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Effects of Filter Cake Fertilization On Soil Chemical Properties and Cassava (*Manihot Esculenta* Crantz) Yield In Swaziland

[1]E.M. Ossom, [2]R.L. Rhykerd and [3]C. Tfwala

[1]Crop Production Department, Faculty of Agriculture, University of Swaziland
Private Bag Luyengo, Luyengo M205, Swaziland
[2]Department of Agriculture, Illinois State University, Normal, IL 61790-5020, U.S.A.
[3]Ministry of Agriculture and Cooperatives, Malkerns Research Station, P.O. Box 4, Malkerns M204, Swaziland

Abstract: A field investigation was conducted in Swaziland in 2007-2008 cropping season to determine the effects of filter cake fertilization on soil chemical properties and cassava (*Manihot esculenta* Crantz) yield. The experimental design was a randomized complete block design, replicated four times. A factorial arrangement was used, with two varieties of cassava ('Nyasa' and 'Line 65') and five levels of soil amendment materials. The treatments were: control (no soil amendment), 20 t ha^{-1} of filter cake; 40 t ha^{-1} of filter cake; 60 t ha^{-1} of filter cake; and 300 kg ha ha^{-1} of mixed fertilizer, N:P:K. Results showed no significant differences in organic matter content (Nyasa, 5.1%; Line 65, 5.2%). Filter cake fertilization modified the soil pH (from the initial pH of 5.6) to: Nyasa, 5.8, Line 65, 6.0, indicating that Line 65 was better at reducing soil acidity. Total nitrogen (Nyasa, 0.171%; Line 65, 0.184%) was not significantly different in the soil. Line 65 yielded 50.1% higher tuber mass (2,893 kg ha^{-1}) than Nyasa (1,443 kg ha^{-1}). Filter cake had advantages on cassava production, the extent of the advantage depending on the cassava variety, and the amount of filter cake used. It is recommended that 60 t ha^{-1} filter cake could be applied to cassava; Line 65 is recommended as the preferred variety to plant under filter cake fertilization. Further research evaluating the impact of filter cake applications above 60 t ha^{-1} on cassava production and long-term studies to further elucidate the impact of filter cake on soil chemical properties are recommended.

Key words: Cassava, Chemical properties, Filter cake, Filter mud, Organic matter

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), also known as tapioca in English, and 'umjumbula' in siSwati, is the second most important root crop after sweetpotato in Swaziland[1]. This crop has not received much positive, agronomic attention that it rightly deserves. Production information on the crop has only recently been compiled[2] and has not been widely made available to the farming communities. Cassava, unlike maize (*Zea mays* L.) that is the staple food in Swaziland, has the ability to grow and give a reasonable yield even where poor weather, pest and disease attacks would lead to the failure of a maize crop[3]. It would be a good idea to introduce cassava into the local cropping system as an insurance against crop failure. The production practice of cassava might be better appreciated by Swazi maize farmers because, unlike maize in which the harvest period is restricted, cassava storage roots can be harvested after 18 months, as there is no fixed time of maturity[4]. The culture of cassava consumption is widespread in West Africa, Uganda, and Zambia[3]; a similar culture of dietary use of cassava could be cultivated among the people of Swaziland. Farmers in Swaziland can be made aware of the potential of growing and marketing cassava as a commercial produce.

Filter mud, filter-press, filter cake, filter muck, and mill mud refer to the same soil-like residue obtained by filtration of the mud, which settles out in the process of clarification of the mixed juice from sugarcane[5]. In the process of sugar refining at sugar mills, some by-products are discharged. The three most important are filter cake, bagasse (fibre), and molasses.

Filter cake, when applied to land, increases soil fertility by providing nitrogen and phosphorous for crops or ground cover growth[5]. The filter cake, because of its chemical nature, might increase the organic matter content of the soil. This beneficial aspect of filter cake makes it useful where attempts have been made to restore or increase the fertility of eroded, clay-textured or strip-mined land. It was

Corresponding Author: Ossom, E.M., Crop Production Department, Faculty of Agriculture, University of Swaziland.
Email: emossom@agric.uniswa.sz

advised[6] that in order to maintain a sustainable cycle of nutrients, the leaves of sugarcane should not be burned during harvesting, and filter cake should be properly returned to the field.

Agronomic information on cassava production in Swaziland is scarce. The Farmer's Handbook[7] totally omitted crop production information on cassava. However, the Ministry of Agriculture and Cooperatives[2] recently produced a cassava-production booklet for use in Swaziland. The booklet is silent on the possible uses of filter cake as fertiliser in cassava production. Other countries where cassava is cultivated in East and Southern Africa include Botswana, Lesotho, Tanzania and Zambia[8], but in none of these countries is filter cake extensively used as a fertilizer, by small-scale farmers.

Cassava's low input requirement, a trait that fits well with the region's resource endowment, makes it suitable for the difficulties that African farmers face. The shortage of chemical input and organic matter and the limited irrigation facilities in the region also make cassava a crop of choice for Swazi farmers. Higher prices, increased market access for farmers, and higher yields have also played a role in cassava's emergence as a cash crop in most of the Southern Africa Development Community (SADC) region[9]. This commercialisation of the crop is particularly significant, given that the share of urban population is expected to increase 30 to 50% by 2020[10].

Promotion of cassava for industrial purposes has been encouraged in Swaziland. A company, United Distillers, advertised[11] for Swaziland farmers to sell cassava tubers to it, for industrial production of alcohol. In 2006, cassava farmers were guaranteed a market for cassava in the E150-million factory that was planned to be constructed in Madlangempisi in Swaziland, by a company known as C.S. Manufacturing[12]. Thus, the future is very promising for cassava production in Swaziland. However, a reduction in production inputs (such as use of less artificial fertilisers if filter cake use could be a viable and cheaper alternative) could widen the profit margin of growers and encourage more farmers to go into cassava production.

MATERIALS AND METHODS

Site, Treatments, Experimental Design and Plot Size: The experiment was conducted at Malkerns Research Station (740 m above sea level) in the Middleveld ecological zone of Swaziland. Malkerns has a rainfall range of 800-1460 mm during the crop season, and has a mean temperature range from 7.3^{o}C to 26.6^{o}C during the growing season.

The investigation was a field experiment consisting of 10 treatment combinations (Table 1): two varieties of cassava ('Nyasa' and 'Line 65'), and five levels of filter cake (a factorial arrangement) in a randomized complete block design. Each treatment was replicated four times. Each plot measured 10.0 m long and x 7.0 m wide, and consisted of seven (gross) ridges/rows, each measuring 10.0 m in length, and three ridges of net plots. There was a 1.0-m distance between treatments and between blocks. There were four discard ridges, two at each end of the plot. Inter-row spacing was 100 cm, and the intra-row spacing was 100 cm, giving 10,000 plants/ha.

Soil and Filter Cake Analyses: Soil analysis was carried out twice – at the start and end of the experiment, to assess the chemical composition of the soil and the effects of the filter cake. Filter cake was analyzed at the start of the investigation, to assess its chemical properties and the concentrations of mineral nutrients in it. No liming was carried out because the during the initial soil analysis, pH was 5.6), well above the lower limit of 5.3 when lime needs to be applied for cassava in Luyengo area. The crop was planted on the same day after, ploughing, disking and ridging were completed.

Preparations Before Planting, and Planting: Cuttings of two recommended varieties of cassava ('Nyasa' and 'Line 65') were obtained from Malkerns Research Station. Each cutting was from mature stems, and measured 30 cm in length. Filter cake was applied on top of the ridges, and worked into the soil, using spades and garden forks. Thereafter, cassava cuttings were planted (11-13 December 2007) at an angle of about 45^{o} from the horizontal, on top of the ridge, with 5-10 cm of each cutting being below the soil surface[4].To simulate the small-scale farmers' condition of minimal use of agro-chemicals, there was no chemical treatment of cuttings before planting, which was done after the fertilizer and filter cake were applied.

Inorganic and Organic Fertilizer Application: Inorganic and organic fertilizer application was made as follows:

i. 300 kg ha^{-1} of NPK [2:3:2 (22)], that also contained 0.5% Zn, was applied only to the plots that required a fertilizer treatment (Treatments 5 and 10).
ii. 100 kg ha^{-1} of superphosphate (10.5% P), was also applied only to the plots that required a fertilizer treatment.

iii. 100 kg ha^{-1} of KCl (60% K) was also applied only to the plots that required a fertilizer treatment.

These were applied one week before planting, using the banding and incorporation method, 15 cm away from the planting rows. At six weeks after planting (WAP), limestone ammonium nitrate (LAN) that contained 28% nitrogen was applied (100 kg ha^{-1}) as a side dressing to the cassava plots that required inorganic fertilizer. Both inorganic fertilisers and filter cake were applied before planting the cuttings, so as to avoid disturbing the cuttings after planting.

Data Collection and Data Analysis: Meteorological data were obtained from Malkerns Research Meteorological records. After harvest, soils in each plot were sampled (15-cm depth); the samples were air-dried in the laboratory, and were shipped to the United States, where detailed chemical analyses were carried out using recommended procedures[13]. Data were analyzed using MSTAT-C statistical package, version 1.3[14]. Mean separation was done using the standard error and least significant difference test[15] methods

RESULTS AND DISCUSSION

Meteorological Data and Initial Chemical Properties: Meteorological data during the period of the investigation are shown in Table 2. The total rainfall during the period was 618.5 mm; the mean temperature ranged from a low of 8.7ºC in July 2008, to a high of 28.7ºC in February 2008. Among the climatic factors that influence crop growth and performance are rainfall distribution and amounts as well as air and soil temperatures. The cropping period was much drier than the same months for the previous 10 years (1997-2007), that had a mean annual rainfall of 113.5 mm. Low rainfall could influence crop yields.

The chemical characteristics of the soil at the beginning of the investigation were: pH, 5.6; N, 0.11%; P, 0.69%; K, 2.84%; exchangeable acidity, 0.15%; and organic matter, 2.72%. The soil appeared low in nitrogen, with moderate concentrations of P and K. It was reported[16] that the optimum pH range for sweetpotato is 5.2-6.0; on this account, it would be proper to assume that the soil pH of 5.6 was adequate. The chemical properties of the filter cake were as follows: pH, 7.98; N, 1.77%; P, 2340.0 cmole kg^{-1}; K, 999 cmole kg^{-1}; Mg, 37.89 cmole kg^{-1}; Ca, 10.15 cmole kg^{-1}; and exchangeable acidity, 0.10 cmole kg^{-1}. As noted, the pH of the filter cake was in the alkaline range that would have complemented the soil pH.

Soil Chemical Properties: Table 3 shows the chemical properties of the soil at harvest. There were no significant differences in organic matter content (Nyasa, 5.1%; Line 65, 5.2%). Organic matter levels were not significantly different among the soil amendment materials, but were as follows: control, 5.2%; 20 t ha^{-1} of filter cake, 5.2%; 40 t ha^{-1} of filter cake, 5.1%; 60 t ha^{-1} of filter cake, 5.3%; and 300 kg ha^{-1} of artificial fertilizer, 5.0%. Filter cake fertilization modified the soil pH (from the initial soil pH of 5.6) to: Nyasa, 5.8, Line 65, 6.0, indicating that Line 65 was better at improving soil acidity, under fertilization with filter cake. The difference in pH between the two varieties was not significant, but the differences among the five treatments were significant ($P < 0.05$).

The means of the soil amendment materials were as follows: control, 5.7; 20 t ha^{-1} of filter cake, 6.0; 40 t ha^{-1} of filter cake, 6.1; 60 t ha^{-1} of filter cake, 6.4; and 300 kg ha^{-1} of artificial fertilizer, 5.6. There was no significant difference in aluminium concentrations (Nyasa, 4.9 mg kg^{-1}; Line 65, 4.6 mg kg^{-1}) between the two varieties.

As shown in Table 4, total nitrogen (Nyasa, 0.171%; Line 65, 0.184%) was not significantly higher in soil grown to Line 65 than in Nyasa soil. Among the soil amendment materials, the means were as follows: control, 0.171%; 20 t ha^{-1} of filter cake, 0.172%; 40 t ha^{-1} of filter cake, 0.182%; 60 t ha^{-1} of filter cake; and 300 kg ha^{-1} of artificial fertilizer, 0.188%.

The interaction effects were not significant. There were no significant differences in the concentrations of sulphur and micronutrients (Table 5) in the soil between the varieties and among the interaction effects at 32 weeks. In an experiment comparing soil nutrient concentrations under different lime regimes in monocropped sweetpotato (*Ipomoea batatas* L.), a storage root crop like cassava, non-significant concentrations of soil P, K, Ca, cation exchange capacity, nitrate nitrogen and total N levels were reported[17].

Storage Root Yields: As shown in Table 6, the tuber yield (2,893 kg ha^{-1}) of Line 65 was significantly ($P < 0.01$) higher than that of Nyasa 1,443 kg ha^{-1}). These tuber yields were low, but might have been higher if the tubers had stayed longer in the soil or the weather climate was more favourable during the cropping period.

The yield of tubers (averaged over both varieties) relative to the amount of soil amendments applied was as follows: control, 745.0 kg ha^{-1}; 20 t ha^{-1} of filter cake, 1,691.3 kg ha^{-1}, 40 t ha^{-1} of filter cake, 2,652.5 kg ha^{-1}; 60 t ha^{-1} of filter cake, 2,768.8 kg ha^{-1}; and 300 kg ha^{-1} artificial fertilizer, 2,982.5 kg ha^{-1}. The interaction effects were not significant. Optimum yields in cassava could be determined by a number of factors: fertility status of the farmland, cropping system adopted, and the rainfall pattern during the growing season[18].

Table 1: Treatment description for the experiment

Treatment code	Cassava variety	Rate of filter cake (t ha^{-1})	Rate of compound fertilizer (kg ha^{-1})
1	'Nyasa'	0 (Control)	0
2	'Nyasa'	20	0
3	'Nyasa'	40	0
4	'Nyasa'	60	0
5	'Nyasa'	0	300
6	'Line 65'	0 (Control)	0
7	'Line 65'	20	0
8	'Line 65'	40	0
9	'Line 65'	60	0
10	'Line 65'	0	300

Table 2: Meteorological data during the period of the investigation

Month	Mean air temperatures (ºC)		Mean monthly rainfall (mm)
	Maximum	Minimum	
December 2007	27.1	16.9	111.7
January 2008	27.1	18.2	81.9
February 2008	28.7	17.3	75.0
March 2008	26.4	16.5	195.6
April 2008	23.9	13.1	95.7
May 2008	25.6	11.4	22.2
June 2008	22.8	9.0	25.0
July 2008	24.2	8.7	4.8
August 2008	26.3	10.6	6.6
Totals	-	-	618.5
Means	25.8	13.5	68.7

Table 3: Soil chemical properties under filter cake application on two cassava varieties

Cassava varieties	Fertilizer rates	Organic matter (%)	P (mg kg-1)	K (mg kg-1)	Mg (mg kg-1)	Ca (mg kg-1)	pH	CEC (me/100 g)
Nyasa	No fertilizer	5.2	17.8	48.8	145.0	525.0	5.8	6.1
Nyasa	20 t/ha filter cake	5.0	39.8	70.8	153.8	587.5	6.0	5.9
Nyasa	40 t/ha filter cake	5.2	48.5	73.3	138.8	800.0	6.2	6.6
Nyasa	60 t/ha filter cake	5.2	55.5	85.3	161.3	812.5	6.1	7.1
Nyasa	300 kg/ha NPK	5.1	37.5	79.8	128.8	487.5	5.5	6.1
Mean		5.1	39.8	71.6	145.5	642.5	5.8	6.3
Line 65	No fertilizer	5.3	33.3	61.5	138.8	537.5	5.9	5.0
Line 65	20 t/ha filter cake	5.4	34.5	70.8	153.8	612.5	6.1	5.7
Line 65	40 t/ha filter cake	5.1	39.3	78.3	150.0	612.5	6.1	6.0

Table 3: Continue

Line 65	60 t/ha filter cake	5.4	76.8	96.0	171.3	850.0	6.3	6.9
Line 65	300 kg/ha NPK	5.0	32.3	82.5	141.3	700.0	5.8	7.0
Mean		5.2	43.2	77.8	151.0	662.5	6.0	6.1
Grand mean	-	5.2	41.5	74.7	148.3	652.5	5.92	6.2
Standard error (V x F)	-	0.14	11.46	7.69	15.48	101.08	0.18	0.64

Table 4: Base saturation, exchangeable Al and total nitrogen in soil at 32 weeks after planting as influenced by filter cake application on two cassava varieties

Cassava varieties	Fertilizer rates	Base saturation (%)				Exc. Al (mg kg^{-1})	Total soil N (%)
		K	Mg	Ca	H		
Nyasa	No fertilizer	2.2	21.4	43.2	33.2	4.0	0.174
Nyasa	20 t/ha filter cake	3.1	21.1	47.9	27.9	6.8	0.181
Nyasa	40 t/ha filter cake	2.9	17.8	60.8	18.6	4.0	0.168
Nyasa	60 t/ha filter cake	3.1	18.9	57.0	21.1	4.5	0.149
Nyasa	300 kg/ha NPK	3.6	18.0	39.0	39.5	5.3	0.180
Mean		2.98	19.4	47.1	28.0	4.9	0.171
Line 65	No fertilizer	3.3	23.3	51.0	22.5	5.3	0.168
Line 65	20 t/ha filter cake	3.2	22.2	53.5	21.1	3.0	0.163
Line 65	40 t/ha filter cake	3.3	20.6	50.4	25.7	4.5	0.195
Line 65	60 t/ha filter cake	3.7	21.2	59.6	15.5	3.8	0.196
Line 65	300 kg/ha NPK	3.1	17.7	50.1	29.1	6.5	0.195
Mean	-	3.3	21.0	50.7	22.8	4.6	0.184
Grand mean	-	3.1	20.2	51.2	25.4	4.8	0.177
Standard error (V x F)	-	0.43	2.02	4.07	4.74	1.47	0.023
Significance	-	NS	NS	NS	NS	NS	NS

NS, not significant at $P > 0.05$.

Table 5: Sulphur and micronutrient concentrations in soil as influenced by filter cake application

Cassava varieties	Fertilizer rates	Sulphur (mg kg^{-1})	Micronutrient concentration (mg kg^{-1})				
			Zinc	Manga-nese	Iron	Copper	Boron
Nyasa	No fertilizer	16.8	5.2	10.5	1.0	2.0	0.3
Nyasa	20 t/ha filter cake	18.0	5.4	17.0	1.5	2.1	0.3
Nyasa	40 t/ha filter cake	17.2	4.4	18.5	1.3	2.0	0.3
Nyasa	60 t/ha filter cake	17.8	5.0	21.8	1.3	2.0	0.3
Nyasa	300 kg/ha NPK	18.5	5.3	12.8	1.0	2.1	0.3
Mean		17.7	5.06	16.1	1.2	2.0	0.3
Line 65	No fertilizer	15.8	5.1	14.0	1.0	2.1	0.3
Line 65	20 t/ha filter cake	17.8	4.7	15.8	1.0	2.1	0.3
Line 65	40 t/ha filter cake	20.5	5.3	17.5	1.0	2.1	0.3
Line 65	60 t/ha filter cake	19.3	5.2	23.8	3.3	2.2	0.3

Table 5: Continue

Line 65	300 kg/ha NPK	20.5	4.4	12.3	1.0	1.9	0.3
Mean	-	18.8	4.94	16.7	1.5	2.1	0.3
Grand mean	-	18.2	5.00	16.4	1.3	2.1	0.3
Standard error(V x F)	-	1.76	0.39	2.82	0.71	0.11	0.02

Table 6: Cassava tuber yield and tuber fresh mass/plant at harvest

Cassava varieties	Fertilizer rates	Tuber yield (kg/ha)	Tuber fresh mass/plant (g)
Nyasa	No fertilizer	400.0	91.9
Nyasa	20 t/ha filter cake	975.0	129.4
Nyasa	40 t/ha filter cake	2457.5	203.7
Nyasa	60 t/ha filter cake	2027.5	153.0
Nyasa	300 kg/ha NPK	1355.0	123.9
Mean		745.00	146.18
Line 65	No fertilizer	1090.0	123.9
Line 65	20 t/ha filter cake	2407.5	221.0
Line 65	40 t/ha filter cake	2847.5	271.9
Line 65	60 t/ha filter cake	3510.0	250.0
Line 65	300 kg/ha NPK	4610.0	393.8
Mean	-	1691.25	252.10
Grand mean	-	2168.0	199.14
Standard error (V x F)	-	547.19	46.42
Significance	-	**	*

*Significant at $P < 0.05$;
**Significant at $P < 0.01$.

Conclusion and Recommendation: Filter cake has advantages on cassava production, the extent of the advantage depending on the variety of cassava grown, and the amount of filter cake used. It is recommended that 60 t ha^{-1} of filter cake be applied in cassava fields to optimize yields. Additional studies evaluating applications of filter cake mud above 60 t ha^{-1} should be determined in another investigation along with multi-year studies to further elucidate the impact of filter cake on soil chemical properties. Line 65 is recommended as the preferred variety to plant under filter cake fertilization.

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