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Effect of potassium and zinc on growth, yield and economics of sweet potato (*Ipomoea batatas* L.) cv. CO-34

Pravin Singh[1*], Kavita Aravindakshan[1], I. B. Maurya[1], Jitendra Singh[2], Bhim Singh[3]and M. K. Sharma[4]

[1]Department of Vegetable Science, College of Horticulture and Forestry, Agriculture University, Kota, Jhalawar-326023 (Rajasthan), INDIA
[2]Department of Fruit Science, College of Horticulture and Forestry, Agriculture University, Kota, Jhalawar-326023 (Rajasthan), INDIA
[3]Department of Agriculture Statistics, College of Horticulture and Forestry, Agriculture University, Kota, Jhalawar -326023 (Rajasthan), INDIA
[4]Department of NRM, College of Horticulture and Forestry, Agriculture University, Kota, Jhalawar-326023 (Rajasthan), INDIA
*Corresponding autor. E-mail: hortiveg511@gmail.com

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Abstract: A field experiment was conducted to study the effect of different levels of potassium and zinc on growth, yield and economics of sweet potato. The experiment was laid out on clay and loam soil by adopting randomized block design with factorial technique (FRBD). The sixteen treatments consisted of combination of four levels of potassium (0, 80, 100 and 120 kg/ha through muriate of potash and four levels of foliar zinc (control i.e. water spray, 10, 20 and 30ppm) through zinc sulphate. The individual application of potassium 120 kg K_2O/ha significantly increased the number of tubers per plant (4.60), average weight of tuber (275.31 g), length of tuber (16.77 cm), diameter of tuber (5.69 cm), tuber yield per plot (9.71 kg), tuber yield per hectare (49.04 t) respectively as compared to control. With the foliar application of zinc (30 ppm) significant increase in number of tubers per plant (4.18), average weight of tuber (234.73 g), length of tuber (18.12 cm), diameter of tuber (5.16 cm), tuber yield per plot (8.33 kg) and tuber yield per hectare (42.05 t) was recordedas compared to control. The treatment combination (120 kg K_2O+30ppm Zn) recorded the maximum yield parameters i.e. chlorophyll content (37.00 mg/100 g), average weight of tuber (302.17 g), length of tuber (19.82 cm), diameter of tuber (5.97 cm), maximum tuber yield per plot (11.02 kg), tuber yield per hectare (55.67 t) and benefit-cost ratio (B: C ratio) of 4.22:1.While, the treatment (120 kg K_2O+30ppm Zn) had the maximum number of tuber (4.86), minimum number of tuber was recorded in control. From the experiment, it appeared that application of potassium and zinc can be used to improve yield and higher net monetary returns of sweet potato.

Keywords: Growth, Potassium, Sweet potato, Zinc, Yield

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is an herbaceous dicotyledonous plant with creeping, perennial vines and adventitious roots and belongs to the family Convolvulaceae (morning glory) and is one of the important tuber crops of tropical and subtropical regions of the World. It is believed to have originated in Central America and the North Western part of South America. In India, it is the third most important tuber crop after potato and cassava. Globally, India occupies twelfth, eighth and fifth rank in area, production and productivity respectively. It is cultivated predominantly as a rainfed crop in Eastern India, especially in Orissa, West Bengal, Uttar Pradesh, Bihar and Jharkhand, accounting for 77% of area and 82% of production (Edison *et al.,* 2009). The total area in the world under sweet potato is estimated to be 7.95 million ha with a production of 104.26 million tonnes. In India, sweet potato covers 1.12 lakh hectare areas, producing 11.32 lakh tonnes tubers, with the productivity of 10.1 metric tonnes per hectare (Anonymous, 2014). Rajasthan contributes only 0.50 thousand hectare area under sweet potato cultivation with production of 1.64 thousand MT of tuber and Productivity 3.28 Production/ha. (Anonymous, 2014). Potassium is a part of many important regulatory roles in the plant (Cakmak, 2005). It is essential macronutrients and has a wide range of functions in plant growth and development, including cell extension, stomata movement, and control of ionic balance, enzyme activation, photosynthesis, protein synthesis, phloem loading and transport, and tolerance of external stress (Marschner 2012 and Zörb, *et al.* 2014). Potassium appears to be the most important nutrient in the production of sweet potato as its application increases yield by the formation of larger sized tubers. Potassium also influences the number, size, quality and the unit weight of tuberous roots produced, while the minimum levels of potassium is suggested for healthy growth and yield (Degras, 2003). Apart from potassium as major nutrients, micronutrients also form a constituent part of plant. Proper supply of these nutrients is sure to increase yield and positive effect on crop production.With a shortage of potassium many metabolic processes are affected, such as the rate of photosynthesis, the rate of translocation and enzyme systems and deficiency symptoms first appear on older (lower) leaves because potassium is a mobile nutrient, meaning that a plant can allocate potassium to younger leaves. Potassium appears to be the most important nutrient in the production of sweet potato as its application increases yield by the formation of larger sized tubers (Uwah *et al*., 2013). Potassium chloride (KCl), known also as muriate of potash (MOP), is the most widely used source of potassium for agricultural crops (DEFRA, 2010).

The micronutrients on the other hand though are required in small amount but play a great role in plant metabolism (Katyal, 2004 and Kazi *et al*., 2012). Zinc is an essential micronutrient which plays a macro role in the growth and productivity of the plants. Zn is an important component of enzymes that drive and increase the rate of many important metabolic reactions involved in crop growth and development (Potarzycki and Grzebisz, 2009). The symptoms of zinc deficiency are visible generally in younger leaves, starting from inter-veinalchlorosis resulting to a decrease in shoot development and shortening of internodes, mottle leaf, little leaf etc (Kiran, 2006). Sweet potato plants responded positively to foliar application of zinc and produced maximum production of roots (Abd El-baky e*t al.,* 2010). The aim of this work is to investigate effect of potassium and zinc on growth and yield of sweet potato as till traditional practices is followed as it invites low yield. Keeping this in view of the tuber formation and tuber size of sweet potato in information on the above mentioned aspects, the present investigation entitled "effect of potassium and zinc on growth, yield and economic on sweet potato (*Ipomoea batatas* L) cv. CO-34" was undertaken.

MATERIALS AND METHODS

The field experiment was conducted during *rabi* 2014-2015 at Department of Vegetable Science, College of Horticulture and Forestry, Jhalawar (Rajasthan) to study the effect of potassium and zinc on growth, yield and economics of sweet potato. The soil of the site belongs to order Vertisol (USDA, 2010 Classification). The experimental initial soil status was pH 6.67, EC 0.56 dSm^{-1}, available nitrogen 218.3 kg/ha (Subbiah and Asija, 1956), available phosphorus 28.01 kg/ha (Olsen *et al.,* 1954) and available potash 210.60 kg/ha (Metson,1956) and organic carbon 0.58 per cent (Walkley and Black,1934). Experiments were laid out in a randomized block design (FRBD) with factorial technique and three replications. The 16 treatments consisted of combination of four levels of potassium (0, 80, 100 and 120 kg/ha through muriate of potash and four levels of foliar zinc (control i.e. water spray, 10, 20 and 30ppm) through zinc sulphate. Zinc was two foliar applications at 45 and 90 days after transplanting (DAT). The recommended dose of fertilizer (RDF) was applied for sweet potato (50:60 N: P_2O_5 kg ha^{-1}) as per the treatments. The crop was grown on raised beds at 60 x 30 cm spacing on drip system. Each treatment consisted of 10 plants for which 10-cutting were sown in a two rows of 1.5 meter length. The observations were recorded on seven characters namely number of leaves per plant (45 DAT and 90 DAT), chlorophyll content (mg/100g), number of tubers/plant, average weight of tubers/plant and volume of tuber per plant (cc),tubers yield per plot (kg),and tubers yield per hectare(t).The data was subjected to analysis of variance (ANOVA) for testing the significance of variation due to potassium, zinc and their interaction for different characters as described by Gomez and Gomez (1984). Mean values were calculated and compared using F-test at 5% level of significance.

RESULTS

Growth parameters: An appraisal of the data presented in Table 1 indicated that potassium and zinc application significantly increased number of leaves per plant. The number of leaves per plant, at 45DAT and at harvest was significantly higher by 91.37 and 455.55 respectively due to application of treatment K_3 (120 kg K_2O/ha) as higher than the control. The maximum number of leaves per plant i.e., 65.57 and 412.08 at 45 DAT and at harvest respectively was observed in treatment Zn_3 (30ppm). However, the interaction effect of potassium and zinc levels was found non-significant with respect to number of leaves per plant (Table 2)

A perusal of data displayed in Table 1 and Table 2 shows that application of potassium and zinc increased chlorophyll content over control. Application with 120 kg K_2O/ha had significantly maximum chlorophyll (33.80 mg/100g) than control (29.93mg/100g). Also the foliar application of 30ppm zincgave the highest chlorophyll content (33.87 mg/100 g). Whereas, the application of 0 ppm zinc showed significantly the lowest chlorophyll content (31.51 mg/100 g). The maximum chlorophyll content(36.34 mg/100g) was recorded in 120 Kg K_2O/ha and Zn 30ppm as compared to control (28.32 mg/100g).

Yield parameters: Number of tuber per plant, average

Table 1. Effect of potassium and zinc on the growth and yield parameters of sweet potato plants.

Treatment	Number of leaves per plan		Chlorophyll content (mg/100g)	Number of tubers per plant	Average weight of tuber (g)	Volume of tuber (cc)	Yield per plot (kg)	Yield per hectare (t)
	45 DAT	90 DAT						
Potassium								
K_0 – 0 kg K_2O	32.73	264.03	29.93	3.26	196.91	207.40	5.33	26.91
K_1– 80 kg K_2O	51.80	349.22	30.73	3.78	200.42	235.63	6.95	35.11
K_2 – 100 kg K_2O	63.87	387.05	31.49	4.44	225.81	260.36	8.28	41.81
K_3 – 120 kg K_2O	91.37	455.55	33.96	4.60	275.31	284.15	9.71	49.04
S.Em±	1.11	5.74	1.55	0.05	2.69	3.42	0.07	0.36
C.D. at 5%	3.20	16.59	4.50	0.15	7.76	9.89	0.21	1.05
Zinc								
Zn_0 – 0 ppm Zn	52.25	312.38	29.31	3.72	217.37	225.25	6.93	34.98
Zn_1 – 10 ppm Zn	59.75	348.07	30.57	4.02	221.54	244.80	7.34	37.07
Zn_2 – 20 ppm Zn	62.20	383.32	32.14	4.16	224.81	250.26	7.68	38.77
Zn_3 – 30 ppm Zn	65.57	412.08	34.12	4.18	234.73	265.23	8.33	42.05
S.Em.±	1.11	5.74	1.55	0.05	2.69	3.42	0.07	0.36
C.D. at 5%	3.20	16.59	4.50	0.15	7.76	9.89	0.21	1.05

Table 2. Effect of interaction between potassium and zinc application on the growth and yield characters of sweet potato plants.

Treatment	Number of leaves per plant		Chlorophyll content (mg/100g	Number of tubers per plant	Average weight of tuber (g)	Volume of tuber (cc)	Yield per plot (kg)	Yield per hectare (t)
	45 DAT	90 DAT						
Potassium × Zinc								
K_0Zn_0	26.46	207.66	28.32	2.94	194.54	197.51	4.73	23.89
K_0Zn_1	33.00	263.86	29.38	3.30	194.61	208.38	5.23	26.43
K_0Zn_2	34.60	280.33	30.45	3.24	197.40	210.82	5.45	27.52
K_0Zn_3	36.87	304.26	31.57	3.58	201.10	212.88	5.90	29.80
K_1Zn_0	42.93	289.40	28.85	3.23	197.55	217.66	6.26	31.60
K_1Zn_1	55.26	333.46	28.97	3.80	198.06	227.88	6.81	34.37
K_1Zn_2	54.53	363.73	31.16	3.97	201.34	242.82	7.17	36.21
K_1Zn_3	54.46	410.26	34.08	4.10	204.75	254.15	7.58	38.27
K_2Zn_0	55.80	354.60	28.55	4.27	220.97	223.69	7.80	39.39
K_2Zn_1	61.40	370.93	31.10	4.40	225.35	266.06	8.13	41.08
K_2Zn_2	66.93	414.80	32.46	4.57	226.01	273.82	8.37	42.29
K_2Zn_3	71.33	407.86	33.83	4.53	230.90	277.88	8.80	44.47
K_3Zn_0	83.80	397.86	31.51	4.43	256.43	262.12	8.92	45.05
K_3Zn_1	89.33	424.00	32.85	4.57	268.15	276.89	9.19	46.40
K_3Zn_2	92.73	474.40	34.51	4.86	274.48	281.60	9.71	49.04
K_3Zn_3	99.60	525.93	37.00	4.52	302.17	316.00	11.02	55.67
S.Em±	2.21	11.49	3.10	0.10	05.37	6.85	0.14	0.73
C.D. at 5%	NS	NS	9.00	0.30	15.51	19.78	0.42	2.10

weight of tuber and volume of tuber increased with increasing levels of potassium were significant under 120 kg K_2O ha^{-1} as compared to control (Table 1). The percent increase in number of tuber, average weight of tuber and volume of tuber with the application of 120 kg ha^{-1} was observed to be 41.10, 39.81 and 37.00 over control. Increase in the number of tuber per plant, average weight of tuber and volume of tuber with application of 30 ppm Zn was found to be significant over control. Combined application of potassium and zinc showed significant increase in respect to yield attributes.The treatment combination K_3Zn_3 (120 kg K_2O+30ppm Zn) recorded the maximum average weight of tuber (207.40 g) and volume of tuber (284.15 cc) While, the treatment K_3Zn_2 (120 kg K_2O+20ppm Zn) had the maximum number of tuber (4.86) thought minimum number of tuber was recorded in K_0Zn_0 (control).

Significant increase in tuber yield per plot and tuber yield per hector was observed with increasing levels of potassium up to 120 kg K_2O ha^{-1}. Application of 120 kg K_2O ha^{-1} produced the maximum tuber yield per plot and tuber yield per hectareof 9.71 kg and 49.04 t ha^{-1}, representing significant increase of 82.17 and 82.23% over control, respectively (Table-1). Tuber yield per plot and tuber yield per hector influenced significantly with 30 ppm Zn as compared to control. The combined application of K and Zn significantly increased the tuber yield per plot and tuber yield per hector (Table 2). Maximum tuber yield per plot of 11.02 kg and tuber yield per hectare of 55.67 t ha^{-1} was obtained with 120 kg K_2O ha^{-1} plus 30 ppm Zn which was 4.73 kg and 23.89 t ha^{-1} additional over control. Data depicted in Table -3 showed that maximum net returns (Rs. 225039.30 ha^{-1}) and B: C ration (4.22) from sweet potato was obtained with potassium 120 kg ha^{-1} and 30ppm zinc.

DISCUSSION

Generally, the application of potassium at higher rates significantly increased number of leaves per plant, chlorophyll content, number of tubers/plant and average weight of tubers/plant in the trial. This positive response of growth characters to the applied K is attributable to its role in cell multiplication and photosynthesis in conjunction with N, which gave rise to increase in number of leaves and chlorophyll content of leaves. In this respect, Liu (2013) studied that effect of application of K_2O at 24 gm^2 soils on distribution of photosynthates in plants of sweet potatowals improved the chlorophyll content in the early growth stage. Cao and Tibbittis (1991) found that different K concentrations gave significant chlorophyll in potato leaves compared to control treatment. Moreover, K is also essential to the performance of multiple plant enzyme functions, and it regulates the metabolite pattern of higher plants, ultimately changing metabolite concentrations (Mengel, 2001 and Marschner, 2012). The positive response shown by yield characters to K could be directly linked to the well-developed photosynthetic surfaces (number of leaves, number of branches and chlorophyll) and increased physiological activities leading to more assimilates being produced and subsequently translocated and utilized in rapid tuber development and production. Marschner (2012) reported that K plays a crucial role in turgor regulation within the guard cells during stomatal movement. Potassium is an important nutrient for plant meristematic growth and physiological functions, including regulation of water and gas exchange in plants, protein synthesis, enzyme activation, photosynthesis and carbohydrate translocation in plants. Furthermore, K is also essential for the translocation of photo assimilates in root growth also root growth promotion by increased appropriate K supply under K deficient soil was found to increase the root surface that was exposed to soil as a result of increased root water uptake (Romheld and Kirkby, 2010).According to the results obtained from the research of Ummar and Moinuddin (2001) potassium application upto 120 kg K_2O/ha led to increased tuber yield. Also regarding tuber yield as a result of potassium 150 kg K_2O /ha application experiment of Moinuddin*et al.* (2005). Similarly potassium has been reported that application of K_2O at 150 and 200 kg K ha^{-1} significantly increased marketable tuber and fresh tuber yield of sweet potato (Sokoto*et al.* 2007). Similar finding was recorded by (Lu *et al*., 2001 and Uwah*et al.*, 2013) in sweet potato crop. Finally, it could conclude that increase in the potassium fertilization mainly increased yield through the formation of large sized tubers, total number of tubers and their translocation to some extent to the sweet potato.

Zinc is a micronutrient which is required for plant growth and development relatively in small amount. Zinc plays a fundamental role in several critical functions in the cell such as protein metabolism, gene expression, structural and functional integrity of bio membranes and photosynthetic carbon metabolism (Cakmak, 2000). Zinc is main building part of some enzymes viz. alcohol dehydrogenase, carbonic anhydrase, superoxide dismutase that is needed for the root development and increasing the absorption of carbon dioxide per leaf area unit and this increasing the photosynthesis and biomass production and yield (Pedler*et al.,* 2000,Vitosh*et al.,* 1994 and Marschner, 1995) This increase could be due to the fact that Zn plays an important role in regulating the auxin concentration in plants and is an essential component of enzymes which promotes the growth and development of plants. It may also be pointed out that growth and development of plants depend upon physiological and metabolic activity of plants influenced by application of zinc. Sweet potato plants responded positively to

Table 3. Economic feasibility of potassium and zinc treatment in sweet potato cv. 'CO-34'.

Treatment	Treatment Cost (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit cost ratio (BCR)
T_0 (0 Kg K_2O+0 ppm Zn)	49740.23	119434.53	69694.30	1.40
T_1 (0 Kg K_2O+10 ppm Zn)	49797.11	132126.22	82329.11	1.65
T_2 (0 Kg K_2O+20 ppm Zn)	49853.99	137624.48	87770.49	1.76
T_3 (0 Kg K_2O+30 ppm Zn)	49910.87	149023.63	99112.76	1.99
T_4 (80 Kg K_2O+0 ppm Zn)	52006.84	158013.21	106006.37	2.04
T_5 (80 Kg K_2O+10 ppm Zn)	52063.72	171866.53	119802.81	2.30
T_6 (80 Kg K_2O+20 ppm Zn)	52120.6	181032.35	128911.75	2.47
T_7 (80 Kg K_2O+30 ppm Zn)	52177.48	191329.98	139152.50	2.67
T_8 (100 Kg K_2O+0 ppm Zn)	52573.45	196954.00	144380.55	2.75
T_9 (100 Kg K_2O+10 ppm Zn)	52630.33	205408.16	152777.83	2.90
T_{10} (100 Kg K_2O+20 ppm Zn)	52687.21	211466.49	158779.28	3.01
T_{11} (100 Kg K_2O+30 ppm Zn)	52744.09	222346.54	169602.45	3.22
T_{12}(120 Kg K_2O+0 ppm Zn)	53140.06	225259.87	172119.81	3.24
T_{13} (120 Kg K_2O+10 ppm Zn)	53196.94	232021.88	178824.94	3.36
T_{14} (120 Kg K_2O+20 ppm Zn)	53253.82	245224.93	191971.11	3.60
T_{15} (120 Kg K_2O+30 ppm Zn)	53310.7	278350.00	225039.30	4.22

Sale price of sweet potato @ ₹ 5.00/kg.

foliar application Zn @ (10 to 30 ppm) and the highest production of roots was obtained with the highest zinc dose as indicated by Abd EI-Baky *et al.* (2010). Appreciable increase in sweet potato yield by foliar application of Zn was reported by George and Mittra (1996) in the trials conducted at Kharagpur in West Bengal. In another finding Singh and Singh (2004) observed the beneficial of zinc (0, 10, 20 and 30 ppm) at 30 and 60 DAT in increasing the yield and quality of cauliflower.

Potassium has also an important role in improving sweet potato yield as indicate by Abd EI-Baky *et al.* (2010) who found that the maximum estimated sweet potato yield was obtained with combination of the rate of 120 kg K_2O/fed applied to the application of 30 ppm zinc. Moreover, El-Hadidi and Mansour (2008) found that application of potassium 48 kg/fed combined with foliar application of zinc at the rate of 30 ppm gave the highest total tubers yield of sweet potato plants. The interaction effect of potassium and zinc responded synergistic relationship to K and Zn increasing rate (Malvi, 2011). This positive effect may be attributed to the increasing K availability in soil. In addition, K is a key factor in regulating plant water status (Marschner, 1995), which reflects on plant growth and hence yield Thus, the combined application of potassium and zinc provided all the essential nutrients, required by plants for its growth and development. It was suggested that, Zn is involved in stomatal opening, possibly as a constituent of the enzyme carbonic anhydrase and/or as a factor in maintaining membrane integrity and K^+ uptake (Sharma *et al.,* 1995).

Conclusion

On the basis of experimental findings it can be concluded that external application of potassium and zinc either singly or in combination produced the vital effect on various yield parameters. But growth parameters (number of leaves per plant) was remaining uninfluenced after application of potassium and zinc in combinations. The application of (120 kg K_2O/ha + 30ppm Zn) has recorded for higher productivity and economic returns from in the study area of sweet potato.

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