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EFFECT OF POTASSIUM AND ZINC FERTILIZATION ON GROWTH, NUTRIENTS CONTENTS, YIELD AND QUALITY OF SWEET POTATO PLANT GROWN ON CLAY SOIL

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ABSTRACT

Two field experiments were carried out during the two successive summer seasons 2003 and 2004 in Borg Nor El-Homse village; Aga district (31° 03⁻, 31° 23⁻ and 7 m); Dakahlia Governorate, Egypt, to study the effect of potassium and zinc fertilization on the plant growth, yield, chemical constituents of sweet potato roots [*Ipomoea batatas L. (Lam)*] Abees cultivar.

Potassium fertilizer rates (0, 48 and 96 kg K_2O fed^{-1}) as potassium sulphate (48% K_2O) were arranged in main plots, while foliar application doses of zinc (0, 0.1 and 0.2% Zn fed^{-1}) as zinc sulphate (26% Zn) were subjected in sub-main plots. The studied treatments were in split plot design with three replicates.

The growth parameters (plant height, leaves number, stems number, chlorophyll content and leaf area), yield and yield component, chemical composition and nutrients contents and tuber quality were determined in both seasons.

The increases in growth parameter, resulting from potassium application, were not significant in both seasons except tuber dry matter in the 1st season as well as plant height and vine dry matter in the 2nd season.

Spraying sweet potato with zinc sulphate at a rate of 0.2% increased significantly most growth parameter.

The data obtained revealed that the highest yield of sweet potato tubers and high tubers quality were obtained from the interactions between potassium fertilization at 48 kg K_2O fed^{-1} and zinc foliar application at a rate of 0.2%.

Keywords: Sweet Potato, Potassium, Zinc, Growth, Chemical Composition, Yield, Quality

INTRODUCTION

Sweet potato, [*Ipomoea batatas L. (Lam)*] belongs to the family convolvulaceae. It is cultivated in more than 100 countries and considered to be one of the important energy vegetable crops, especially in tropics and subtropics regions of the world; and ranks 6th or 7th among the most important food crops worldwide (Scott, 1992). The governorates of Alexandria, Behaira, Damietta, Kafr El-Shiekh, Gharbia, Monofiya and Dakahliya are the highest producers of sweet potato in the Nile Delta of Egypt.

Potassium is classified as a macronutrient, as are N and P. While K is not a constituent of any plant structures or compounds, it plays an important role in many important regulatory roles in the plant (Marschner, 1995). It is essential in nearly all processes needed to sustain plant growth and reproduction. It plays a vital role and has many functions in plant growth:- photosynthesis, translocation of photosynthesis and this agree with (Gardener *et al.*, 1985), protein synthesis (Evans and Wildes, 1971), control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes to metabolize carbohydrates for the manufacture of amino acids and proteins, increases root growth (Marschner, 1995) and many other processes. It is generally recognized that K deficiency suppresses plant growth and disturbs many aspects of leaf metabolism, such as carbohydrate concentrations, as well as photosynthetic and translocation rates (Huber, 1984).

Ayoub (1998), El-Denary (1998), Arisha and Bardisi (1999), El-Sawy *et al.*, (2000), Alphonse *et al.*, (2001), and Byju and Ray (2002) indicated that K increased significantly most of growth parameter, yield, chemical composition and quality of sweet potato.

Zinc is very important micronutrient for increasing grain yield in corn and sorghum, as well as onion and spinach. Barley, beets, cucumber, lettuce, soybean, potato, tobacco, and tomato have a medium requirement of Zn. Other crops have a low requirement and very seldom show deficiencies. Also, Zn is an essential component of various enzyme systems, (more than 80 enzymes), for energy production, protein synthesis, growth regulation, prevention of the absorption of and lowering toxicity effect of boron, cadmium and lead, had positive interaction with K, increases of plant stress resistance to salinity, water stress, drought, cold, etc., and is necessary for chlorophyll synthesis and carbohydrate formation. Also, Saif El-Deen (2005) found that foliar application of Zn fertilizer had significant effect on growth, yield, chemical composition and quality of sweet potato.

Therefore, the main objectives of this research were to:-

(i) study the effect of potassium and zinc fertilization and their interactions on growth, yield, quality and chemical composition of sweet potato plants, and **(ii)** determine the optimum needs from potassium and zinc fertilization for producing the highest growth and yield of sweet potato.

MATERIALS AND METHODS

Experimented layout:

Two field experiments were carried out during two successive summer seasons 2003 and 2004 in Borg Nor El-Homse village; Aga district (31˚ 03-, 31˚ 23- and 7 m); Dakahlia Governorate, Egypt, to study the effect of potassium and zinc fertilization on growth and quality of sweet potato roots [*Ipomoea batatas L. (Lam)*] Abees cultivar.

The transplant of sweet potato Abees cultivar was used in this study. The transplanting date was during the 3rd week of April in both seasons (April 16th 2003 and April 22nd 2004 in the 1st and 2nd seasons, respectively). Harvesting was done after 150 days from transplanting in both seasons (August 16th 2003, and August 22nd 2004 for the 1st and 2nd season, respectively).

The experimental design was split plot with 3 replicates. The three levels of K occupied the main plots which were subdivided into three sub-plots each one contained three levels of Zn treatments. The sub plot area was 6.3 m^2 which contained 2 rows, 2.1 m length and 1.5 m width.

Table 1. The main physical and chemical properties of the experimental soil before growing seasons.

Soil character			1st Season 2003	2nd season 2004
Particle size distribution	Coarse Sand%		0.85	0.90
	Fine Sand%		13.15	14.30
	Silt%		24.00	22.73
	Clay%		62.00	62.07
	Texture Class		Clay	Clay
Some physico-chemical properties	HW%		10.93	10.86
	pH* (in 1:2.5 suspension)		7.80	7.60
	EC** $dS\ m^{-1}$		1.78	2.09
	$CaCO_3$%		2.23	2.84
	OM%		2.06	2.70
	SP (saturation%)		88.73	88.84
	FC%		44.37	44.42
	WP%		24.11	24.14
	AW%		20.26	20.28
	Bulk Density ($g\ cm^{-3}$)		1.20	1.30
	Real Density ($g\ cm^{-3}$)		2.64	2.66
	Porosity%		45.45	39.32
Soluble Cations	Ca^{++}	$meq\ L^{-1}$	4.94	6.60
	Mg^{++}	$meq\ L^{-1}$	3.25	3.30
	K^{+}	$meq\ L^{-1}$	0.11	0.27
	Na^{+}	$meq\ L^{-1}$	8.90	9.53
Soluble Anions	CO_3^{-}	$meq\ L^{-1}$	n.d***	n.d***
	HCO_3^{--}	$meq\ L^{-1}$	4.20	5.40
	Cl^{-}	$meq\ L^{-1}$	8.60	9.60
	SO_4^{--}	$meq\ L^{-1}$	4.40	4.70
Available nutrients (ppm)	Nitrogen (N)		70.55	71.86
	Phosphorus (P)		18.80	20.50
	Potassium (K)		390.2	407.8
	Zinc (Zn)		0.88	1.12

*** pH was determined in 1:2.5 soil-water suspension.**
**** EC and soluble ions were determined in soil paste extract.**
***** n.d = not detected**

The experiment included 9 treatments as follows:

1. The1st factor: potassium was applied at three rates **K_1**: 0 kg K_2O fed^{-1} (control), **K_2**: 48 kg K_2O fed^{-1} and **K_3**: 96 kg K_2O fed^{-1} as potassium sulphate, 48% K_2O. Each rate was divided into 2 doses which were added in hills apart from plant.
2. The 2nd factor: zinc was sprayed at three rates **Z_1**: 0 kg Zn fed^{-1} (control), **Z_2**: 0.1% Zn foliar fed^{-1} and **Z_3**: 0.2% Zn fed^{-1} as zinc sulphate, 26% Zn. The rates were divided into 2 doses which were sprayed on the green foliage

The normal cultural practices, for sweet potato commercial production, were followed according to the instruction laid down by the Ministry of Agriculture and land reclamation, Egypt. Other cultural practices such as irrigation which was carried out every 15-20 days and stopped at four weeks before harvesting. weeds, insects and pests control programs were conducted.

Sampling and analysis:

Composite soil sample (0-30 cm) were collected from the experimental field before cultivation and analyzed for the determination of the main physical and chemical properties. The soil was collected before cultivation of the first and second growing seasons.

Particle size distribution was determined by the international pipette method as described by (Piper, 1950), saturation percentage and field capacity of the soil were determined using the method described by (Richards, 1954), available water was calculated by the difference between the filed capacity and permanent wilting point, soil pH was determined in saturated soil paste (Richards, 1954), total soluble salts were determined in saturation extract of soil (Richards, 1954), total carbonate ($CaCO_3$%) was determined by using Collin's calcimeter according to (Piper, 1950), bulk density was determined by using paraffin wax method (Dewis and Freitas, 1970), real density was determined using pycnometer method (Black, 1965), porosity was calculated according to (Hillel, 1972), soil organic matter was determined according to Walkley and Black method (Hesse, 1971), the a concentration of water soluble ions were determined in saturation extract by methods according (Hesse, 1971) as follows:- Ca^{++} and Mg^{++} were determined by the versenate method, Na^+ and K^+ were determined by flame photometer, carbonate and biocarbonate were determined by titration with standardized H_2SO_4 solution, chloride was titrated with silver nitrate and sulfate was determined by the difference between sum of cations and anions, available N (NH_4+NO_3) were extracted using 2.0 M KCl (Hesse, 1971) and determined by magnesium oxide-devarda alloy method using macro-kjeldahl apparatus, available P was determined as described by (Jackson, 1967), available K was determined according to (Hesse, 1971) and available Zn was determined as described by (Cottenie *et al.*, 1982). The main physical and chemical properties of these soils (1st and 2nd growing seasons) are shown in Table 1.

Plant sampling and analysis:

i. ***Vegetative growth*:** After 150 days from transplanting, one plant was randomly collected from each sub plot to measure plant vegetative growth as follow: fresh weight per plant (g $plant^{-1}$), dry weight of shoot per plant, dry weight of roots per plant, dry tuber yield (ton fed^{-1}), dry shoots yield, vine yield (ton fed^{-1}), main vine length (cm), number of branches per plant, number of leaves per plant, leaf area index (LAI, m^2 $plant^{-1}$) according to **(**Koller, 1972), total chlorophyll contents (%) by a Minolta SPAD chlorophyll meter (Yadava, 1986) and tuber weight $plant^{-1}$.

ii ***Yield and yield components*:** Sweet potatoes were harvested after 150 days from transplanting, the weight of all tuber roots of plants grown in each sub plot (12 plants) were measured and the following parameters were recorded: number of storage root per plot, number of storage root per plant, total fresh tuber yield (ton fed^{-1}), dry vine yield (ton fed^{-1}), marketable tuber yield (ton fed^{-1}), non-marketable tuber yield (ton fed^{-1}) and fresh tuber yield (ton fed^{-1}).

iii ***Tuber root trait*:** Tuber root sample (1 storage root) was randomly collected at harvest from each plot and cleaned to determine tuber root traits as follows: average tuber weight, root length (L, cm), root diameter (D, cm) and root shape index (L/D)

iv ***Plant analysis***: The harvested shoots and tuber roots (after 150 days from transplanting) were washed with tap water then by distilled water and oven dried at 70°C to a constant weight. The oven- dried plant materials were finely ground using stainless steel mill and stored for analysis (Chapman and Pratt, 1961). The ground oven dried sample of 0.2 gm was wet digested (Peterburgski, 1968). And Ca and Zn were determined (Chapman and Pratt, 1961). In the digestive solution. Also, total N content (%) was determined as described by Hesse, 1971, total P and K were determined as described by Jackson, 1967 and total Zn was determined as described by Chapman and Pratt, 1961.

The contents of N, P, K, Ca and Zn for different plant parts of sweet potato were calculated by multiplying the concentration of such elements with dry weight of the plant and then transformed per fadden, where were the uptake expressed as ton fed^{-1} for N, P, K, Ca and kg fed^{-1} for Zn.

v ***Tuber quality parameters at harvest*****:** Moisture (%), dry matter (%), and tuber starch content (%) were recorded by formula according to Burton, (1948), where starch content (%) = 17.547 + 0.891 (tuber dry matter) - 24.182. Specific gravity (SG) was determined by the equation according to Burton, (1948). Crude protein content (%) was calculated using conversion factor as multiplying N (%) with 6.25 according to (Ranganna, 1979). Protein yield was calculated by multiplying protein percentages with dry tuber yield, total and reducing sugars (%) were extracted according to the method of Ranganna, (1979) and determined spectrophotometerically as described by Nelson, (1944) with some modifications of (Naguib, 1964).

Vi ***Statistical analysis*****:** The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) and the least significant difference (L.S.D) method was used to compare the deference between the means of treatment values (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

1. Effect of K, Zn and their interactions on growth of Sweet Potato.

Table 2 showed that K application markedly increased all growth parameters of sweet potato. However, these increases were not significant for all parameters in both seasons except tuber dry matter in 1st season as well as plant height and vine dry matter in 2nd season.

It can be noticed that growth parameters increased with increasing K rates and the highest mean values were recorded at the rates of K_2 and K_3 (48 and 96 kg K_2O fed^{-1}) in both seasons. It could be suggested that, the application of medium rate of K_2 was more blenifrcal and more enough for enhancing the growth characters of sweet potato. It is obvious that K involved in several biochemical processes in plant.

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Evans and Wildes (1971) reported that K involved in a number of steps in protein synthesis. The increase in leaves and shoots number due to mineral fertilization might be referred to the favorable effect of N, P and K on the meristematic activity of plant tissues. Similar results were obtained by Nambiar *et al.,* (1976) who reported that sweet potato leaves were expanded and widened by mineral fertilization as a result of the enhancing effect of N, P, and K on the meristematic activity and cell turgidity of leaf tissues.

Gardener *et al.,* (1985) and Mengel and Kirkby (1987) reported that potassium was found to serve a vital role in photosynthesis by direct increasing in growth and leaf area index and hence CO_2 assimilation and increasing the outward translocation of photosynthates, similar conclusion was obtained by Jagridar *et al.,* (1984), Ibrahim *et al.*, (1987), Khalil (1990), Shehata and Abo Sedera (1994), Arisha and Bradisi (1999).

Table 2 show that zinc application increased markedly but not significantly most of sweet potato growth parameters in both seasons. It is worthy to note that, the highest increases of some parameters except vine dry matter of the 1st season and leaf area, vine dry matter and tuber dry matter which were significantly increased with foliar application with Zn_2 (0.1%).On the other hand, the highest mean values were obtained due to spraying plants with Zn_3 (0.2%) for some parameters in the 2nd season.

The positive effect of zinc on plant vegetative growth parameters might be due to its essential role in many important metabolic functions such as transport of carbohydrates, regulation of meristematic activity, photosynthesis, respiration, energy production and protein metabolism. Such functions would directly or indirectly contribute to plant growth (Srivastva and Gupta, 1996).

The obtained results are in harmony with those obtained by Badillo and Lopez (1976) on sweet potato, they found that spraying plants with zinc increased vine growth of plants as compared with the untreated ones. The superiority of Zn foliar application at a rate of 0.1% on tuber dry matter of sweet potato is in agreement with those found by Saif El-Deen, (2005)

The interactions effects between K and Zn on growth parameters of sweet potato were not significant for some parameters in both seasons except plant height, number of leaves, vine dry matter and tuber dry matter in the 1st season and number of stems, number of leaves, leaf area, vine dry matter in the 2nd season which were significantly increased.

It could be concluded that the increase in the vegetative growth, fresh and dry weight of sweet potato by K fertilization is the function of the increase in leaf area, vine length as well as number of leaves and stems. This might be due to the increased photosynthetic activity which was the reflection of the higher net assimilation rate, relative growth rate and crop growth rate of sweet potato plants (Bourke, 1985).

2. Effect of K, Zn and their interactions on yield of sweet potato.

2.1. Yield Components.

Table 3 revealed that potassium fertilization of sweet potato had no significant effect on all parameters of yield components in both seasons except tuber fresh weight which was significant in a 1st season.

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It is clear that K application had a general marked positive trend for tuber fresh weight (g $plant^{-1}$) and root number than the other parameters where K application increased both tuber fresh weight and number of roots in both seasons. The effect of K application on tuber fresh weight was pronounced in 1^{st} season where both rates (K_2 & K_3) increased the tuber fresh weight high significantly than control (K_1).

The marketable of observation indicated that the superiority was due to applying K at the rate of 48 kg K_2O fed^{-1} (K_2) than the rate of 96 kg K_2O fed^{-1} (K_3) where the difference between them did not reach to the level of significance.

The superiority of potassium application on tuber fresh weight in 1^{st} season in comparison with the 2^{nd} season may be attributed to the medium content of available K (390.2 ppm) in the experimental soil of 1^{st} season and the high content (407.8 ppm) of the 2^{nd} season as compared with the criteria (low < 200, medium = 200-400 and high > 400 ppm) of Hamissa *et al.,* (1993).

The obtained mean values of tuber fresh weight were: 259.07, 264.52 and 338.54 and 985.18, 945.10 and 901.52 (g $plant^{-1}$) for the treatments: K_1, K_2 and K_3 in both seasons, respectively. Also, the obtained mean values of root number $plant^{-1}$ at harvest stage (150 DAT) were: 2.49, 2.71 and 3.01 and 5.23, 4.82 and 5.15 for the treatments: K_1, K_2, and K_3 in both seasons, respectively.

Table 3 indicated that the effect of foliar zinc application on yield component was not significant at harvest stage in both seasons except tuber fresh weight and root diameter which significant in the 1^{st} season, while that of tubers F.W. was significant in the 2^{nd} season.

The obtained mean values of tuber fresh weight were: 328.81, 329.03 and 204.29 and 794.94, 978.11 and 1058.75 (g $plant^{-1}$) for the treatments: Zn_1, Zn_2 and Zn_3 in both seasons, respectively. Also, the obtained mean values of root number $plant^{-1}$ at harvest stage (150 DAT) were: 2.97, 3.01 & 2.28 and 4.81, 4.76 & 5.63 for the treatments of Zn_1, Zn_2 and Zn_3 in both seasons, respectively.

The improving effect of Zinc may be resulted from their effect on increasing vegetative growth of plant, which subsequently replicated positively on the physical properties of root tubers.

Table 3 showed that the interactions between potassium fertilization (K), and zinc foliar application (Zn) had significant effects on tubers F.W., root number, root diameter, and root shape for plants grown in the 1^{st} season, which their effects on root length were not significant. On the other hand, the K-Zn interactions on growth parameters were not significant in the 2^{nd} season.

2.2. Fresh and Dry Yield of Vine.

Table 4 demonstrated that increasing potassium fertilization increased markedly and not significant fresh and dry yield of vine of the 1^{st} season and significantly of the 2^{nd} season. On the other hand, there were significant increases of the fresh and dry tuber of the 1^{st} season and only marked but not significant increase in the 2^{nd} season.

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It is obvious that adding potassium fertilizer at rate of 96 kg K_2O fed^{-1} (K_2) increased both fresh and dry yield of vine in comparison with the medium rate of 48 kg K_2O fed^{-1} (K_2) and the differences reached to the level of non significance for fresh and dry yield of sweet potato vine in 1st season. On the other hand, the both deference reached to the level of high significance in 2nd season and the rate of 48 kg K_2O fed^{-1} (K_2) increased both fresh and dry yield of vine in comparison with the high rate of 96 kg K_2O fed^{-1} (K_2).

Table 4 also indicated that foliar application of zinc increased significantly in 1st and in 2nd seasons both fresh and dry yield of vine. The differences between the means for both increasing and decreasing in comparison with control were reached to the level of high significant for fresh vine yield in both seasons and to significant and high significant for dry vine yield in the 1st and 2nd seasons, respectively.

The interactions between potassium fertilization, and foliar application of zinc had a high significant effect on fresh and dry yield of vine in the 1st and 2nd seasons.

2.3. Fresh and Dry Yield of Tubers.

Table 4 demonstrated that increasing potassium fertilization increased significantly fresh and dry yield of tubers in the 1st and 2nd seasons. The differences between the means in comparison with control were found to be highly significant for fresh tubers and dry tubers in 1st season and not significant in 2nd season.

The increase or decrease percentages of tuber yield, due to potassium at both rates of K_2 (48 kg K_2O fed^{-1}) and K_3 (96 kg K_2O fed^{-1}) over control, were 1.96 and 23.4% for tubers fresh yield in the 1st season, -4.23 and -9.27% for tubers fresh yield in the 2nd season, 4.82 and 31.00% for tubers dry yield in the1st season and 4.5 and 4.03% for tubers dry yield in the 2nd season. From these results, it can be observed, increasing the obtained percentages in the 1st season in comparison with the 2nd season and also decreasing the percentages at the high level of potassium (K_3) in the 2nd season. This finding may be attributed to the medium content of K (390.2 ppm) in experiment soil of the1st season and the high content of K (407.8 ppm) in experiment soil of the 2nd season.

It is pronounced from the data that the superiority for the treatment of applying potassium at a rate of 48 kg K_2O fed^{-1} (K_2) in comparison with the high rate of 96 kg K_2O fed^{-1} (K_3) where the differences between them for both fresh and dry yield of tuber in both seasons did not reach to the level of significance. Thus, it can be recommended that by fertilization sweet potato with K at a rate of 48 kg K_2O fed^{-1} (K_2) would procedure the highest fresh and dry tubers yield.

The increases in total yield of storage root which were obtained by potassium fertilization were the sum of the increases in marketable and non-marketable yield. This increase might be due to the increase in number and weight of storage roots of individual plant. The increase in total yield of sweet potato due to K fertilization might be attributed to its favorable effect on the vegetative growth, nutrient content, and DM accumulation throughout plant tissues.

This might be related to the favorable effects of K on the vegetative growth and photosynthetic pigments which possibly increased the efficiency of photosynthesis and resulted in more accumulation of stored food in the tubers. These results are agreeable with those obtained by Arisha and Bardisi (1999) and Abd El-Kader (2002). This increase in dry yield may be attributed to the fact that potassium is required as Co-factor (enzyme activator) for different enzymes.

Table 4 showed the important role of zinc foliar application where both fresh and dry yield of tubers were increased in the 2^{nd} season. The differences between the means reached to the level of high significance for fresh tubers yield.

The obtained data indicated that zinc foliar application, at high level of Zn_3 (0.2%), led to a high fresh and dry tuber yield of sweet potato in the 2^{nd} season and the differences in comparison with both control (Zn_1) and the rate of 0.1% (Zn_2) reached to the level of high significant in both seasons. The non significant differences between the high level of zinc (Zn_3) and both control (Zn_1) and the rate of 0.1% (Zn_2) in the1^{st} season may be attributed to the medium content of available zinc (1.12 ppm) in soil experiment.

Thus, it can be recommended that foliar spraying of zinc at high level of 0.2% (Zn_3) produced the maximum tuber yield. The improving effect of Zn on yield and its components might be attributed to their positive role on enhancing photosynthesis, biosynthesis of proteins and carbohydrate assimilation diverted to the tuber roots (Epstien, 1972). This is in coincidence with the findings of Badillo and Lopez (1976) on sweet potato.

Generally, it is noticed that the highest yield of sweet potato tubers was obtained from the interaction of potassium at 48 kg K_2O fed^{-1} (K_2) and zinc at high rate of 0.2% (Zn_3). Also, it is noticed that the yield increased due to increasing the yield components which were representative in tuber fresh weight and root number $plant^{-1}$.

In conclusion, the study can recommend applying the treatment of interaction $K_2 \times Zn_3$ (48 kg K_2O fed^{-1} x 0.2% Zn) where this interaction produced the highest tuber yield.

3. Effect of K, Zn and their interactions on chemical composition of sweet potato.

Table 5 showed that applying K fertilization decreased the concentration of N, P, and K in vine of sweet potato. This may be attributed to the accumulation of vine dry matte. However, tubers behaved in different ways where application of K_2 rate increased markedly N and P and significant K content in tubers of the 1^{st} season, and increased N, P and K markedly in tubers of the 2^{nd} seasons.

The favorable effect of potassium on chemical constituents of roots might be due to potassium serve to balance the changes of anions and influence their uptake and transport. Potassium also, linked with carbohydrate metabolism and sugar translocation and enhanced the transport of nitrate. Obtained results were similar to those reported by Midan *et al.,* (1987), Das and Behera (1989). Patil *et al.,* (1990), Mukhopadhyay *et al.,* (1993) and Ayoub (1998) on sweet potato.

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Table 5 showed that potassium application decreased Ca concentration in sweet potato vine in both seasons. This may be attributed to the antagonism between K and Ca for uptake by plant. It is also, clear that potassium application decreased Zn concentration in sweet potato vine and tubers in both seasons.

Table 5 showed that zinc application had non significant effect on P and K in vine and tubers in both seasons and decreased significantly Ca in sweet potato vine in both seasons. however, Zn_2 (spraying 0.1%) recorded the highest mean values of N, P, K, Ca and Zn in sweet potato vine especially in the 2^{nd} season.

The data also indicated that spray zinc fertilizer increased significantly Zn concentration in vine and tuber in the 1^{st} season and decreased them in the 2^{nd} season and both of increased and decrease were reached to the level of high significance. It is noticed that the maximum Zn contents were obtained at level of Zn_2 (0.1%) in comparison with the control and Zn_3 (0.2%).

As regards, to the effect of interactions between K-Zn on N, P, K, Ca, and Zn contents in vine and tubers of sweet potato, the data revealed that the effect of interactions were not significant in both seasons for N, P and K but were significant for Ca and Zn in sweet potato vine and tubers which reached the level of high significance in both seasons. This may be attributed to the dry matter accumulation in sweet potato tubers.

These increases in elemental constituents of leaves and tuber roots of sweet potato may be due to the effect of Zn on stimulating biological activities, i.e., enzyme activity, chlorophyll synthesis, rate of translocation of photosynthetic products and increased nutrient uptake through roots after foliar fertilization. The obtained results are in accordance with those of Das and Behera, (1989) and Patil *et al.,* (1990) who found that spraying potato plants with micronutrients significantly increased N, P, K, Ca and Zn concentrations in different plant parts.

4. Effect of Potassium and Zinc Fertilization and their interactions on Quality Parameters of Sweet Potato.

Table 6, 7 showed that increasing K rates significantly increased all forms of sugar concentrations in sweet potato tubers at most treatments in the 1^{st} season in comparison with the 2^{nd} season which were decreased. The finding of decreasing may be attributed to the dilution effect due to increasing tuber growth and yield with increasing potassium fertilization. However, the starch concentration in tubers were almost very close with increasing K rates in the 1^{st} season, and increased significantly in the 2^{nd} season. Also, moisture content was not significant by K application in the 1^{st} season while it is significantly decreased in the 2^{nd} season.

Table 6 showed that foliar application of zinc increased significantly all forms of sugar in tubers of sweet potato in both seasons. The differences between the means reached to the level of high significance. The results reflected the superiority of spraying zinc at 0.1% (Zn_2) where it gave the highest sugar concentrations (all forms) in comparison with the two other treatments in both seasons. Thus, it can be recommended the foliar application of zinc at rate of 0.1% (Zn_2) on sweet potato would produce the highest tuber yield and sugars concentrations.

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Increasing starch in sweet potato tubers increased the absolute amounts in tubers and will be increased due to increasing the yield. Thus, it can be concluded that the treatment for high sweet potato tuber yield and the interactions will result in high amounts of starch as the recommended interaction of potassium at rate of 48 kg K_2O fed^{-1} (K_2) and spraying zinc at rate of 0.2% (Zn_3).

As shown in the Table, all the main factors and their interactions had non significant effects in both seasons on moisture percentage of sweet potato tubers. This may be due to potassium application resulted in relatively high starch contents which led to decrease in moisture content.

Table 7 showed that all the main factors (K, Zn) and their interactions had non significant effects on protein, marketable and non-marketable root number in both seasons while fiber was significant in both seasons while specific gravity was not significant in the1st season and significant in the 2nd season.

Also, data revealed that foliar application of zinc had no significant effect on specific gravity and non marketable root in both seasons while fiber content was significant in both seasons and protein was no significant in the 1st season and significant in the 2nd season while marketable root number was the opposite.

It is worthy to point out that, although decreasing the protein concentration in sweet potato tubers due to the dilution effect (increasing the yield), the absolute amounts of protein in tubers can be increased due to increasing the yield which is resulted from the treatments of K and Zn.

Data in tables showed that in interactions between K and Zn had non significant effect at most quality parameters. However, the interactions between $K_2 \times Zn_3$ recorded the highest mean values for fiber, non and marketable roots in number especially in the 1st season.

SUMMERY AND CONCLUSION

This conclusion study showed that the highest yield of sweet potato tubers and tuber quality were obtained from the interaction of potassium fertilization at 48 kg K_2O fed^{-1} (K_2) and zinc foliar application at a rate of 0.2% (Zn_3).

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تأثير التسميد بالبوتاسيوم والزنك علي نمو ومحتوي العناصر وجودة محصول نبات البطاطا النامي في ارض طينية

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أقيمت تجربة حقلية خلال الموسمين الزراعيين 2003، 2004 بقرية برج نور الحمص - مركز أجا - محافظة الدقهلية لدراسة تأثير التسميد بالبوتاسيوم والزنك علي نمو وامتصاص وجودة ومحصول البطاطا صنف أبيس.

كان التصميم التجريبي المستخدم هو القطع المنشقة مرة واحدة مع 3 مكررات وكانت معاملات التسميد البوتاسي (صفر، 48، 96 كجم K_2O فدان$^{-1}$) في القطع الرئيسية باستخدام سماد سلفات البوتاسيوم (48% K_2O) كإضافة أرضية بينما كانت معاملات الزنك (صفر، 0.1، 0.2% Zn فدان$^{-1}$) في القطع المنشقة وأضيف رشاً باستخدام سماد سلفات الزنك (26% Zn).

أجريت بعض قياسات النمو مثل (طول النبات، عدد السيقان، عدد الأوراق، الكلوروفيل، المساحة الورقية، الوزن الطازج والجاف بالجم نبات$^{-1}$)، قياسات المحصول مثل (المحصول الطازج والجاف بالطن فدان$^{-1}$)، تركيز كل من النيتروجين والفوسفور والبوتاسيوم والكالسيوم والزنك، تحليلات الجودة (النشا، الرطوبة، البروتين، الوزن النوعي، الألياف، السكريات الكلية والمختزلة وغير المختزلة، المحصول التسويقي وغير التسويقي).

وكانت الزيادة في صفات النمو المدروسة نتيجة التسميد بالبوتاسيوم غير معنوية في كلا الموسمين ماعدا المادة الجافة للدرنات في الموسم الأول وكذلك طول النبات والمادة الجافة للعرش في الموسم الثاني. وأدي الرش الورقي لسلفات الزنك بتركيز 0.2% إلي زيادة معنوية في معظم صفات النمو المدروسة.

وعموماً، أثبتت النتائج المتحصل عليها زيادة نمو ومحصول وجودة درنات البطاطا نتيجة التفاعل بين كل من التسميد البوتاسي عند 48 كجم بو2ا فدان$^{-1}$ والرش الورقي بالزنك بتركيز 0.2%.

Table 2. The effect of potassium and zinc application and their interactions on plant height (cm), number of stems, number of leaves, chlorophyll contents, leaf area (m^2 $plant^{-1}$), vine dry matter (g $plant^{-1}$) and tuber dry matter (g $plant^{-1}$) of sweet potato plant at harvest (after 150 days) during the 1st and 2nd seasons.

Treatments	1st Season							2nd Season						
	plant height (cm)	No. of stems	No. of leaves	Chlorophyll Contents	Leaf Area (m^2 $plant^{-1}$)	Vine DM (g $plant^{-1}$)	Tuber DM (g $plant^{-1}$)	plant height (cm)	No. of stems	No. of leaves	Chlorophyll Contents	Leaf Area(m^2 $plant^{-1}$)	Vine DM (g $plant^{-1}$)	Tuber DM (g $plant^{-1}$)
Potassium														
K_1	206.33	16.11	233.00	46.86	1.56	170.34	55.10	190.44	17.44	264.78	46.80	3.81	208.86	237.62
K_2	211.33	16.56	254.44	47.37	2.07	163.09	58.08	202.89	16.33	268.00	47.11	3.70	267.52	248.73
K_3	208.78	17.56	243.44	46.68	2.02	171.04	79.84	190.22	15.33	262.22	46.85	2.98	185.24	247.43
Significance	NS	NS	NS	NS	NS	NS	*	**	NS	NS	NS	NS	**	NS
LSD 5%	-	-	-	-	-	-	16.97	6.38	-	-	-	-	20.95	-
LSD 1%	-	-	-	-	-	-	-	10.58	-	-	-	-	34.75	-
Zinc														
Zn_1	205.89	16.00	238.44	47.74	1.95	154.96	75.04	184.67	14.44	258.33	46.80	4.49	242.15	201.62
Zn_2	213.89	16.89	246.89	46.68	1.91	180.27	66.10	202.11	16.78	272.89	46.78	3.25	192.93	253.20
Zn_3	206.67	17.33	245.56	46.48	1.79	169.24	51.87	196.78	17.89	263.78	47.18	2.75	226.55	278.95
Significance	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	**	**
LSD 5%	-	-	-	-	-	19.59	-	-	-	-	-	1.31	23.64	41.44
LSD 1%	-	-	-	-	-	-	-	-	-	-	-	-	33.15	58.10
Interactions potassium and zinc														
K_1Zn_1	191.00	14.33	259.67	47.11	1.43	134.49	65.93	196.67	13.33	260.67	46.79	4.73	190.75	201.05
K_1Zn_2	223.00	17.00	182.67	47.57	1.26	171.68	68.29	185.67	16.00	280.67	46.81	4.27	190.82	258.30
K_1Zn_3	205.00	17.00	256.67	45.89	1.98	204.85	31.07	189.00	23.00	253.00	46.79	2.42	245.01	253.50
K_2Zn_1	218.67	15.67	196.67	48.81	2.52	148.54	36.16	176.67	16.00	229.33	47.14	6.18	341.12	194.96
K_2Zn_2	193.33	16.33	300.33	46.25	2.16	188.34	65.63	212.67	16.00	307.33	46.00	2.40	195.51	249.51
K_2Zn_3	222.00	17.67	266.33	47.05	1.52	152.40	72.46	219.33	17.00	267.33	48.19	2.51	265.94	301.71
K_3Zn_1	208.00	18.00	259.00	47.29	1.90	181.84	123.03	180.67	14.00	285.00	46.47	2.56	194.58	208.86
K_3Zn_2	225.33	17.33	257.67	46.23	2.30	180.79	64.38	208.00	18.33	230.67	47.53	3.08	192.46	251.80
K_3Zn_3	193.00	17.33	213.67	46.51	1.86	150.48	52.09	182.00	13.67	271.00	46.55	3.31	168.69	281.63
Significance	**	NS	*	NS	NS	**	**	NS	*	*	NS	*	**	NS
LSD 5%	19.92	-	82.59	-	-	33.94	33.33	-	5.45	54.61	-	2.28	40.95	-
LSD 1%	27.93	-	-	-	-	47.58	46.72	-	-	-	-	-	57.41	-

K = Potassium, Zn = Zinc.
K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).
Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).
*** = significant, ** = High significant, NS = Non significant.**

Table 3. The effect of potassium and zinc application and their interactions on tubers fresh weight (g plant^{-1}), root number plant^{-1}, root length (cm), root diameter (cm) and root shape (root length/root diameter) of sweet potato plants at harvest (after 150 days) during the 1st and 2nd seasons.

Treatments	1st Season					2nd Season				
	Tubers FW (g plant^{-1})	Root number plant^{-1}	Root length (cm)	Root diameter (cm)	root shape	Tubers FW (g plant^{-1})	Root number plant^{-1}	Root length (cm)	Root diameter(cm)	root shape
Potassium										
K_1	259.07	2.49	20.13	6.46	3.13	985.18	5.23	22.23	6.91	3.22
K_2	264.52	2.71	19.84	6.88	2.95	945.10	4.82	22.80	6.76	3.44
K_3	338.54	3.06	20.80	6.72	3.13	901.52	5.15	21.98	6.32	3.49
Significance	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD 5%	23.53	-	-	-	-	-	-	-	-	-
LSD 1%	39.02	-	-	-	-	-	-	-	-	-
Zinc										
Zn_1	328.81	2.97	19.71	6.95	2.84	794.94	4.81	22.88	6.75	3.41
Zn_2	329.03	3.01	21.94	7.11	3.14	978.11	4.76	21.44	6.75	3.23
Zn_3	204.29	2.28	19.12	6.00	3.23	1058.75	5.63	22.69	6.49	3.51
Significance	**	NS	NS	**	NS	**	NS	NS	NS	NS
LSD 5%	33.17	-	-	0.64	-	72.81	-	-	-	-
LSD 1%	46.50	-	-	0.89	-	102.09	-	-	-	-
Interactions potassium and zinc										
K_1Zn_1	324.87	3.17	18.60	6.01	3.09	820.54	5.17	22.80	7.16	3.20
K_1Zn_2	306.94	2.75	20.33	6.22	3.29	1074.31	4.53	20.63	6.81	3.03
K_1Zn_3	145.40	1.56	21.47	7.14	3.01	1060.70	6.00	23.27	6.75	3.44
K_2Zn_1	166.11	1.83	20.57	7.33	2.80	781.76	4.44	23.60	6.63	3.55
K_2Zn_2	387.58	3.58	20.53	8.10	2.55	971.90	4.67	21.27	7.20	3.06
K_2Zn_3	239.86	2.72	18.43	5.22	3.51	1081.64	5.36	23.53	6.44	3.69
K_3Zn_1	495.45	3.92	19.97	7.53	2.64	782.51	4.83	22.23	6.45	3.48
K_3Zn_2	292.55	2.69	24.97	7.01	3.58	888.13	5.08	22.43	6.24	3.59
K_3Zn_3	227.62	2.56	17.47	5.63	3.16	1033.91	5.53	21.27	6.28	3.40
Significance	**	**	NS	**	*	NS	NS	NS	NS	NS
LSD 5%	57.45	1.14	-	1.10	0.62	-	-	-	-	-
LSD 1%	80.55	1.60	-	1.55	-	-	-	-	-	-

K = Potassium, Zn = Zinc.
K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).
Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).
*** = significant, ** = High significant, NS = Non significant.**

Table 4. The effect of potassium and zinc application and their interactions on fresh vine (ton fed^{-1}), dry vine (ton fed^{-1}), fresh tubers (ton fed^{-1}) and dry tubers (ton fed^{-1}) of sweet potato plants at harvest (after 150 days) during the 1st and 2nd seasons.

Treatments		1st Season				2nd Season			
		Fresh vine (ton fed^{-1})	Dry vine (ton fed^{-1})	Fresh tubers (ton fed^{-1})	Dry tubers (ton fed^{-1})	Fresh vine (ton fed^{-1})	Dry vine (ton fed^{-1})	Fresh tubers (ton fed^{-1})	Dry tubers (ton fed^{-1})
Potassium									
K_1		31.62	4.26	6.48	1.38	33.83	5.22	24.63	5.94
K_2		33.22	4.08	6.61	1.45	42.99	6.69	23.63	6.22
K_3		34.48	4.28	8.46	2.00	29.64	4.63	22.54	6.19
Significance		NS	NS	**	*	**	**	NS	NS
LSD	5%	-	-	0.59	0.42	5.32	0.52	-	-
	1%	-	-	0.98	-	8.82	0.87	-	-
Zinc									
Zn_1		30.31	3.87	8.22	1.88	37.48	6.05	19.87	5.04
Zn_2		34.28	4.51	8.23	1.65	32.46	4.82	24.45	6.33
Zn_3		34.73	4.23	5.11	1.30	36.51	5.66	26.47	6.97
Significance		**	*	**	NS	**	**	**	**
LSD	5%	1.71	0.49	0.83	-	1.51	0.59	1.82	1.04
	1%	2.40	-	1.16	-	2.12	0.83	2.55	1.45
Interactions potassium and zinc									
K_1Zn_1		23.17	3.36	8.12	1.65	29.19	4.77	20.51	5.03
K_1Zn_2		30.90	4.29	7.67	1.71	33.15	4.77	26.86	6.46
K_1Zn_3		40.80	5.12	3.64	0.78	39.13	6.13	26.52	6.34
K_2Zn_1		31.34	3.71	4.15	0.90	51.34	8.53	19.54	4.87
K_2Zn_2		36.24	4.71	9.69	1.64	33.39	4.89	24.30	6.24
K_2Zn_3		32.07	3.81	6.00	1.81	44.23	6.65	27.04	7.54
K_3Zn_1		36.41	4.55	12.39	3.08	31.90	4.86	19.56	5.22
K_3Zn_2		35.70	4.52	7.31	1.61	30.84	4.81	22.20	6.29
K_3Zn_3		31.33	3.76	5.69	1.30	26.17	4.22	25.85	7.04
Significance		**	**	**	**	**	**	NS	NS
LSD	5%	2.96	0.85	1.44	0.83	2.62	1.02	-	-
	1%	4.16	1.19	2.01	1.17	3.67	1.44	-	-

K = Potassium, Zn = Zinc.
K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).
Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).
*** = significant, ** = High significant, NS = Non significant.**

Table 5. The effect of potassium and zinc application and their interactions on N, P, K, Ca and Zn concentration of sweet potato vine and tubers at harvest (after 150 days) during 2003 and 2004 seasons.

Treatments	1st Season										2nd Season									
	N (%)		P (%)		K (%)		Ca (%)		Zn (ppm)		N (%)		P (%)		K (%)		Ca (%)		Zn (ppm)	
	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber	Vine	Tuber
Potassium																				
K_1	3.16	1.41	1.19	0.37	5.28	1.58	0.99	0.53	317.42	197.67	2.76	1.50	1.04	0.31	4.52	1.96	1.06	0.25	278.25	219.42
K_2	2.93	1.40	1.18	0.45	5.38	1.79	0.84	0.29	299.92	247.83	2.73	1.60	1.12	0.31	5.08	2.10	1.36	0.27	258.17	189.42
K_3	3.33	1.16	1.19	0.30	5.05	1.58	0.89	0.47	317.83	218.08	2.73	1.44	1.06	0.36	4.98	2.06	0.99	0.25	291.58	194.50
Significance	NS	NS	NS	NS	NS	*	NS	*	**	**	NS	NS	NS	NS	NS	NS	**	NS	**	**
LSD 5%	-	-	-	-	-	0.15	-	0.15	0.15	0.15	-	-	-	-	-	-	0.15	-	0.15	0.15
LSD 1%	-	-	-	-	-	-	-	-	0.25	0.25	-	-	-	-	-	-	0.25	-	0.25	0.25
Zinc																				
Zn_1	3.38	1.37	1.18	0.34	5.38	1.64	0.99	0.41	312.92	259.67	2.76	1.43	1.10	0.36	4.92	2.00	1.02	0.25	271.17	213.50
Zn_2	2.70	1.25	1.10	0.43	5.05	1.73	0.92	0.43	322.33	208.42	2.83	1.34	1.12	0.35	5.03	2.03	1.28	0.28	281.75	199.33
Zn_3	3.35	1.35	1.28	0.34	5.27	1.57	0.81	0.45	299.92	195.50	2.64	1.78	1.01	0.27	4.64	2.09	1.11	0.24	275.08	190.50
Significance	*	NS	NS	NS	NS	NS	**	NS	**	**	NS	*	NS	NS	NS	NS	**	NS	**	**
LSD 5%	0.49	-	-	-	-	-	0.06	-	0.06	0.06	-	0.34	-	-	-	-	0.06	-	0.06	0.06
LSD 1%	-	-	-	-	-	-	0.09	-	0.09	0.09	-	-	-	-	-	-	0.09	-	0.09	0.09
Interactions potassium and zinc																				
K_1Zn_1	3.28	1.54	1.24	0.40	5.46	1.61	1.04	0.71	316.50	204.50	2.85	1.29	1.05	0.40	4.73	1.94	1.13	0.18	261.50	244.25
K_1Zn_2	2.76	1.34	1.09	0.41	5.24	1.60	1.22	0.44	318.50	193.50	3.08	1.25	1.33	0.33	5.04	2.04	0.95	0.36	269.50	206.25
K_1Zn_3	3.42	1.36	1.22	0.29	5.15	1.52	0.71	0.45	317.25	195.00	2.33	1.97	0.75	0.19	3.79	1.91	1.09	0.21	303.75	207.75
K_2Zn_1	2.92	1.38	1.01	0.34	5.44	1.67	0.74	0.23	288.75	308.00	2.61	1.74	1.17	0.28	5.00	1.95	0.83	0.35	276.00	199.00
K_2Zn_2	2.47	1.22	1.16	0.48	5.19	1.89	0.72	0.32	329.50	224.00	2.81	1.13	1.05	0.38	4.97	2.00	1.86	0.18	250.75	191.25
K_2Zn_3	3.40	1.59	1.37	0.52	5.50	1.80	1.06	0.33	281.50	211.50	2.79	1.93	1.15	0.26	5.28	2.37	1.39	0.27	247.75	178.00
K_3Zn_1	3.92	1.18	1.29	0.29	5.24	1.63	1.18	0.30	333.50	266.50	2.81	1.25	1.07	0.40	5.02	2.11	1.10	0.21	276.00	197.25
K_3Zn_2	2.85	1.18	1.04	0.40	4.73	1.71	0.81	0.54	319.00	207.75	2.61	1.63	0.98	0.34	5.06	2.05	1.03	0.30	325.00	200.50
K_3Zn_3	3.22	1.11	1.25	0.22	5.17	1.39	0.68	0.57	301.00	180.00	2.79	1.45	1.11	0.34	4.86	2.01	0.84	0.23	273.75	185.75
Significance	NS	NS	NS	NS	NS	NS	**	**	**	**	NS	NS	NS	NS	NS	NS	**	**	**	**
LSD 5%	-	-	-	-	-	-	0.11	0.11	0.11	0.11	-	-	-	-	-	-	0.11	0.11	0.11	0.11
LSD 1%	-	-	-	-	-	-	0.15	0.15	0.15	0.15	-	-	-	-	-	-	0.15	0.15	0.15	0.15

K = Potassium, Zn = Zinc.

K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).

Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).

*** = significant, ** = High significant, NS = Non significant.**

Table 6. The effect of potassium and zinc application and their interactions on moisture percentage total sugar (mg 100 g^{-1}), reduced sugar (mg 100 g^{-1}), non-reduced sugar (mg 100 g^{-1}) and starch concentration of sweet potato tubers at harvest (after 150 days) during the 1st and 2nd seasons.

Treatments	1st Season					2nd Season				
	Moisture (%)	Total sugar (mg 100 g^{-1})	Reduced sugar (mg 100 g^{-1})	Non-reduced sugar (mg 100 g^{-1})	Starch (%)	Moisture (%)	Total sugar (mg 100 g^{-1})	Reduced sugar (mg 100 g^{-1})	Non-reduced sugar (mg 100 g^{-1})	Starch (%)
Potassium										
K_1	78.50	38.98	0.47	38.51	25.35	75.81	45.83	0.53	45.31	25.49
K_2	77.04	43.66	0.47	43.19	25.43	73.82	28.82	0.30	28.52	25.60
K_3	76.79	50.30	0.54	49.76	25.44	72.43	32.00	0.36	31.64	25.68
Significance	NS	**	*	**	NS	*	**	**	**	*
LSD 5%	-	0.06	0.06	0.06	-	1.62	0.06	0.06	0.06	0.09
LSD 1%	-	0.09	-	0.09	-	-	0.09	0.09	0.09	-
Zinc										
Zn_1	79.88	36.73	0.49	36.24	25.40	74.19	35.81	0.38	35.43	25.57
Zn_2	74.37	50.16	0.56	49.60	25.29	73.58	38.98	0.42	38.57	25.59
Zn_3	78.09	46.05	0.43	45.61	25.53	74.30	31.86	0.39	31.47	25.62
Significance	NS	**	**	**	NS	NS	**	*	**	NS
LSD 5%	-	0.02	0.02	0.02	-	-	0.02	0.02	0.02	-
LSD 1%	-	0.03	0.03	0.03	-	-	0.03	-	0.03	-
Interactions potassium and zinc										
K_1Zn_1	79.54	40.07	0.45	39.61	25.29	75.61	51.48	0.61	50.87	25.50
K_1Zn_2	77.78	36.64	0.59	36.04	25.39	75.90	52.07	0.55	51.51	25.49
K_1Zn_3	78.17	40.23	0.36	39.86	25.37	75.92	33.95	0.42	33.54	25.49
K_2Zn_1	82.97	34.14	0.50	33.63	25.37	74.44	28.18	0.20	27.98	25.54
K_2Zn_2	70.15	40.00	0.47	39.53	25.11	72.07	26.66	0.30	26.36	25.57
K_2Zn_3	78.01	56.84	0.42	56.42	25.80	74.96	31.61	0.40	31.21	25.70
K_3Zn_1	77.12	35.98	0.50	35.48	25.53	72.53	27.77	0.34	27.43	25.66
K_3Zn_2	75.17	73.84	0.61	73.23	25.37	72.75	38.23	0.40	37.83	25.70
K_3Zn_3	78.08	41.07	0.51	40.56	25.42	72.00	30.00	0.34	29.66	25.67
Significance	NS	**	**	**	NS	NS	**	**	**	NS
LSD 5%	-	0.04	0.04	0.04	-	-	0.04	0.04	0.04	-
LSD 1%	-	0.06	0.06	0.06	-	-	0.06	0.06	0.06	-

K = Potassium, Zn = Zinc.
K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).
Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).
*** = significant, ** = High significant, NS = Non significant.**

Table 7. The effect of potassium and zinc application and their interactions on protein concentration, fiber percentage, specific gravity (SG), non-marketable roots number plant^{-1} and marketable roots number plant^{-1} of sweet potato tubers at harvest (after 150 days) during the 1st and 2nd seasons.

Treatments	1st Season					2nd Season				
	Protein (%)	Fiber (%)	Specific gravity (SG)	Non-marketable roots number plant^{-1}	Marketable roots number plant^{-1}	Protein (%)	Fiber (%)	Specific gravity (SG)	Non-marketable roots number plant^{-1}	Marketable roots number plant^{-1}
					Potassium					
K_1	8.83	2.67	1.190	0.81	1.69	9.39	1.83	1.202	1.74	3.49
K_2	8.73	2.50	1.196	0.94	1.77	10.01	2.17	1.210	1.59	3.23
K_3	7.22	3.00	1.197	1.15	1.91	9.01	2.33	1.216	1.83	3.31
Significance	NS	*	NS	NS	NS	NS	*	*	NS	NS
LSD 5%	-	0.29	-	-	-	-	0.29	0.01	-	-
LSD 1%	-	-	-	-	-	-	-	-	-	-
					Zinc					
Zn_1	8.54	2.33	1.194	0.98	1.99	8.92	1.83	1.207	1.75	3.06
Zn_2	7.79	2.83	1.185	1.00	2.01	8.35	2.00	1.209	1.64	3.12
Zn_3	8.45	3.00	1.204	0.92	1.36	11.14	2.50	1.211	1.78	3.85
Significance	NS	**	NS	NS	*	*	**	NS	NS	NS
LSD 5%	-	0.30	-	-	0.49	2.13	0.30	-	-	-
LSD 1%	-	0.43	-	-	-	-	0.43	-	-	-
					Interactions potassium and zinc					
K_1Zn_1	9.63	2.00	1.19	0.94	2.22	8.07	1.50	1.20	1.64	3.53
K_1Zn_2	8.35	3.50	1.19	0.83	1.92	7.79	2.00	1.20	1.67	2.86
K_1Zn_3	8.50	2.50	1.19	0.64	0.92	12.32	2.00	1.20	1.92	4.08
K_2Zn_1	8.64	2.50	1.19	0.53	1.31	10.90	2.00	1.21	1.75	2.69
K_2Zn_2	7.65	2.00	1.17	1.28	2.31	7.08	2.00	1.21	1.53	3.14
K_2Zn_3	9.91	3.00	1.23	1.03	1.69	12.04	2.50	1.22	1.50	3.86
K_3Zn_1	7.36	2.50	1.20	1.47	2.44	7.79	2.00	1.21	1.86	2.97
K_3Zn_2	7.36	3.00	1.19	0.89	1.81	10.19	2.00	1.22	1.72	3.36
K_3Zn_3	6.94	3.50	1.20	1.08	1.47	9.06	3.00	1.22	1.92	3.61
Significance	NS	**	NS	**	*	NS	NS	NS	NS	NS
LSD 5%	-	0.53	-	0.42	0.84	-	-	-	-	-
LSD 1%	-	0.74	-	0.59	-	-	-	-	-	-

K = Potassium, Zn = Zinc.
K_1 (control, without potassium), K_2 (48 kg K_2O fed^{-1} as K_2SO_4), K_3 (96 kg K_2O fed^{-1} as K_2SO_4).
Zn_1 (control, without zinc), Zn_2 (0.1% Zn fed^{-1} as zinc sulphate), Zn_3 (0.2% Zn fed^{-1} as zinc sulphate).
*** = significant, ** = High significant, NS = Non significant.**