Influence of Application Systems of K_2SO_4 and Foliar Application of Micronutrient Mixtures on Cassava Grown in Sandy Soil

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ABSTRACT

The effect of the application systems of K_2SO_4 and foliar application of micronutrient mixtures levels on growth, yield and quality of cassava (Indonesian, cv) was studied at Experimental Farm of South Tahrir Horticulture Research Station, at Ali Mubarak Village, EL-Bostan region, Behera, Egypt during 2012/2013 and 2013/2014 seasons. The experimental design used was the split plot system in randomized complete block design with 3 replications. Cassava plant that receiving five equal doses of K_2SO_4 gave the highest values of plant height, number of leaves and number of branches plant^{-1}, root weight, root length, root diameter, total yield plant^{-1} and total yield fad^{-1}, as well as tuberous root dry matter, root starch, and total sugar of root. The results also showed that, increasing of the micronutrients mixture levels concentrations up to 30 % were gradually increased the productivity of cassava plants. In addition, tuberous root quality; dry matter %, starch %, and total sugar as well as elements contents; N, K, Zn, Mn, Fe and Cu showed positive response to various micronutrients mixtures levels. The combination treatment application system of K_2SO_4 at five equal doses + foliar application of micronutrient mixture levels at the rate of 20 or 30 % gave the highest values of vegetative growth, total tuberous root yield (kg plant^{-1}and ton fed^{-1}), tuberous root quality and chemical constituents characters of cassava plants.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the fourth of most important source of food energy in the tropics regions (Abdullahi *et al.,* 2014).Cassava is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root and as a major source of carbohydrates (Kenneth, 2011). The crop is a low cost production and is one of the cheapest foods (Shams, 2011). The future demand for fresh cassava may depend on improved storage methods. The markets for cassava as a substitute for cereal flours in bakery products and as source in animal feed rations are likely to expand. The use of cassava as a source of ethanol for fuel depends on finding an efficient source of energy for distillation or an improved method of separating ethanol from water (Cock,1982*)*. Cassava only realizes its high yield potential when it is supplied with adequate light, nutrients and water. Cassava extracts large amounts of K in the root harvest and K deficiency becomes the most limiting nutrition factor, especially in sandy soil, if it is grown continuously without adequate K fertilization.

Potassium ions (K^+) are highly soluble and will easily leached from sandy soils because sandy soils do not contain enough colloids (Datnoff *et al*., 2007) ; clay and organic matter to hold K^+. Wherefore, these soils require precise annual K^+ application through the addition of K^+ on several doses, since it is not possible to build up high potassium reserves in the sandy soil. Potassium (K^+) in plants has a special role in carbohydrate synthesis and its translocation, as it also regulate the balance between assimilation and respiration in a way that improves net assimilation (Imas and John, 2013). K^+ is required for numerous plant growth processes (Donald *et al*., 1998). Moreover, K^+ plays an important role in the synthesis of amino acid and protein as well as translocation of sugar and assimilates within the plant as well as the accumulation of high molecular carbohydrate (Yagodin 1982; Archer, 1985). In addition, it has active the enzymes involved in biosynthesis of organic acid (Evans and Sorger, 1996), as well as accelerating translocation of carbohydrate necessary for fruit formation and development (Marschner,1986) which leads to increase plant growth and yield. The application of potassium (80 kg ha^{-1}) had positive effects on growth parameter (plant height and number of branches, gave the optimum yield and its components of cassava (Uwah *et al*., 2013; Taufiq *et al*., 2012) and enhances tuber root yield and quality (Boateng and Boadi, 2010). Adekayode and Adeola (2009) found that increasing potassium rate to 120 kg ha^{-1} resulted in higher cassava yield. Potassium fertilization improve starch and quality parameters of cassava tuberos root (Nair and Aiyer,1986). Parkes *et al*., (2012) reporter that the higher percent starch content in cassava tuberos root of Tuaka F2 genotype was achieved with fertilizers rate (120N – 60 P_2O_5 – 180 K_2O kg ha^{-1}).

Micronutrient such as manganese (Mn) zinc (Zn) and iron (Fe) are essential for plant growth, crop yield, and its quality, they play an important role in balance crop nutrition (Mousavi *et al*., 2011). Manganese is one of the main micronutrients, which has an important role in plant as a component of enzymes involved in photosynthesis and other processes (Mousavi *et al*.,

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2011). Foliar fertilizer treatment with zinc, magnesium and sulfur, it had grater effects on yield and quality of cassava root (Panitnok *et al.,* 2013). Ahmed *et al.* (2011) indicated that foliar application of zinc stimulated the vegetative growth characters, improved tuber quality and increased the productivity of potato plants. Moreover, Zn and Mn application increased the tuber yield and its quality of potato (Mousavi *et al.,* 2007). On the other hand, iron function in the synthesis of chloroplast protein and thus may interfere with chlorophyll synthesis. Copper acts as a component of phenolases and ascorbic acid (enzymes), and its role as a part of these enzymes (Fred, 1983).

The present study conducted to explore the effect of the application systems of K_2SO_4 and foliar application of micronutrient mixture on the growth, tuberous root yield and quality of cassava, under sandy soil.

MATERIALIS AND METHODS

The present study was conducted at the experimental farm of South Tahrir Horticulture Research Station, at the Ali Moubarak village, El-Bostan region, Behera, Egypt during the agricultural seasons of 2012/2013 and 2013/2014, to study the effect of the application systems of K_2SO_4 and foliar application of micronutrient mixture on the growth, tuberous root yield and quality of cassava. Prior to the initiation of the investigation, in each season, soil samples from the soil surface of the two experimental sites up to 40 cm depths were collected and analyzed for some chemical and physical properties according to the standard procedures of (Black,1983). Results of analysis are presented in Table 1. Soil of the two experimental sites was newly reclaimed poor, deep and well drained sandy soil with a pH ranged from 8.32 to 8.4. During field preparation, chicken manure was incorporated under drip irrigation lines at rate of 10 m^3 fad^{-1}. Drip irrigation system was used in both experiments.

Cassava cv. Indonesian characterized with high dry matter, good maleness and ground storability and well adapted to Egyptian environmental conditions as well as can also bulk early and easy to process. Healthy cassava stem cuttings (middle internodes) 20–25 cm length with about 5–7 nodes were chosen. To overcome stem-borne pests stem cuttings were treated by dipping them in a dilute fungicide solution (Vitavax 75%) and transplanted vertically, on April 20^{th} in both growing seasons, on the both sides of the GR drip irrigation lines at ridges 1m width and 1 meter apart from each other.

The experimental design used was split-plot system in a randomized complete block design (RCBD) with three replications. Main plots were consisted of three application systems of K_2SO_4 treatments (three equal doses (at 60,90 and 120 days after transplanting (DAT), four equal doses (at 60,90,120 and 150 DAT) and five equal doses (at 69,90,120,150 and 180 DAT), at rate 100 kg K_2O fed^{-1}. While, sub-plots were devoted to foliar application of micronutrient mixtures with four concentrations (0, 10, 20 and 30%). Each sub-plot having area of 10 m^2. The mixture of micronutrients (Fe + Zn + Mn + Cu) added as Fe-EDTA (6% Fe), Zn-EDTA (15% Zn), Mn-EDTA (12% Mn), and CuSO4.5H2O (25.45 % Cu) with three different concentrations (0, 10, 20 and 30 g 100 L^{-1} H_2O) of the mixture. Cassava plants were sprayed with micronutrients solution during the growing seasons, at 60, 90,120, 150 and 180 DAT at rate 200 L^{-1} H_2O fad^{-1} (Pathleen *et al.,* 2011). The recommended cultural practices for commercial cassava production were followed. Irrigation was daily achieved according to the applied irrigation water quantity.

Nitrogen, phosphorus and potassium fertilizers were fertigated at rates of 180, 70 and 100 kg N, P_2O_5 and K_2O fad^{-1}, respectively as ammonium nitrate (33.5%N), phosphoric acid (58%) and potassium sulfate (48 %), respectively.

Harvesting was carried out when the cassava leaves tops became pale green and exhibits some necrosis of the tissue, which is usually a good indicator of harvest maturity. This appearance was corresponding to the harvest doses after 6-18 months (Bokanga, 1999, Pathleen *et al*., 2011).

Data recorded

The cassava plants reached sufficient size for this variety after about 280 days. Prior to harvest, five plants were pulled from each experimental unit to measure the vegetative growth characters; plant height, number leaves $plant^{-1}$ and number of main branches $plant^{-1}$. In addition, cassava tuberous root characters such as average root weight (g), root length (cm), root diameter (cm).Yield and its components such as number of tuber roots $plant^{-1}$, total tuber yield kg $plant^{-1}$, total tuber yield ton fad^{-1} were determined. The harvested tuber roots were cured by drying. Tubers roots random sample (five roots) from each experimental unit were dried in oven at 70^0 C up to constant weight and then dry matter (%) was determined.

Chemical constituents of cassava tuberous roots

Total sugar ($mg.g^{-1}$.d.w) of each sample was determined according to Malik and Singh, 1980 and % starch (A.O.A.C, 1990) methods. Nitrogen, phosphorus and potassium were determined as described by (Evenhuis, 1976, Murphy and Riley, 1962 and Jackson, 1967), respectively. Zn, Mn, Fe and Cu concentration (ppm) were measured by atomic absorption.

Table 1. Some chemical and physical characteristics of the soil at Ali Moubarake experimental farm in the two growing seasons

Characteristics	Growing Season			
	2012/ 2013		2013/ 2014	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
EC, dS m^{-1}	0.35	0.29	0.39	0.30
pH (1:2.5)	8.32	8.28	8.38	8.40
OM; %	0.21	0.13	0.25	0.16
$CaCO_3$; %	5.35	5.28	5.36	5.54
$NO_3 + NH_4$; µg g^{-1}	31.30	40.50	39.60	42.15
Exch.-K; µg g^{-1}	128.20	102.70	115.70	100.30
$NaHCO_3$-P; µg g^{-1}	8.44	5.92	10.80	7.20
DTPA-Fe; µg g^{-1}	4.50	nd*	3.99	Nd
DTPA-Zn; µg g^{-1}	0.95	Nd	0.92	Nd
DTPA-Mn; µg g^{-1}	2.76	Nd	2.71	Nd
DTPA-Cu; µg g^{-1}	0.85	Nd	0.82	Nd
Sand; %	93.10	92.90	91.9	92.75
Soil texture class	Sandy	Sandy	Sandy	Sandy

* nd = not determined

Statistical analysis

All obtained data, were arranged and statistically analyzed, using M-statc software computer program according to (Freed,1988). The comparisons among the different treatments' means were detected using Duncan's multiple ranged test (L.S.R), as illustrated by (Steel and Torrir, 1984).

RESULTS AND DISCUSSION

Vegetative growth characters

Concerning the effects of three application systems of K_2SO_4 on the studied vegetative growth characters of cassava plants, the results illustrated that the gradual increment of K_2SO_4 up to five equal doses resulted in significant corresponding increases on plant height of cassava plants. In addition, cassava plants that received K_2SO_4 up to five equal doses increased significantly the number of branches plant^{-1} in the second season (Table, 2).

The obtained results appeared that increasing the levels of the chelated mixture of micronutrients up to 30% were associated with marked and significant stimulating effects for plant height, number of leaves and branches plant^{-1} ,in both studied seasons.

Table (2) shows the comparisons among the means of treatment combinations between application systems of K_2SO_4 and chelated mixture of micronutrients rates. The comparisons illustrated that, the effect of chelated mixture of micronutrients rates on the vegetative growth characters appeared clear with the three application systems of K_2SO_4. Where, cassava plants receiving five equal doses of K_2SO_4 + 30% of chelated mixture of micronutrients caused the highest significant increase in the plant height, number of leaves and branches plant^{-1}, in two experiments.

Tuberous root characters

Data in (Table 2) indicated clearly that tuberous root characters (weight, length and diameter of root) positively responded to application systems of K_2SO_4 from three to five equal doses of K_2SO_4 in the two studied seasons. Cassava plants receiving five equal doses of K_2SO_4 recorded significant maximum increments in all tuberous root characters.

Foliar application of micronutrients chelated mixtures significantly increased cassava tuberous root characters compared with control treatment, in both growing seasons (Table 2). Cassava plants that sprayed with the micronutrients chelated mixtures at rate 20% achieved highest increase in the root weight in both seasons and tuberous root length in the second only. Whereas, cassava plants received micronutrients chelated mixtures at rate 30% appeared highest increment in the tuberous root diameter, in both seasons.

The interaction effects between application systems of K_2SO_4 and foliar application of micronutrients mixtures on the tuberous root characters were found to be significant, in both seasons (Table 3).

Table 2. Vegetative growth characters of cassava plants, grown in sandy soil, as influenced by application systems of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014

Characters / Treatment: K_2SO_4 doses	Micro nutrients level	Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}	Plant height (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}
		Season 2012/2013			Season 2013/2014		
Three		121.67 b	93.83 a	3.16 b	99.58 c	90.00b	2.91 b
four		131.25 a	98.50 a	3.75 ab	120.83b	95.25a	2.82 b
Five		139.17 a	93.00 a	3.50 b	127.50a	93.50a	3.12 a
	10%	132.78 b	94.78 b	2.89 bc	115.00 c	92.56 b	2.81 c
	20%	136.67ab	101.56ab	3.49 ab	121.67 b	96.89 a	3.17 b
	30%	145.00 a	104.11 a	3.82 a	127.22 a	98.22 a	3.32 a
Cont		108.33 c	86.00 c	2.36 c	100.00 c	84.11 c	2.49 d
Three	10%	123.33de	90.00 cd	2.14 ef	95.00 cd	86.67 d	2.80 cd
	20%	130.00 cd	100.00ab	2.52 cd	105.00ab	98.67 a-c	3.13 ab
	30%	140.00 b	101.00ab	2.78 b	115.00ab	92.67 c	3.30 ab
	Cont	93.33 g	84.33d	2.00 f	83.33d	82.33 d	2.40 e
Four	10%	133.33 bc	99.33d	2.39 d	120.00ab	97.67 a-c	2.53 de
	20%	138.33 bc	102.67ab	2.43 cd	126.67ab	96.67 a-c	3.03 bc
	30%	141.67 b	105.00a	2.80 b	130.00a	100.33ab	3.27 ab
	Cont	111.67 f	87.00 d	2.23 e	106.67d	86.33 d	2.43 e
Five	10%	141.67 b	95.00 bc	2.96 a	130.00bc	93.33 c	3.10 ab
	20%	141.67 b	102.00ab	3.10 a	133.33ab	95.33 bc	3.33 ab
	30%	153.33 a	106.33 a	3.10 a	136.67a	101.67 a	3.40 a
	Cont	120.00 ef	86.67 b	2.57 c	110.00d	86.67 d	2.63 de

The most significant results for the tuberous root weight, root length and root diameter were attained due to the combined five equal doses of K_2SO_4 with foliar application of micronutrients mixtures at rate 30%.

Tuberous roots yield

Cassava plants receiving five equal doses of K_2SO_4 achieved a significantly higher number of tuberous roots per plant, tuberous roots yield plant^{-1} and total yield fed^{-1} compared to cassava plants receiving three equal doses of K_2SO_4, in both seasons (Table 4).

Increasing rate of micronutrients mixture level up to 20% significantly increased the number of tuberous roots per plant, tuberous roots yield plant^{-1} and total yield fad$^{-1,}$ over the cassava plants in the control, in both growing seasons (Table 4).

The results in (Table 4) showed some significant differences with respect the interaction effects between various application systems of K_2SO_4 and foliar application of micronutrients mixtures. The comparisons between the mean values of the different treatments combination indicated that, at any application systems of K_2SO_4 treatment, foliar application of micronutrients mixtures, significantly, increased the number of tuberous roots per plant, tuberous roots yield plant^{-1} and total yield fed^{-1}compared with the control treatment. The best significant result for the number of tuberous root plant^{-1} was attained due to the combined application of five equal doses of K_2SO_4 with foliar application of micronutrients mixtures up to 30%, in both seasons.

Meanwhile, it was also noticed that the highest mean values of tuberous roots yield plant^{-1} and total yield fed^{-1} were recorded as a result of the application of five equal doses of K_2SO_4 with foliar application of micronutrients mixtures up to 20%, in both seasons.

Chemical constituents of cassava tuberous roots

Results in (Table 5) showed that increasing doses of K_2SO_4 from three to five doses were associated with marked and significant stimulating effects on chemical constituents of cassava tuberous roots; dry matter, starch and total sugar, in both growing seasons.

Results of (Table 5) showed that foliar application of micronutrient mixtures up to 30 % resulted in the highest significant effect on the chemical constituents of cassava tuberous roots; root dry matter (%), starch (%) and total sugar (mg.g^{-1} d. w), in both studied seasons.

Comparisons among the mean values of various treatment combinations in (Table 5), reflected clear progressive and significant influences for application systems K_2SO_4 treatments with foliar application of micronutrients mixtures on the chemical constituents of cassava roots, in both studied seasons. The best significant results for the chemical constituents of cassava tuberous roots; root dry matter (%), starch (%) and total sugar (mg.g^{-1} d.w), were attained due to the combined application of five equal doses of K_2SO_4 with foliar application of micronutrients mixtures up to 30%, in both seasons.

NPK content of cassava tuberous roots

The obtained results in (Table 6) showed that application systems of K_2SO_4 up to five equal doses had a significant effect on the K content of cassava tuberous roots, in both growing seasons. However, cassava plants with supply of equal doses of K_2SO_4 gave a significantly higher P content of tuberous roots, in the first season only.

Table 3. Tuberous root characters of cassava plants, grown in sandy soil, as influenced by application system of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014.

Characters / Treatment: K_2SO_4 doses	Micro nutrients level	Root weight (g)	Root length (cm)	Root diameter (cm)	Root weight (g)	Root length (cm)	Root diameter (cm)
		Season 2012/2013			Season 2013/2014		
Three		384.17 c	24.49 b	4.14 c	368.11 c	23.08 c	3.99 c
four		418.40 b	25.71 b	4.28 b	400.22 b	24.52 b	4.14 b
Five		499.26 a	27.86 a	4.38 a	475.27 a	25.82 a	4.25 a
	10%	447.42 a	25.66 bc	4.29 b	422.64 b	24.27 b	4.13 a
	20%	465.37 a	26.81 ab	4.40 a	445.36 a	25.26 a	4.26 a
	30%	461.18 a	27.22 a	4.42 a	435.86 ab	25.11 a	4.42 a
	Cont.	361.80 b	24.39 c	3.96 c	354.26 c	23.27 c	3.88 b
Three	10%	399.12 d	24.70 c-d	4.17 e	370.75 ef	23.33 ef	4.00 cd
	20%	399.02 d	24.77 c-d	4.23 e	380.52 de	23.17 ef	4.10 bc
	30%	413.81 cd	25.00 c-d	4.27 de	378.83 de	23.50 d-f	4.07 cd
	Cont.	324.74 e	23.50 e	3.90 g	342.31 fg	22.33 f	3.80 e
Four	10%	431.03b-d	25.10 c-d	4.23 e	413.78b-d	42.1 c-e	4.10 bc
	20%	458.71 b	26.17 b	4.37cd	440.18 b	24.87 b-d	4.30 a
	30%	445.6 bc	27.33 b	4.47 cd	426.92 bc	25.90 b	4.27 ab
	Cont.	338.25 e	24.23 de	4.03 f	319.99 g	23.23 ef	3.90 de
Five	10%	512.11 a	27.17 b	4.47 bc	483.39 a	25.37 bc	4.30 a
	20%	538.38 a	29.50 a	4.60 a	515.38 a	27.73 a	4.37 a
	30%	524.13 a	29.33 a	4.53 ab	501.84 a	25.93 b	4.40 a
	Cont.	422.4cd	25.93 cd	3.93 fg	400.47c-e	24.23 c-e	3.93 c-e

Table (6) shows that foliar application of micronutrients mixtures up to 30% level, generally, significant increased N and K contents of cassava tuberous roots but decreased P content of cassava tuberous roots, in both studied seasons.

Concerning the interaction effect of application systems of K_2SO_4 and the micronutrients mixtures on NPK contents of cassava tuberous roots, were significant in both seasons (Table 6). Cassava plants that received five equal doses of K_2SO_4 with foliar application of micronutrients mixtures up to 30% level, gave the highest mean values of N and K contents and lowest P content of cassava tuberous roots, in both seasons.

Micro-elements content of cassava tuberous roots

Data presented in (Table 7) indicated clearly that, increasing doses of K_2SO_4 up to five doses, to the growing cassava plants, led to progressive significant increases in macro-elements content (Zn, Mn, Fe and Cu) of cassava tuberous roots, in two growing seasons.

Table (7) shows, clearly, that increasing the foliar application of micronutrients mixtures up to 30% level, to the growing cassava plants, significantly, increased the macro-elements content (Zn, Mn, Fe and Cu) of cassava tuberous roots compared with other treatments, in two growing seasons.

Table 4. Tuberous root yield of cassava plants, grown in sandy soil, as influenced by application system of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014.

Characters / Treatment: K_2SO_4 doses	Micro nutrients Conc.	Number of tuber root plant^{-1}	Total tuber yield plant^{-1} (kg)	Total tuber yield fad.$^{-1}$ (tons)	Number of tuber root plant^{-1}	Total tuber yield plant^{-1} (kg)	Total tuber yield fad.$^{-1}$ (tons)
		Season 2012/2013			Season 2013/2014		
Three		7.10 a	2.67 c	10.69 c	7.09 b	2.63 c	10.19 c
four		7.12 a	3.05 b	12.20 b	7.21 b	2.91 b	11.52 b
Five		7.20 a	3.61 a	14.44 a	7.30 a	3.49 a	13.94 a
	10%	7.18 a	3.19 b	8.60 b	7.24 b	3.14 b	12.15 b
	20%	7.51 a	3.49 a	13.97 a	7.52 a	3.35 a	13.23 a
	30%	7.49 a	3.45 a	13.81 a	7.60 a	3.31 a	13.23 a
	Cont	6.38 b	2.31 c	9.24 c	6.31 c	2.29 c	8.92 c
Three	10%	6.50 b	2.50 f	10.00 f	6.77 b	2.52 e	9.73 f
	20%	7.53 a	3.00 e	12.01 e	7.57 a	2.88 d	11.14 e
	30%	7.43 a	3.09 de	12.30 de	7.67 a	2.91 d	11.63 de
	Cont	6.50 b	2.10 g	8.47 g	6.37 c	2.19 f	8.26 g
Four	10%	7.63 a	3.28 cd	13.15 cd	7.47 a	3.09 cd	12.25 cd
	20%	7.50 a	3.43 c	13.73 c	7.40 a	3.26 c	12.93 c
	30%	7.50 a	3.31 cd	13.35 c	7.50 a	3.20 c	12.61 c
	Cont	6.43 b	2.18 g	8.60 g	6.47 bc	2.08 f	8.28 g
Five	10%	7.40 a	3.79 b	15.15 b	7.50 a	3.63 b	14.47 b
	20%	7.50 a	4.03 a	16.17 a	7.60 a	3.92 a	15.74 a
	30%	7.53 a	3.95 ab	15.78 ab	7.63 a	3.83 ab	15.45 a
	Cont	6.20 b	2.66 f	10.65 f	6.47 bc	2.59 e	10.21 f

Table 5. chemical constituents of cassava tuberous root , grown in sandy soil, as influenced by application system of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014

Characters / Treatment		Root dry matter (%)	Root starch (%)	Root total sugar ($mg.g^{-1}$.d.w)	Root dry matter (%)	Root starch (%)	Root total sugar ($mg.g^{-1}$.d.w)
K_2SO_4 doses	Micro nutrients Conc.	Season 2012/2013			Season 2013/2014		
Three		37.81 c	16.84 c	7.69 c	39.46 c	18.16 c	7.20 c
four		43.72 b	18.35 b	7.98 b	45.15 b	19.87 b	7.63 b
Five		46.20 a	19.21 a	8.89 a	47.02 a	20.49 a	8.01 a
	10%	41.66 c	18.14 c	7.92 c	43.50 c	19.43 c	7.46 c
	20%	44 .37 b	18.99 b	8.50 b	44.83 b	20.65 b	7.58 b
	30%	45.06 a	19.20 a	8.81 a	46.78 a	21.01 a	8.29 a
	Cont	39.23 d	16.20 d	7.26 d	40.39 d	16.95 d	7.12 d
Three	10%	35.40 g	16.73 g	7.67 e	38.40 e	18.57 e	7.07 f
	20%	41.33 f	17.21 f	7.83 e	41.03 d	18.88 e	7.03 f
	30%	42.07 ef	17.73 e	8.17 d	43.80 bc	18.83 e	7.83 bc
	Cont	32.43 h	15.70 h	7.10 f	34.60 f	16.37 g	6.87 f
Four	10%	43.07de	18.27 d	7.80 e	44.53 bc	19.97 d	7.37 e
	20%	44.63 c	19.57 c	8.40 cd	45.60 b	20.86 c	7.70 cd
	30%	45.20 c	19.20 c	8.67 c	47.83 a	21.67 b	8.43 a
	Cont	42.00 ef	16.37 g	7.07 f	42.63 cd	17.00 f	7.00 f
Five	10%	46.50 b	19.43 c	8.30 d	47.57 a	19.77 d	7.93 b
	20%	47.13ab	20.20 b	9.27 b	47.87 a	22.20 ab	8.00 b
	30%	47.90 a	20.67 a	9.60 a	48.70 a	22.54 a	8.60 a
	Cont	43.27 d	16.53 g	7.60 e	43.93 bc	17.47 f	7.50 de

Data in (Table 7) revealed that the interactions of application systems of K_2SO_4 by the foliar application of micronutrients mixtures had significant influences on macro-elements content (Zn, Mn, Fe and Cu) of cassava tuberous roots. The results showed that application of K_2SO_4 at five split applications + foliar application of micronutrients mixtures up to 30% level was the favorite combination treatment for macro-elements content of cassava tuberous roots.

DISCUSSION

Sandy soil is poor in content of nutrients, especially potassium (K^+). In addition to, the potassium fertilizer added to the sandy soil is liable to be lost, where K^+ are highly soluble and will easily leached from sandy soils because sandy soils do not contain enough colloids (Datnoff *et al*., 2007); clay and organic matter to hold K^+. Moreover, cassava extracts large amounts of K^+ in the harvested tuberous root and K^+ deficiency becomes the most limiting nutrition factor, especially in sandy soil, if it is grown continuously without adequate K^+ fertilization. Therefore, this research suggests to studying the effect of application systems of K_2SO_4 and foliar application of micronutrient mixtures on the growth, tuberous root yield and quality of cassava grown in sandy soil.

The increments in vegetative, tuberous root yield, and total yield fad^{-1}, as well as tuberous root contents; dry matter, starch, and total sugar characters of cassava plants by adding five equal doses of K_2SO_4 might be related to the positive role of K^+ in carbohydrate synthesis and its translocation (Jansson, 1980).

Increasing the tuberous root characters (weight, length and diameter of root) by K^+ application may be due to the ability of K^+ to produce sufficient forms of assimilated N required for the formation of meristematic tissues, which in turn are necessary for rapid increase in tuberous root characters of cassava plants. Addition, K^+ regulates the balance between assimilation and respiration in a way that improves net assimilation (Imas and John, 2013). Moreover, K^+ plays an important role in the synthesis of amino acid and protein as well as translocation of sugar and assimilates within the plant as well as the accumulation of high molecular carbohydrate (Yagodin 1982; Archer, 1985). In addition, it has active the enzymes involved in biosynthesis of organic acid (Evans and Sorger, 1996), as well as accelerating translocation of carbohydrate necessary for fruit formation and development (Marschner,1986) which leads to increase plant growth and yield. These results, generally, agreed to those reported by (Davenport and Bentley, 2001 and Kelling *et al.,* 2002, Abd El-Baky *et al.,* 2010, Munawar *et al.,* 2010). Muoneke (2010) found that total tuber yield of sweet potato significant increased with increasing the application doses of K^+.

The results also showed that, increasing of the micronutrients mixtures levels up to 30 % were gradually increased the productivity of cassava plants. In addition, tuberous root quality; dry matter percentage, starch percentage, and total sugar as well as elements contents; N, K, Zn, Mn, Fe and Cu showed positive response to various micronutrients mixtures levels.

Table 6. NPK content of cassava tuberous roots, grown in sandy soil, as influenced by application system of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014

Treatment (K_2SO_4 doses)	Characters / Micro nutrients Conc.	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
		Season 2012/2013			Season 2013/2014		
Three		2.25 a	0.60 c	2.39 b	2.17 a	0.60 a	2.31 b
Four		2.22 a	0.66 a	2.47 a	2.14 a	0.57 a	2.41 a
Five		2.34 a	0.64 b	2.51 a	2.22 a	0.61 a	2.43 a
	10%	2.20 c	0.69 b	2.42 d	2.15 c	0.63 b	2.36 c
	20%	2.33 b	0.59 c	2.48 b	2.20 b	0.54 c	2.39 ab
	30%	2.46 a	0.51 d	2.49 a	2.29 a	0.51 d	2.42 a
	Cont	2.10 d	0.75 a	2.44 c	2.07 d	0.69 a	2.37 bc
Three	10%	2.23 b-c	0.63 c	2.35 l	2.18 cd	0.64 bc	2.28 e
	20%	2.28 bc	0.55 de	2.40 j	2.18 cd	0.56 de	2.33 c-e
	30%	2.38 b	0.46 f	2.42 h	2.27 b	0.49 f	2.34 cd
	Cont	2.12 cd	0.74 ab	2.38 k	2.04 f	0.71 a	2.29 d
Four	10%	2.16 cd	0.70 b	2.4 i	2.12 de	0.61 cd	.36 c
	20%	2.31 bc	0.62 c	2.49 e	2.14 de	0.51 ef	2.42 ab
	30%	2.36 b	0.53 de	2.51 c	2.24 bc	0.50 f	2.44 ab
	Cont	2.04 d	0.77 a	2.47 f	2.06 de	0.68 ab	2.43 ab
Five	10%	2.20 b-d	0.72 ab	2.49 d	2.14 de	0.65 bc	2.43 ab
	20%	2.40 b	0.59 cd	2.53 b	2.28 a	0.56 de	2.43 ab

	30%	2.63 a	0.53 e	2.54 a	2.35 a	0.54 ef	2.47 a
	Cont	2.13 cd	0.74 ab	2.46 g	2.10 d-f	0.68 ab	2.38 bc

Table 7. Micro-elements content of cassava tuberous roots, grown in sandy soil, as influenced by application system of K_2SO_4 and foliar application of micronutrients mixture levels and their interactions during the seasons of 2012/2013 and 2013/2014

Characters / Treatment		Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
K_2SO_4 doses	**Micro nutrients Conc.**	**Season 2012/2013**				**Season 2013/2014**			
Three		1.86 c	8.63 c	73.75c	2.91 c	1.93 c	9.00 b	77.68 c	2.78 c
Four		1.80 b	9.07 b	78.67b	3.31 b	2.06 b	9.22 a	81.47 b	3.12 b
Five		2.11 a	9.14 a	81.95a	3.50 a	2.16 a	9.25 a	83.37 a	3.37 a
	10%	1.94 c	8.65 c	75.62c	3.37 c	2.02 c	8.80 b	76.73 c	3.21 c
	20%	2.05 b	9.50 b	87.28b	3.47 b	2.15 b	9.82 a	91.22 b	3.31 b
	30%	2.19 a	9.71 a	93.06a	3.57 a	2.26 a	9.87 a	94.37 a	3.42 a
	Cont	1.76 d	7.92 d	57.87d	2.56 d	1.77 d	8.14 c	61.02 d	2.42 d
Three	10%	1.80 f	8.32 f	70.00f	2.97 d	1.89 f	8.55 c	74.37 e	2.87 f
	20%	1.92 e	9.35 c	82.57d	3.16 c	1.97 e	9.77 a	88.40 c	3.00 e
	30%	2.01 d	9.42 c	87.50c	3.38 b	2.11 d	9.81 a	88.03 c	3.18 d
	Cont	1.72 g	7.44 h	54.93h	2.16 g	1.74 h	7.87 e	59.90 g	2.05 i
Four	10%	1.90 e	8.73 e	74.87e	3.42 b	1.98 e	8.88 b	77.97 d	3.20 d
	20%	2.05 d	9.60 b	87.90c	3.47 b	2.19 c	9.84 a	92.37 b	3.32 c
	30%	2.19 b	9.82 a	94.57a	3.65 a	2.30 b	9.88 a	96.73 a	3.46 b
	Cont	1.76 fg	8.14 g	57.32h	2.70 f	1.77gh	8.27 d	58.80 g	2.51 h
Five	10%	2.12 c	8.91 d	76.00e	3.72 a	2.20 c	8.97 b	77.87 d	3.56 a
	20%	2.18 b	9.56 b	91.37b	3.78 a	2.2 b	9.83 a	92.90 b	3.62 a
	30%	2.36 a	9.90 a	97.10a	3.69 a	2.36 a	9.91 a	98.33 a	3.62 a
	Cont	1.78 f	8.19 g	61.33g	2.83 f	1.79 g	8.27 d	6437 f	2.70 g

The stimulating effects of the micronutrients mixtures on cassava plants can be explained based on that micronutrient such as Mn, Zn and Fe are essential for plant growth, crop yield, and its quality, they play an important role in balance crop nutrition (Mousavi *et al*., 2012). Moreover, micronutrient had role in increasing photosynthesis efficiency and synthesis of carbohydrates such as starch (Mousavi *et al*., 2012). Mousavi *et al*., (2007) found that Zn and Mn application increased all potato plant characters relating to tuber yield and quality.

The positive effects of interaction between application systems of K_2SO_4 and foliar application of micronutrient mixtures levels on vegetative growth, total tuberous root yield (kg $plant^{-1}$and ton fed^{-1}), tuberous root quality and chemical constituents' characters of cassava plants may be attributed to stimulate the photosynthesis process. Besides, application of K^+ at five equal doses may led to K^+ remaining concentrated near the point of application, thus helps in improved K^+ availability in the root zone, increase nutrient uptake, thus stimulate a growth of the tuberous root and whole plant of cassava.

CONCLUSIONS

Based on the results from this study, the application systems of K_2SO_4 up to five equal doses and foliar application of micronutrient mixtures levels up to 30% is the most efficient combination treatment, which gave the best results for tuberous roots yield of cassava plants grown in sandy soil. This work recommends that application of five equal doses of K_2SO_4 + micronutrient mixtures treatment could offer an economical and simple application to improving cassava production grown in sandy soil.

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الملخص العربي

تأثير نظام إضافة كبريتات البوتاسيوم، والرش الورقي بتركيزات مختلفة من العناصر الصغرى على الكاسافا تحت ظروف الأراضي الرملية

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تمت دراسة تأثير نظام إضافة كبريتات البوتاسيوم، والرش بالعناصر الصغرى على النمو الخضري والمحصول والجودة على الكاسافا (الصنف الأندونيسى). والدراسة تمت في محطة البحوث الزراعية بعلي مبارك بمنطقة البستان في التحرير بالنوبارية خلال موسمي ٢٠١٢-٢٠١٣، و٢٠١٣-٢٠١٤. صممت التجربة باستخدام نظام القطاعات العشوائية الكاملة المنشقة في ثلاث مكررات، وكان العامل الرئيسي لهذه التجربة هو إضافة السماد البوتاسى على(ثلاث دفعات متساوية بعد ٦٠و، ٩٠ و١٢٠- أربع دفعات متساوية ٦٠و ٩٠ و١٢٠و١٥٠- خمس دفعات متساوية بعد ٦٠ و،٩٠و١٢٠و١٥٠ و ١٨٠ يوم من الشتل) والعامل الثانوي هو الرش بأربع مستويات من العناصر الصغرى وهى الحديد والزنك والمنجنيز والنحاس بتركيزات (صفر، و١٠ و٢٠ و٣٠%). وأوضحت النتائج التالي أن إضافة السماد البوتاسى على خمس دفعات أعطت أعلى القيم في صفات النمو الخضري وهى (ارتفاع النبات، وعدد الأوراق للنبات وعدد الأفرع للنبات) وأيضا أعطت أعلى القيم لصفات الجذور والمحصول ومكوناته المتمثلة في (قطر الجذر وطول الجذر ومتوسط وزن الجذر والإنتاجية الكلية للنبات، وللفدان) وصفات الجودة الخاصة بالجذر وهى (المادة الجافة للجذور ونسبة النشا ونسبة السكريات الكلية). أيضا أوضحت النتائج انه بزيادة تركيز الرش بالعناصر الصغرى حتى ٣٠% أعطت زيادة تدريجية في الإنتاجية، وجودة الجذور المتكونة للمادة الجافة، والسكريات الكلية والنشا بالإضافة إلى محتوى الجذور من العناصر. أيضا كان هناك استجابة معنوية للتداخل بين تجزئة تسميد البوتاسيوم والرش بتركيزات مختلفة من العناصر الصغرى على نباتات الكاسافا فأشارت النتائج أن إضافة السماد البوتاسى على خمس دفعات مع رش النباتات بتركيز ٢٠ أو٣٠% حيث أعطى أعلى القيم على صفات النمو الخضري، والإنتاجية الكلية للنبات، وجودة الجذور، والمحتوى الكيماوي للجذور من العناصر.