ghij	0. 67 a	18. 17 j	24. 79a	4. 03a	2. 63a	1. 30a	14. 00a
Zero K_2SO_4	1. 5% K humate	27. 80a	3. 99 a	1. 10hij	0. 53 a	16. 80 k	24. 97a	3. 73a	2. 43a	1. 10a	13. 93a
	1. 0% K humate	27. 23a	3. 40 a	0. 93j	0. 57 a	16. 60 k	24. 93a	4. 30a	2. 37a	1. 13a	13. 90a
	0. 5% K humate	26. 97a	4. 00 a	1. 07hij	0. 52 a	16. 23 l	24. 85a	3. 98a	2. 43a	1. 03a	13. 90a
	0.0% K humate	26. 33a	4. 64 a	1. 00ij	0. 51 a	16. 23 l	24. 67a	3. 70a	2. 27a	1. 03a	13. 97a

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance

3-2- Tubers root yield, yield components and tuber shape index:

The results in Table(3) of tuber yield (tuber yield/plant and tuber yield (ton/fed.)) and its component traits (number of tubers per plant and average tuber weight per plant) reflected significant effects for with AxB interaction. These results indicated that the aforementioned characters responded differently in this respect. In general, applying K_2SO_4 at the rate of 200 Kg/fed., combined with 1.5 % K- humate, gave the highest record, corresponding total yield (ton/fed.) trait, followed by the treatment of 200 Kg K_2SO_4 / fed., combined with 1.0 % K- humate; but without significant differences in the two studied seasons (Table, 3, and Figs. 3a and 3b). These results might be due to that the stimulation of vegetative growth happened by foliar application of potassium humate, as illustrated in Table (2). The present results indicated also that the recommended dose of K_2SO_4 could be reduced, from 200 Kg/fed. (200 Kg/fed. + zero K-humate) down to 150 Kg/fed., by spraying 1.5 % K-humate to the growing plants four times during the growing period to obtain approximately the same yield of sweet potato tubers per plant as that of the commonly recommended dose (200 Kg K_2SO_4/fed.), as appears in Table (3).

The tuber yield (Y) was regressed with the potassium sulfate fertilizer (X_1) and potassium humate sprays (X_2), as shown in Figs. 3a and 3b. The regression equations for such a relationship, in the first and the second seasons, could be presented as follows:

The first season: $Y_1 = 12.931 + 0.052\ X_1 + 2.180\ X_2$

$R^2 = 0.839$ (P<0.01)

The second season: $Y_2 = 9.239 + 0.069\ X_1 + 1.541\ X_2$

$R^2 = 0.725$ (P<0.01)

These parameters indicated that tuber yield was strongly affected with the two utilized variables, especially with the potassium humate rate, under the experimental conditions.

Thus, the efficiency of potassium sulphate level: K-humate rate was estimated to be equal to 0.052: 2.180, in the first season, and to 0.069: 1.541 in the second season or as 1.00: 41.92 and 1.00: 22.33 in the first and second seasons, respectively. These equations can be used to predict potassium sulphate level and K-humate rate to be added to the growing sweet potato plants to produce maximum sweet potato yield, under the similar conditions of this study.

Tuber shape index trait did not reflect different responses for the various combinations of the two studied variables, suggesting the absence of AxB interaction. This means that there were stable responses with both potassium sulphate and k-humate rates regarding tuber shape index.

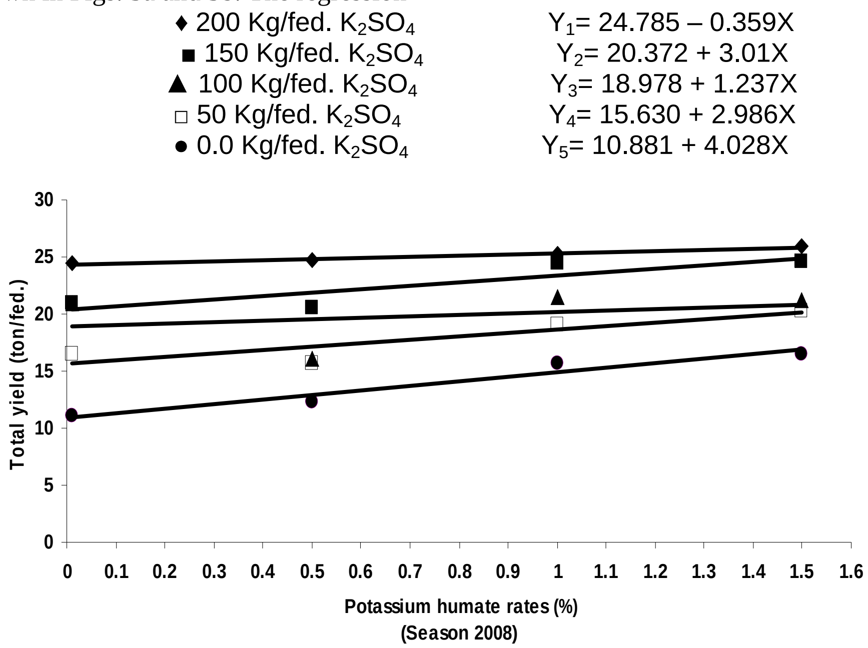

Fig. 3a. The relationship between total sweet potato yield (ton/fed.) and potassium humate spraying rates at different potassium sulphate fertilizer rates in the first season (2008)

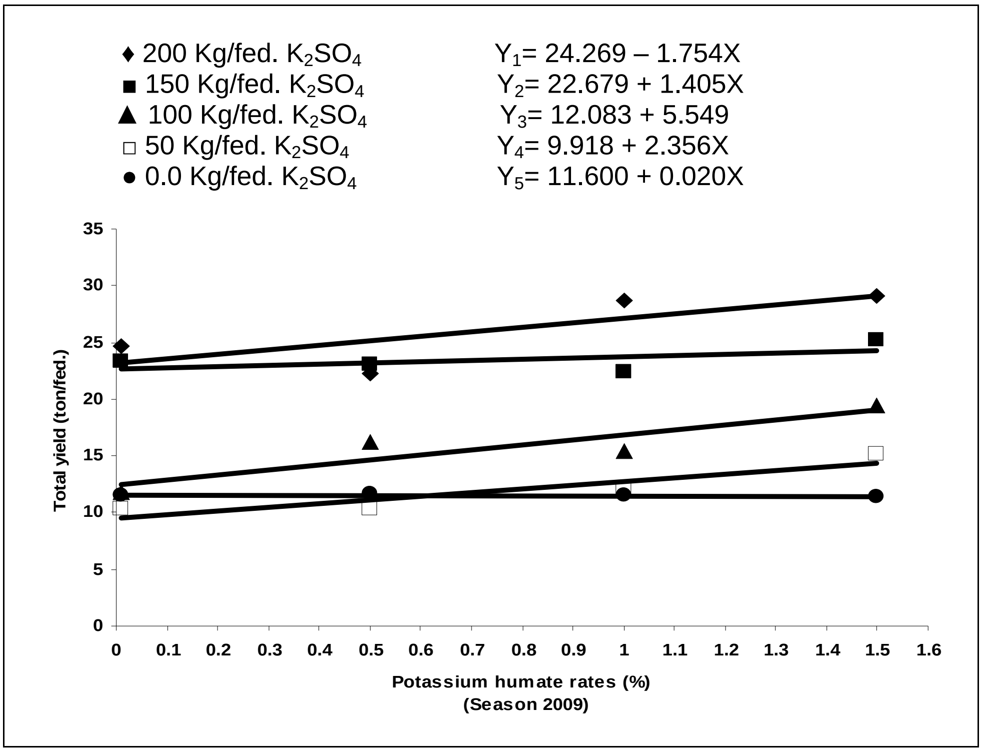

Fig 3b. The relationship between total sweet potato yield (ton/fed.)and potassium humate spraying rates at different potassium sulphate fertilizer rates in the second season (2009)

3-3- Quality attributes of tubers root characters:

Data presented in Table(4) indicated that at high combined levels of K_2SO_4 with k-humate, the highest percentages of dry matter content were recorded and vice versa were noticed regarding the low levels of the combinations, but without any significant differences among all studied treatment combinations.

However, the treatment 200 Kg K_2SO_4/fed. + 1.5% K-humate resulted in the highest dry matter percentage values in the two seasons of the trial (31.84% and 28.40%, respectively). This result might be due to the increased foliage fresh weight per plant and leaf chlorophyll content per plant which enhanced photosynthesis, as explained by Chen and Aviad (1990). Data presented in Table (4) indicated that, only in the first trial, both reducing sugars and starch percentage traits were significantly affected with the interaction between potassium sulphate fertilizer doses and potassium humate rates (AxB interactions); while, the other studied characteristics did not reflect any significant differences in this regard. Generally, while carotene content seemed to be unaffected with this interaction, in the two seasons, the reducing and non-reducing sugars and starch percentages in tuber roots appeared to be somewhat reduced with the lower levels of this interaction and vice versa with the higher levels of fertilizer. For example, the highest values of starch percentage (25.00% and 17.87%) were obtained with the 200 Kg K_2SO_4 +1.5% k-humate treatment, followed by the treatment 200 Kg K_2SO_4 + 1.0% K-humate (23.20% and 17.50%) in the two seasons, respectively. On the other hand, the lowest starch percentages were recorded for the treatments zero K_2SO_4 combined with K-humate levels (Table, 4). These results confirmed the previous results regarding enhancing the growth of vegetative characters (Table, 2) which resulted in higher percentages of tuber dry matter percentage (Table, 3). Similar trends were also noticed by El- Gamel (1980), Bourke (1985), Barakat (1987) and Sherif *et al.* (2003).

CONCLUSIONS

The obtained results demonstrated that spraying potassium humate (K-humate) four times (1.5% level) to the growing sweet potato plants was found effective in reducing the amount of the mineral potassium sulphate fertilizer (K_2SO_4), to be applied by 25 % compared with the commonly recommended dose, under the conditions of this study. This result means that it is possible to reduce the feddan production cost by applying the potassium humate organic fertilizer to the growing sweet potato plants. Also, the data showed clearly the possibility of maximizing the feddan production up to 10% or 15%, as well as, producing high quality tuber roots by combining the recommended dose of potassium sulphate fertilizer (200 Kg/fed) with spraying 1.5% level of potassium humate four times.

Thus, the present study recommended spraying sweet potato field, fertilized with 150 Kg K_2SO_4 only, with potassium humate fertilizer, at the rate of 1.5%, to produce a higher tuber yield of good quality.

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د

الملخص العربي

تأثير التسميد البوتاسى المعدنى والعضوى على محصول البطاطا النامية فى الأراضى حديثة الإستصلاح

هالة أحمد عبد العال، نشوة إبراهيم أبوالفضل، سامح عبد المنعم محمد موسى

أجريت هذه الدراسة خلال الموسمين الصيفيين لعامي ٢٠٠٨ و٢٠٠٩ بالمزرعة البحثية لمعهد الدراسات والبحوث البيئية- بمدينة السادات- جامعة المنوفية، جمهورية مصر العربية.

الغرض من الدراسة هو التعرف على تأثير المستويات المختلفة من كل من سماد كبريتات البوتاسيوم (صفر، ٥٠، ١٠٠، ١٥٠، ٢٠٠ كجم/فدان) والتسميد بالرش بهيومات البوتاسيوم K_2O (١١%) بمعدلات: صفر، ٥ر٠، ٠ر١، ٥ر١% وتتبع تأثيرات التداخل بينهما علي صفات النمو الخضري، المحصول الكلى ومكوناته، صفات وجودة الجذور الدرنية لصنف البطاطا منوفية ٦٦.

كما تهدف الدراسة لمحاولة إيجاد حلول تساهم فى تقليل كميات الأسمدة البوتاسية المعدنية المستخدمة فى تسميد البطاطا من خلال استخدام مواد أخرى مكملة مثل السماد العضوى هيومات البوتاسيوم، مما يقلل كثيرا من تكاليف الكلية للإنتاج، مع إعطاء إنتاج أعلى وبجودة مرتفعة.

أستخدم فى تطبيق التجربتين نظام القطع المنشقة فى تصميم القطاعات الكاملة العشوائية، وذلك بثلاث مكررات، حيث وزعت عشوائيا معاملات التسميد المعدنى(كبريتات البوتاسيوم) على القطع الرئيسية، بينما معاملات الرش بهيومات البوتاسيوم فوزعت على القطع تحت الرئيسية.

أوضحت الدراسة النتائج التالية:-

١- إستخدام ٢٠٠ كجم كبريتات بوتاسيوم / فدان كانت هى المعاملة الأفضل من حيث زيادة المحصول الكلى للفدان مقارنة بالمستويات الأخرى من هذا السماد وقد عكست النتائج نفس الاتجاه بالنسبة للتسميد بالرش باستخدام هيومات البوتاسيوم بتركيز ٥ر١%، أي أن زيادة تركيز هذا السماد قد أدت الي تحسن كمي ونوعى في المحصول، وقد تأكد تباين تأثير التداخل بين نوعي السماد من هذا المنظور.

٢- أوضحت النتائج حدوث زيادة في المحصول الكلي للجذور الدرنية بنحو ١٠%، ١٥% فى موسمى الدراسة على التوالى، عندما استخدم ٢٠٠كجم كبريتات بوتاسيوم/ فدان مع الرش بتركيز ٥ر١% هيومات البوتاسيوم، وذلك مقارنة مع الكنترول الذي تم تسميده باستخدام ٢٠٠كجم كبريتات بوتاسيوم/فدان فقط، ودون رش هيومات البوتاسيوم، فى موسمى الدراسة.

٣- أوضحت النتائج أنه يمكن تخفيض كمية سماد كبريتات البوتاسيوم بنسبة ٢٥% من الجرعة الموصى بها(٢٠٠ كجم للفدان) مع الحفاظ على إنتاجية الفدان وجودة الجذور الناتجة، وذلك من متابعة نتائج نباتات البطاطا المسمدة بكمية ١٥٠ كجم كبريتات بوتاسيوم والتى رشت بهيومات البوتاسيوم بتركيز ٥ر١% أربعة مرات على مدار الموسم.

بناءا على النتائج المتحصل عليها من هذه الدراسة، فإنه يوصى بإستخدام هيومات البوتاسيوم بالرش بنسبة ٥ر١% على نباتات البطاطا المسمدة بـ١٥٠كجم كبريتات البوتاسيوم للحصول على أعلى محصول كلى وجودة عالية.