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Effects of Lime on Soil and Tuber Chemical Properties and Yield of Sweetpotato [*Ipomoea batatas* (L.) Lam.] in Swaziland

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Abstract: Sweetpotato [*Ipomoea batatas* (L.) Lam.] is the most important storage root crop grown in Swaziland. Yet there are few data examining the impact of lime on sweetpotato production. Small-scale farmers do not typically lime their soils. A field study was conducted in 2006/2007 cropping season to determine the effects of different lime levels on soil and tuber chemical properties and sweetpotato tuber yields. The experimental design was a randomized complete block consisting of five lime treatments replicated four times. The treatments were a control (no lime) and 1, 1.5, 2 and 2.5 tonnes dolomitic lime ha^{-1}. Results showed significant differences ($P < 0.05$) in soil organic matter among treatments (no lime, 2.775%; 1.0 t ha^{-1}, 2.325%; 1.5 t ha^{-1}, 3.175%; 2.0 t ha^{-1}, 2.950%; 2.5 t ha^{-1}, 3.000%). Magnesium concentrations significantly ($P < 0.05$) varied with lime levels applied (no lime, 112.500 mg kg^{-1}; 1.0 t ha^{-1}, 148.750 mg kg^{-1}; 1.5 t ha^{-1}, 167.500 mg kg^{-1}; 2.0 t ha^{-1}, 168.750 mg kg^{-1}; 2.5 t ha^{-1}, 227.500 mg kg^{-1}). Soil pH levels also showed significant differences ($P < 0.05$) to among treatments (no lime, 5.375; 1.0 t ha^{-1}, 5.600; 1.5 t ha^{-1}, 5.825; 2.0 t ha^{-1}, 5.750; 2.5 t ha^{-1}, 6.025) were varied significantly. Base saturation showed significant differences ($P < 0.05$) only in Mg, H, Fe and Al concentrations. There were no significant differences in mineral nutrient concentrations in storage roots. Marketable and total tuber yields did not significantly differ among the treatments. Because lime applications to acidic soils generally improve soil properties, which in turn enhance crop yield, long-term studies on more acid soils are recommended to evaluate if the changes enhance sweetpotato yield. Applying lime to a near neutral soil did not increase yields. Based on these results, it is recommended that soil testing be used as the best guide to lime application in small-scale farming in Swaziland.

Key words: Dolomitic lime · small-scale farming · soil chemical properties · storage root crop · sweetpotato · tuber mineral nutrient concentrations

INTRODUCTION

Sweetpotato [*Ipomoea batatas* (L.) Lam.] is the major storage root crop commonly grown in Swaziland [1]. It is a short-season crop, which reliably provides food on marginal and degraded soils, with little labour and few or no inputs from outside the farm [2]. In recent years, cassava (*Manihot utilissima* Pohl) has been introduced to Swaziland small-scale farmers in an effort to make farmers to diversify their farm produce and increase food security in the country. Though usually cultivated as a monocrop, sweetpotato can also be intercropped with groundnut (*Arachis hypogaea* L.), field beans (*Phaseolus vulgaris* L.) or any other crop that the small-scale farmer considers to be important. Soil acidity is a major problem in most agricultural soils of the tropics [3]. Acid soils are the predominant soils in Swaziland (G.N. Shongwe, University of Swaziland, personal communication, 2007). To make soils less acid, it is a common practice to apply a material that contains calcium and/or magnesium oxides or carbonates. While ground agricultural limestone ($CaCO_3$) is most frequently used [4], dolomite (MgCaO) is also commonly used and provides the essential element Mg in addition to Ca. Though there are free soil-testing facilities provided at Malkerns Research Station, Malkerns, most small-scale farmers do not routinely test their farm soils. In the absence of a specific recommendation based on soil tests, it was advised [5] that in the Highveld and Middleveld ecological zones, farmers in Swaziland could apply 1-2

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tonnes ha^{-1} of dolomitic lime every 3-4 years. Despite this advice, small-scale farmers simply grow their crops from year to year without soil testing. Lime is important because it can improve soil pH, making nutrient elements more available to plants [3]. Because there are few data evaluating the impact of lime on sweetpotato production, the objective of this experiment was to determine the effects of different levels of dolomitic lime on soil chemical properties, tuber mineral nutrient concentrations, growth and storage root yield of sweetpotato.

MATERIALS AND METHODS

Location and experimental design: The field experiment was conducted at the Crop Production Department Experiment Farm in the Faculty of Agriculture, University of Swaziland, Luyengo (26.34°S, 31.10°E; 732.5 m above sea level; mean annual temperature, 18°C; mean annual rainfall range, 850-1000 mm) in the Middleveld agro-ecological zone of Swaziland. The soil type was an Oxisol (M-set) of the Malkerns series [6]. The research design was a randomized complete block of five lime treatments, replicated four times. The treatments were: (1), control (no lime); (2), 1.0 tonne lime ha^{-1}; (3), 1.5 tonnes lime ha^{-1}, (4), 2.0 tonnes lime ha^{-1} and (5), 2.5 tonnes lime ha^{-1}.

Land preparation: The land was prepared using a tractor-mounted moldboard plow, followed by disk harrowing. Thereafter, 1.0-m ridges were prepared using disk ridgers. Before marking out the plots, a composite soil sample of the experiment site was taken (15-cm depth) using a soil probe. There were seven ridges per plot, each measuring 5.0 m x 6.0 m. Each plot and each replicate was separated from contiguous ones by a 1.0-m space; also, a 1.0-m perimeter non-experimental space surrounded the area. Before planting, dolomitic lime (CaMgO) was broadcast and mixed on the ridges using spades and garden forks and thereafter, re-constructing the ridges.

Planting and fertilization: Planting was done on September 25, 2006. The planting materials consisted of terminal vines of sweetpotato, each being approximately 30-cm length. The variety of sweetpotato planted was ‘Kenya’ and was obtained from Malkerns Research Station, Malkerns. The crop spacing was 30 cm along the row and 100 cm between rows (33,333 plants ha^{-1}). At planting, 350 kg ha^{-1} of compound fertilizer [N:P:K, 2:3:2 (22)] that also contained 0.5% Zn, was applied, 10 cm away from the planting rows [5]. Single superphosphate (10.5% P) at the rate of 50 kg ha^{-1} was also applied to all plots at planting. At 6 weeks after planting (WAP), a side dressing of a mixture of 10 parts urea (45% N) and muriate of potash, KCl (50% K) was applied at the rate of 120 kg ha^{-1} [5], to all plots. All fertilizer applications were made using the same method of banding and incorporation. For the first 2 WAP, overhead sprinklers were used to irrigate the plots to field capacity, until rains became regular. Thereafter, the crop was managed, by weeding at 4 and 8 WAP.

Data collection and analysis: The crop was managed until harvest at 20 WAP; garden forks were used to dig up the tubers and pods. Total tuber yield and marketable tuber yields were determined at harvest. Marketable tubers were whole tubers weighing between 100 g and 1.4 kg and having no harvest wounds, pest or disease damage. Tubers outside this mass range are not usually liked or bought by consumers. Harvested tuber samples were obtained from 5 tubers in each treatment; the samples were washed and air-dried for 2 hours on a laboratory bench. Thereafter, the unpeeled tubers were sliced using a sharp knife and 500 g per plot were weighed and dried in a hot-air oven at 80°C for 5 days. The dried samples were ground, sifted and shipped in labeled, plastic bags, for chemical analyses by standard analytical procedures [7], in a reputable laboratory in the United States. The tuber samples were analyzed for concentrations of N, S, P, K, Mg, Ca and Na, in addition to the micronutrients.

After harvest, soil samples (10 from each plot) were collected (15-cm depth), using a soil auger. The 10 samples from each plot were thoroughly mixed in a plastic bucket to obtain one composite sample for each plot. The composite samples were dried on a laboratory bench for 5 days, after which they were sifted, put into labeled plastic bags and shipped for chemical analysis [7] in the same laboratory that analyzed the tuber samples. The soil samples were analyzed for organic matter, N, P, K, Mg, Ca, pH, cation exchange capacity (CEC), nitrate N, total N, base saturation, S, Zn, Mn, Fe, Cu, B and Al concentrations. Data were analyzed using the MSTAT-C statistical package, version 1.3 [8]. Mean comparisons were made using the least significant ($P < 0.05$) difference test [9].

RESULTS AND DISCUSSION

Soil fertility status: Initial fertility status of the soil was as follows: pH in calcium chloride, 6.3; organic matter, 3.3%; cation exchange capacity, 0.7 cmole kg^{-1}; exchangeable Al, 2.5 cmole kg^{-1} and exchangeable H, 1.5 cmole kg^{-1}. The soil texture was a coarse loam.

Table 1: Effects of lime levels on some chemical properties of soil grown to sweetpotato (*Ipomoea batatas* L.)

Lime levels	Organic matter (%)	mg kg^{-1} P	K	Mg	Ca	pH	Cation exchange capacity (me/100 g)	Nitrate N (mg kg^{-1})	Total N (%)
No lime	2.775	50.000	87.750	112.500	400.000	5.375	4.975	5.250	0.088
1.0 tonne ha^{-1}	2.325	54.750	81.250	148.750	475.000	5.600	5.625	6.250	0.081
1.5 tonnes ha^{-1}	3.175	44.500	93.500	167.500	487.500	5.825	5.275	6.000	0.092
2.0 tonnes ha^{-1}	2.950	54.250	13.000	168.750	450.000	5.750	5.100	6.500	0.090
2.5 tonnes ha^{-1}	3.000	58.750	76.750	227.500	537.500	6.025	6.000	6.000	0.091
Means	2.845	52.450	88.450	165.000	470.000	5.715	5.395	6.000	0.088
[1]LSD $_{(0.05)}$	0.478	18.643	49.195	56.296	203.445	0.329	1.825	1.670	0.018
Significance	*	Ns	Ns	*	Ns	*	Ns	Ns	Ns

[1]Least significant difference; *, significant at P < 0.05; Ns, not significant at P > 0.05.

Table 2: Influence of five lime levels on base saturation and other chemical soil properties under sweetpotato (*Ipomoea batatas* L.)

	Base saturation (%)				mg kg^{-1}						
Lime levels	K	Mg	Ca	H	S	Zn	Mn	Fe	Cu	B	Al
No lime	4.675	19.425	39.500	36.000	13.000	5.900	33.00	8.000	1.125	0.250	10.500
1.0 tonne ha^{-1}	3.850	22.275	41.950	31.925	12.750	5.825	32.750	5.250	1.075	0.275	4.750
1.5 tonnes ha^{-1}	4.525	26.600	45.900	23.025	11.750	5.600	32.000	4.000	1.050	0.325	3.500
2.0 tonnes ha^{-1}	5.150	27.350	43.625	23.875	13.000	5.800	31.750	5.000	1.150	0.325	4.000
2.5 tonnes ha^{-1}	3.400	31.225	44.400	20.950	12.000	6.375	32.250	4.000	1.125	0.350	5.000
Means	4.320	25.375	43.155	27.155	12.500	5.900	32.350	5.250	1.105	0.305	5.550
[1]LSD $_{(0.05)}$	2.280	3.722	7.935	7.609	2.657	1.038	1.441	1.553	0.106	0.136	5.458
Significance	Ns	*	Ns	*	Ns	Ns	Ns	*	Ns	Ns	*

[1]Least significant difference; *, significant at P < 0.05; Ns, not significant at P>0.05

Table 3: Effects of lime levels on mineral nutrient concentrations in sweetpotato (*Ipomoea batatas* L.) tubers

	Mineral concentration (%)						
Lime levels	N	S	P	K	Mg	Ca	Na
No lime	0.612	0.060	0.168	1.180	0.070	0.072	0.075
1.0 tonne ha^{-1}	0.757	0.063	0.172	1.235	0.070	0.058	0.083
1.5 tonnes ha^{-1}	0.667	0.062	0.165	1.243	0.103	0.060	0.065
2.0 tonnes ha^{-1}	0.730	0.067	0.160	0.915	0.100	0.095	0.095
2.5 tonnes ha^{-1}	0.695	0.058	0.160	1.277	0.067	0.058	0.070
Means	0.692	0.062	0.165	1.170	0.082	0.069	0.078
[1]LSD $_{(0.05)}$	0.222	0.014	0.049	0.366	0.041	0.058	0.057
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns

[1]Least significant difference; Ns, not significant at P > 0.05

Soil chemical properties: Table 1 shows the effects of lime treatments on the soil chemical properties investigated. Organic matter showed significant (P < 0.05) differences, with the lowest (2.325%) from the treatment receiving 1.0 t lime ha^{-1}; the highest (3.175%) was observed when 1.5 t ha^{-1} of lime was applied. When 2.5 t ha^{-1} of lime was applied, soil organic matter decreased. Magnesium concentrations also significantly (P < 0.05) varied with lime levels, increasing directly with a corresponding increase in the amounts of lime applied. The control had the lowest concentration (112.500 mg kg^{-1}) of Mg, whereas 2.5 t ha^{-1} of lime had 227.500 mg kg^{-1} of Mg. Soil pH increased from 5.375 (no lime) to 6.025 (2.5 t ha^{-1} of lime). Base saturation (Table 2) showed significant differences only in the concentrations of Mg, H and Al. Other soil mineral nutrients did not show any significant differences.

Organic matter plays important roles in essential nutrient availability and soil improvement [3, 10]. [11] adviced of the need to wisely manage soil organic matter

Table 4: Effects of lime levels on micronutrient and aluminum concentrations and yield of sweetpotato (*Ipomoea batatas* L.) tubers

	Mineral concentrations (mg kg^{-1})							
Lime levels	B	Zn	Mn	Fe	Cu	Al	Total tuber yield (tonnes ha^{-1})	Marketable tuber yield (tonnes ha^{-1})
No lime	4.500	12.000	8.250	168.000	4.500	175.750	29.33	24.55
1.0 tonne ha^{-1}	5.000	10.750	6.250	137.250	4.750	135.750	23.55	20.13
1.5 tonnes ha^{-1}	4.750	11.250	7.750	122.000	4.750	113.250	27.28	22.48
2.0 tonnes ha^{-1}	4.750	10.250	8.500	147.500	4.750	143.000	23.70	19.53
2.5 tonnes ha^{-1}	4.750	12.750	6.000	135.000	4.500	128.750	25.13	20.83
Means	4.750	11.400	7.350	141.950	4.650	139.300	25.80	21.50
[1]LSD $_{(0.05)}$	0.878	3.608	2.837	58.575	1.521	58.808	6.411	5.405
Significance	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns

[1]Least significant difference; *, significant at $P < 0.05$; Ns, not significant at $P > 0.05$

in order to improve family agriculture in Zimbabwe. These methods include the addition of manures to the soil, the return of crop residues to the soil after harvest and avoidance of bush burning. [12] observed favorable pH changes in soil when lime was applied to soybean (*Glycine max* L.).

Tuber mineral nutrient concentrations: Table 3 shows the effects of lime levels on mineral nutrient concentrations in sweetpotato tubers. All macronutrients investigated showed no significant differences among the lime levels. However, it is worthy to note that when no lime was applied, tuber N was lowest (0.612% and highest (0.757%) when 1.0 t lime ha^{-1} was applied. Applying 2.5 t lime ha^{-1} reduced tuber N to 0.695%. Table 4 shows that only Al concentration in sweetpotato tubers significantly varied among the lime levels. As would be expected, the tubers from the control had the highest Al concentration (175.750 mg kg^{-1}).

Total tuber yields and marketable tuber yields: Total tuber yields (Table 4) was highest (29.33 t ha^{-1}) when no lime was applied and lowest (23.55 t ha^{-1}) when 1.0 t ha^{-1} of lime was applied. No definite yield trend could be associated with the lime levels applied. Marketable tuber yields (Table 4) also showed no explicit yield trend. However, it should be pointed out that among the factors that could influence the yield of marketable tubers would be: care taken to have no wounds on the tubers during harvest, care taken to ensure whole tubers are dug out and the absence of pests and diseases.

CONCLUSION

The data on soil chemical properties and tuber mineral nutrients observed in this investigation did not show a clear and unmistakable trend to warrant an exclusive recommendation for lime application without first testing the soil. Thus, it is recommended that soil testing be used as the best guide to lime application in small-scale farming in Swaziland

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