Transactions of the Illinois State Academy of Science
(2007), Volume 100, #3&4, pp. 197-208

received 4/23/07
accepted 9/30/07

Response of *Ipomoea batatas* (L.) Lam. to Soil Fertilization with Filter Cake

E. M. Ossom
Professor of Agronomy
Crop Production Department, Faculty of Agriculture
University of Swaziland
P.O. Luyengo, Luyengo M205, Swaziland
R. L. Rhykerd[1]
Associate Professor, Campus Box 5020
Department of Agriculture
Illinois State University
Normal, IL 61790-5020, USA
[1]Corresponding author: Email: rrhyker@ilstu.edu

ABSTRACT

Filter cake is a waste product from sugarcane (*Saccharum officinarum* L.) processing. Filter cake is often found as a waste product near locations of sugar mills. Currently, sweetpotato [*Ipomoea batatas* (L.) Lam.] farmers do not use filter cake as fertilizer. If the benefits of filter cake as a soil-improvement material for sweetpotato could be demonstrated, sweetpotato farmers could obtain and use this waste product. Five soil-improvement materials (no filter cake; 10,000 kg ha^{-1} filter cake; 20,000 kg ha^{-1} filter cake; 40,000 kg ha^{-1} filter cake; and 600 kg ha^{-1} compound fertilizer) were assessed in a randomized complete block design that was replicated five times. The objective of this study was to assess the influence of filter cake on yield and yield components of sweetpotato, soil temperature, and weed infestation. Results showed that yields were highest (13,427.4 kg ha^{-1}) with 10,000 kg ha^{-1} of filter cake application, and lowest (11,686.0 kg ha^{-1}) with 40,000 kg ha^{-1}. Mass of tuber/plant made 28.1% ($r = 0.530$; $n = 25$) contribution to increased yield; tuber length contributed 3.5% ($r = 0.186$; $n = 25$) to yield. Weed infestation was negatively, but non-significantly correlated ($r = - 0.161$; $n = 25$) with storage root yield. Soil temperatures did not significantly vary among the treatments, though 5-cm depth temperatures were higher than temperatures at 10-cm depth and soil surface. Based upon the results of this experiment, it is recommended that 10,000 kg ha^{-1} of filter cake be applied to sweetpotato.

Keywords: Filter cake, sweetpotato, soil fertilization, soil temperatures, weed infestation, yield components.

INTRODUCTION

Filter cake is the main solid waste obtained by filtration of the mud, which settles out in the process of clarification of juice from sugarcane processing (Barnes, 1974). It was reported (FAO, 2004) that filter cake could increase soil fertility and supplement inorganic fertilizers. Filter cake or filter mud was described (Blackburn, 1984) as a useful fertilizer, especially when applied to phosphate-deficient soils and to fields in which the topsoil was removed. This beneficial aspect of filter cake could make it useful where attempts are required to restore or increase the fertility of eroded, clay-textured, or strip-mined land. In addition, using filter cake rather than artificial fertilizer would be one way of promoting organic gardening.

Sweetpotato is the most important storage root crop in Swaziland. Its importance in Swazi cuisine is now becoming more prominent as it is being realized that sweetpotato could play a useful role in ameliorating the health conditions of those afflicted with diabetes, HIV or AIDS (Mzileni, P., Nursing Sister, University of Swaziland, Personal Communication, 2005). Usually planted on ridges, sweetpotato takes about 4-6 months to mature; during the growing period, the young leaves can also be harvested and cooked for food.

In Swaziland, the country's four sugar mills produce large quantities of waste, including filter cake. These sugar mills are expected to declare their production of halogenated filter cakes and spent absorbents (Anon., 2004b). The Swaziland Environmental Authority is expected to oversee these declarations; however, it is believed that these reports are imprecise and thus the exact quantity produced is unknown. Swaziland is not alone in its problem of waste management. In a workshop to identify the problems facing the sugar sub-sector in Kenya, the participants declared that Kenya sugar industry made no progress in diversifying its operations and product base from sugar. Among the suggestions to improve the situation was the need to use bagasse (fiber) to produce newsprint, paper, building hardboard, and putting filter cake into an economic use as an organic fertilizer or soil ameliorate (Odek et al., 2003).

The world's population is growing tremendously. The United States Census Bureau (2006) reported that the world's population would increase from 6.5 billion in July 2006 to 6.8 billion by July 2010. This increased population demand will require more food production in order to feed the increasing world population. This is likely to require the farming population to use more inorganic fertilizers to achieve higher crop yields. However, these inorganic fertilizers are expensive whereas organic fertilizers are cheap. If the benefits of filter cake as a fertilizer in sweetpotato production could be demonstrated, Swaziland farmers could obtain filter cake from sugar mills and use this as a soil-improvement material on their farms. The objectives of the investigation were to determine the effects of filter cake on yield and yield components, soil temperature, and weed infestation in sweetpotato.

METHODS

Location and experimental design

The field trial was conducted at Malkerns Research Station (altitude, 740 m above sea level; rainfall, 800-1460 mm; mean temperature, 7.3°C to 26.6°C) from January to June 2006. The soil was an Oxisol (Murdoch, 1968). Five treatments were replicated five times in a randomized complete block design. The treatments (T) were: no filter cake (control); 10,000 kg ha^{-1} of filter cake; 20,000 kg ha^{-1} of filter cake; 40,000 kg ha^{-1} of filter cake; and 600 kg ha^{-1} of compound fertilizer. The amount of filter cake applied was similar to that typically added when applying compost. Plot dimensions were 5.0 m x 7.0 m, with eight ridges per plot. The crop spacing was 30.0 cm within rows, and 100.0 cm between rows, giving a plant population of 33,333 plants ha^{-1} (Ossom et al., 2005). A 200-cm space was allowed between replicates; treatments within the same replicates were spaced 100 cm apart.

Fertilizer application and planting

Initial land preparation consisted of moldboard plowing followed by disking with a tractor-mounted disk harrow. Thereafter, ridge-construction (for 100-cm ridges) was done using tractor-mounted ridgers. Filter cake and fertilizer application was made one day before planting. The fertilizer consisted of 300 kg ha^{-1} of N:P:K [2:3:2: (22) + Zn] mixed with 100 kg ha^{-1} single superphosphate and 100 kg ha^{-1} of muriate of potash (Anon., 1991). At 6 weeks after planting (WAP), 100 kg ha^{-1} of limestone ammonium nitrate (LAN, 28% N) was applied to the fertilizer treatment. Both fertilizer and filter cake were banded and incorporated. The sweetpotato variety used was 'Kenya' that was obtained from Malkerns Research Station. Planting was done on January 9, 2006, by hand, using young vines that were 30 cm in length, at the rate of one vine/planting station. The experiment was not irrigated to simulate small-scale farming activities that typically have no irrigation.

Data Collection

Data were collected on soil temperature, weed infestation and yield and yield components. Alternate ridges were used as guard rows from which no data were taken.

Soil Temperature

Soil temperature was taken every four weeks on bright, sunny days without rain, and between 1400 and 1600 hours. The temperature was recorded using the Fisher brand bimetal-dial thermometers having a gauge diameter of 4.5 cm, a stem length of 20.3 cm, and an accuracy of ± 1.0% of dial range at any point on the dial (Ossom et al., 2001; Ossom et al., 2006). The temperature readings were taken at a distance of 10 cm from the plant rows, and at three depths: soil surface, 5-cm, and 10-cm depths. Three readings were made in each depth/plot, totaling nine readings/plot. A 30-second interval was allowed to elapse before readings were taken in order to allow the thermometers to stabilize.

Weed Infestation

General weeding was done at 4 weeks after planting (WAP) by the use of hand hoes. Weed infestation was assessed at 12 WAP. To assess weed density, a 90-cm square quadrat was used and three assessments/plot were made on each occasion. The descriptions of the range of scores (1-6) that indicated the degree of weed density were: 1, zero weeds within the quadrat; 2, sparse weed coverage of soil within the quadrat; 3, intermediate weed coverage of soil within the quadrat; 4, general weed coverage of soil within the quadrat; 5, severe weed coverage of soil within the quadrat; and 6, complete weed coverage of soil within the quadrat. A similar method of estimating weed density had earlier been used by other workers (Daisley et al., 1988; Ossom et al., 2001; and Ossom et al., 2006). The weed species were also identified and classified (Botha, 2001) within the quadrat at each determination; the presence or absence of weed species was noted to determine if any weed species would be confined to any particular soil-improvement materials. After identification, the dry matter of each weed species was determined by oven drying (Tafaj et al., 2006). Weed sub-samples weighing 300-400 g were dried; where the weeds weighed below 300 g, the entire mass was dried.

Harvesting and Yield data

The crop was manually harvested at 20 WAP, using garden forks. Two lines/plot were used for yield determination, and the fresh mass/plot was converted to kg ha^{-1}. Yield components were determined as follows: petiole length was measured by taking the linear measurements from 10 petioles randomly selected from each of 5 plants/plot; the length of marketable tubers was measured from the proximal end of the tuber to its distal end using a plastic tape measure. Tuber diameter was measured by means of a vernier caliper, measurements being made at the widest part of every marketable tuber from each of 5 plants/plot.

Data analysis

Data were analyzed using MSTAT-C package, version 1.3 (Nissen, 1983). The least significant difference (LSD) test (Steel and Torrie, 1980) was used for mean separation at 5% probability level.

RESULTS AND DISCUSSION

Meteorological Information

Climatic factors that influence crop growth and performance include rainfall distribution and amounts as well as air and soil temperatures. Table 1 shows the meteorological information during the period of the investigation. The air temperatures ranged from a low of 8°C in June (harvest month), to a high of 28.8°C (one month after planting). The total rainfall during the period was 833.4 mm, with a range of 1.7 mm (in May 2006) to 295.5 mm (in January 2006).

Soil Properties

Initial chemical properties of the soil during the investigation were: pH, 5.8; total N, 1.3%; P, 4.54 mg P kg^{-1} soil; K, 1,599 mg K kg^{-1} soil; exchangeable acidity, 0.29 cmol kg^{-1}; and organic matter, 2.4%. The soil appeared low in nitrogen, with moderate concentrations of P and K. The chemical properties of the filter cake were as follows: pH, 7.9; total N, 1.15%; P, 1,289 mg P kg^{-1} soil; K, 1,614 mg K kg^{-1} soil; Mg, 1,305 ppm; and organic matter, 27.1 %. As noted, the pH of the filter cake was in the alkaline range that would have complemented the acid soil. Perry (1997) reported the optimum pH range for sweetpotato to be 5.2-6.0; on this account, the soil pH of 5.8 was adequate for the performance of the crop.

Soil Temperature

Data on soil temperature (Table 2) show that the general trend in temperature values was 5-cm depth > soil surface > 10-cm depth. Slightly lower soil temperatures were recorded at 16 WAP because this period coincided with the onset of winter, when low and fluctuating air and soil temperatures are usually experienced. Yet 20 WAP, the temperatures increased again. However, there were no significant differences between the treatments. That soil temperatures are higher at 5-cm depth than at the soil surface and at 10- and 15-

cm depths agree with earlier observations (Ossom et al., 2001; Ossom, 2003; Thwala, 2004; Ossom and Dlamini, 2006; Ossom et al., 2006) who also reported that same trend in soil temperatures. Soil temperature is reported to influence some physiological processes including seed dormancy, germination (Relf, 1997), seedling emergence, and growth (Anon., 2004a). The soil temperature range (14.7-35.3°C) recorded in our investigation is consistent with soil temperatures in tropical areas (Sanchez, 1976; Ossom et al., 2001; Ossom et al., 2006). Increased physiological activities in the topsoil being a consequence of the greater number of living organisms are given (Ossom et al., 2006; Ossom and Dlamini, 2006) as among the reasons for higher temperatures in the upper layers of the soil (such as 5-cm depth) than in lower depths (such as 10-cm depth).

Weed infestation

Table 3 shows the weed species that were encountered at 12 WAP. The weeds are common weeds of the Luyengo area (Ossom, 2005); no new weed species were introduced through the use of soil-improvement materials. A few edible species (such as *Amaranthus hybridus* L., and *Bidens pilosa* L.) were among the weeds; both species are commonly eaten as vegetables in Swaziland. Weed density showed no significant differences among soil-improvement materials. Weed density was negatively, but non-significantly correlated (r = - 0.161; n = 25) with storage root yield. The coefficient of determination (R^2) of 0.0259 indicates that 2.6% of the variation in tuber yield/ha can be attributed to the adverse effect of weed density at 12 WAP. The species were distributed over 13 genera and 11 families. The distribution was as follows: no filter cake, 12 genera and nine families; 10,000 kg ha^{-1} of filter cake, 13 genera and nine families; 20,000 kg ha^{-1} of filter cake, 10 genera and eight families; 40,000 kg ha^{-1} of filter cake, 13 genera and nine families; and inorganic fertilizer, 13 genera and 11 families of weeds. Based on biomass production, *Bidens pilosa* (L.) and *Richardia brasiliensis* (Gomes.) were the two most troublesome weed species. Our results are consistent with previous reports (Zimdahl, 1993; Thwala, 2004; Ossom et al., 2001; Kelly et al., 2006; and Ossom et al., 2006) that associated crop yield reductions with increased weed infestation. Kelly et al. (2006) observed that the benefits from increased yields by controlling sweetpotato weeds more than outweighed the expense in the exercise.

Yield and yield components

Table 4 shows the influence of soil-improvement materials on yield and yield components in sweetpotato. All yield components are positively correlated with tuber yield, with mass of tuber/plant making the largest (28.1%) contribution to yield. Tuber length contributed the least (3.5%) to tuber yield. Generally, the storage root yields were low compared to yields from previous sweetpotato investigations (Development Associates, Inc., 2003). Previous workers (Hartermink et al., 2000; Ossom et al., 2003) show yields of sweetpotato to be variable and inconsistent.

The 10,000 kg ha^{-1} filter cake yielded highest and the other four treatments were lower than the highest yield by the following percentages: no filter cake, 10.5%; 20,000 kg ha^{-1} filter cake, 10.8%; 40,000 kg ha^{-1} filter cake, 13.0%; and fertilizer, 0.8%. Thus, filter cake at 20,000 kg ha^{-1} resulted in a higher tuber yield than when 40,000 kg ha^{-1} was applied. This is in agreement with the findings of Ossom and Nxumalo (Unpublished data, 2006) on the effects of filter cake on yields of maize (*Zea mays* L.); they indicated a lower grain yield of maize from 40,000 kg ha^{-1} of filter cake than when 20,000 kg ha^{-1} was applied.

Fertilizing soil with filter cake has been investigated in other crops besides sugarcane and maize, and found to have no detrimental effects. Srinarong and Panchaban (2003) investigated the influence of filter cake and other soil-improvement materials on the growth performance of rice and found that filter cake and sludge cake significantly increased soil pH and soil organic matter, but slightly decreased soil electrical conductivity whereas Tzeng et al. (2001) reported no adverse effects of filter cake on soils.

The fact that the application of 10,000 kg ha^{-1} of filter cake produced a tuber yield equivalent to the application of 600 kg ha^{-1} of a compound fertilizer as applied in this experiment is not surprising considering that the chemical properties of this filter cake were: pH 7.9, total N 1.15%, P 1,289 mg P kg^{-1} soil, K 1,614 mg K kg^{-1} soil, Mg 1,305 mg Mg kg^{-1} soil, and organic matter 27.1%. The surprising result was the fact that 20,000 and 40,000 kg ha^{-1} of filter cake produced no increase in yield of sweetpotato tubers compared to the control plots (no filter cake). Long-term studies will be needed to more clearly elucidate the response of sweetpotato to the application of rates of filter cake above 10,000 kg ha^{-1} as a source of fertilizer mineral elements and organic matter.

CONCLUSION AND RECOMMENDATION

Findings from this investigation are that tuber yields were highest when filter cake was applied at the rate of 10,000 kg ha^{-1}. Filter cake did not significantly influence soil temperature in sweetpotato plots. Weed species distribution varied among the soil-improvement materials, but no species could be expressly associated with the use or non-use of filter cake.

While there is need for further long-term investigations into the use of filter cake in sweetpotato production, it is reasoned that if 10,000 kg ha^{-1} filter could give a higher tuber yield than higher rates of filter cake, then sweetpotato farmers who have access to filter cake should adopt this rate of application.

ACKNOWLEDGEMENT

The authors are grateful to Malkerns Research Station for providing the site and security for this investigation.

LITERATURE CITED

Anonymous. (1991). Field Crops Production. p.1-60. In Pitts, C. W. (ed.) Farmer's Handbook. Ministry of Agriculture and Cooperatives, Mbabane.

Anonymous. (2004a). Soil Temperature and Field Vegetable Germination - Frequently Asked Questions. Alberta Agriculture, Food and Rural Development. http://www1.agric.gov.ab.ca/ $department/deptdocs.nsf/all/faq8347?opendocument. 07/17/06.

Anonymous. (2004b). Swaziland - Waste regulations 2000. http://www.elaw.org/resources/ printable.asp?id=2482. 29/08/05.

Barnes, A. C. (1974). The Sugar cane, New York. John Wiley and Sons, Inc., Brumelle.

Blackburn, F. (1984). Sugarcane. Longman. London.

Botha, C. (2001). Common weeds of crops and gardens in Southern Africa. Agricultural Research Council-Grain Crops Institute, Potchefstroom.

Daisley, L. E. A., Chong, S. K., Olsen, F. J., Singh, L., and George, C. (1988). Effects of surface-applied grass mulch on soil water content and yields of cowpea and eggplant in Antigua, *Tropical Agriculture (Trinidad)* 65 (4): 300-304.

Development Associates, Inc. (2003). Cassava and sweet potato multiplication. http://www.sarpn.org.za/documents/d0001223/P1355-ASAP-eval-report_Jan2003_obj3_G.pdf. 07/07/06.

Hartermink, A. E., O'Sullivan, J. N., and Poloma, S. (2000). Integrated nutrient management for sustaining sweet potato yields in the humid lowland. Papua New Guinea Food and Nutrition Conference, 26-30 June 2000, Lae.

FAO. (2004). Fertilizer use by crop in Pakistan. http://www.fao.org/docrep/007/y5460e/y5460e09.htm. 07/17/06.

Kelly, S. T., Miller, D. K., and Shankle, M. W. (2006). Herbicide evaluations for use in sweet potatoes. http://www.lsuagcenter.com/en/crops_livestock/crops/sweet_potatoes/Herbicide+Evaluations+ for+Use+in+Sweet+potatoes.htm. 07/07/06.

Murdoch, G. (1968). Soils and land capability of Swaziland. Swaziland Ministry of Agriculture, Mbabane.

Nissen, O. (1983). MSTAT-C: A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University, East Lansing.

Odek, O., Kegode, P., and Ochola, S. (2003). The challenges and way forward for the sugar sub-sector in Kenya. Published by Friedrich Ebert Stiftung (FES), P. O. Box 14932, Nairobi, Kenya.

Ossom, E. M. (2003). Effect of cucumber management methods on weed infestation and soil temperature in Swaziland. *Tropical Agriculture (Trinidad)* 80 (4): 205-210.

Ossom, E. M. (2005). Effects of weed control methods on weed infestation, soil temperature and maize yield in Swaziland. *UNISWA Research Journal of Agriculture, Science and Technology* 8 (1): 1-15.

Ossom, E. M., and Dlamini, F. (2006). Influence of filter cake on weed infestation, soil temperature and yield of maize in Swaziland. *Botswana Journal of Agriculture and Applied Sciences* 2 (1): 58-66.

Ossom, E. M., Nxumalo, M. H., and Rhykerd, R. L. (2005). Intercropping influences morphological development, weed suppression and yield of *Ipomoea batatas* (L.) Lam. *UNISWA Research Journal of Agriculture, Science, and Technology* 8 (2): 87-102.

Ossom, E. M., Pace, P. F., Rhykerd, R. L., and Rhykerd, C. L. (2001). Effect of mulch on weed infestation, soil temperature, nutrient concentration, and tuber yield in *Ipomoea batatas* (L.) Lam. in Papua New Guinea. *Tropical Agriculture* (*Trinidad*) 78 (3): 144-151.

Ossom, E. M., Pace, P. F., Rhykerd, R. L., and Rhykerd, C. L. (2003). Effect of mulch on nutrient content, growth and yield of sweetpotato [*Ipomoea batatas* (L.) Lam. UNISWA Research Journal of Agriculture, Science and Technology 6 (2): 137-146.

Ossom, E. M., Zwane, S. T., and Rhykerd, L. R. (2006). Plant population effects on ecological characteristics of field bean (*Phaseolus vulgaris* L.) in Swaziland. Transactions of the Illinois State Academy of Science 99: (in press).

Perry, L. P. (1997). pH for the garden. http://www.uvm.edu/extension/publications/oh/oh34.htm. 04/07/06.

Relf, D. (1997). Seed germination and soil temperature. Virginia Cooperative Extension. http://www.ext.vt.edu/departments/envirohort/articles2/sdgrmtmp.html. 03/05/05.

Sanchez, P. A. (1976). Properties and management of soils in the tropics. Wiley, New York.

Srinarong, S., and Panchaban, S. (2003). Effect of filter cake, sludge cake and chemical fertilizer on growth and yield of five rice cultivars (*Oryza sativa* L.) grown on saline soil. *Pakistan Journal of Biological Sciences* 6 (5): 432-436.

Steel, R. G. D., and Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach, 2nd ed. McGraw-Hill, New York.

Tafaj, M., Zebeli, Q., Maulbetsch, A., Steingass, H., and Drochner, W. (2006). Effects of fibre concentration of diets consisting of hay and slowly degradable concentrate on ruminal fermentation and digesta particle size in mid-lactation dairy cows. *Archives of Animal Nutrition* 60 (3): 254-66.

Thwala, M. G. (2004). Effects of maize-legume association on crop growth, yield and weed infestation. Unpublished B.Sc. Dissertation. Faculty of Agriculture, University of Swaziland, Luyengo Campus, Luyengo.

Tzeng, S. J, Wang, P. L., Lin, Y. H, Lu, C. H., and Chou, C. J. (2001). Recycling of filter cake from sugar refinery. Taiwan Sugar Research Institute, Sugar Industry Technologist Inc. http://www.ansinet.org/fulltext/pjbs5432_436pdf. 01/04/2005.

United States Census Bureau. (2006). World POPClock projection. http://www.census.gov/ipc/www/world.html. 02/07/06.

Zimdahl, R. L. (1993). Fundamentals of Weed Science. Academic Press, Inc. New York.

Table 1. Meteorological data during the period of the investigation.

Month	Mean air temperatures (ºC)		Monthly rainfall (mm)	Mean monthly rainfall[1] (mm)
	Maximum	Minimum		
January 2006	27.8	19.1	295.5	192.5
February 2006	28.8	18.9	200.6	187.5
March 2006	25.7	16.3	271.2	116.8
April 2006	27.0	11.4	58.3	56.7
May 2006	23.2	10.2	1.7	40.9
June 2006	21.6	8.0	6.1	15.2
Totals	154.1	83.9	833.4	609.6
Means	**25.7**	**14.0**	**138.9**	**101.6**

[1] Mean monthly rainfall from 1996-2005.

Table 2. Influence of soil-improvement materials on soil temperatures in sweetpotato.

Type of soil fertilizer material	Soil depth	Weeks after planting 4	8	12	16	20	Means
		°C					
No filter cake	Surface	34.3	23.6	29.2	14.7	27.9	25.9
	5-cm	33.7	24.6	29.5	18.0	26.6	26.5
	10-cm	28.9	23.5	26.2	18.7	22.9	24.0
10,000 kg ha^{-1} filter cake	Surface	32.0	24.4	27.9	12.0	26.5	24.6
	5-cm	32.0	24.2	28.0	18.7	25.5	25.5
	10-cm	28.4	23.3	26.7	18.7	22.8	24.0
20,000 kg ha^{-1} filter cake	Surface	35.3	24.3	28.3	12.7	25.7	25.3
	5-cm	31.7	24.4	30.5	16.0	25.3	25.6
	10-cm	28.0	23.2	28.2	18.0	21.4	18.4
40,000 kg ha^{-1} filter cake	Surface	29.3	24.8	27.9	12.7	26.5	24.2
	5-cm	33.0	24.5	29.3	18.0	26.2	26.2
	10-cm	28.5	23.6	26.5	18.0	22.9	23.9
600 kg ha^{-1} fertilizer	Surface	34.7	24.5	27.7	15.4	27.2	25.9
	5-cm	32.8	24.3	30.3	18.0	27.7	26.6
	10-cm	28.6	23.2	27.3	19.3	21.8	24.0
Means	Surface	33.1	24.3	28.2	13.5	26.7	25.2
	5-cm	32.7	24.4	29.5	17.8	26.2	26.1
	10-cm	28.6	23.3	27.0	18.5	22.4	24.0
[1]LSD (0.05)	Surface	6.77	1.48	3.35	3.48	2.91	-
	5-cm	2.03	0.52	3.90	3.32	3.11	-
	10-cm	1.48	0.77	2.33	2.05	2.63	-
Significance ($P < 0.05$)	Surface	Ns	Ns	Ns	Ns	Ns	-
	5-cm	Ns	Ns	Ns	Ns	Ns	-
	10-cm	Ns	Ns	Ns	Ns	Ns	-
[2]Correlation	Surface	0.042Ns	-0.224Ns	- 0.107Ns	- 0.311Ns	0.075Ns	-
	5-cm	- 0.550*	- 0.071Ns	- 0.392Ns	- 0.512*	0.389 Ns	-
	10-cm	- 0.611*	- 0.221Ns	- 0.414*	- 0.427*	0.230 Ns	-

[1]Least significant difference;
Ns, Not significant at $P > 0.05$; *, Significant at $P < 0.05$;
[2]Correlation coefficient of soil temperature with tuber yield.

Table 3. Effects of fertilizer materials on weed species distribution in sweetpotato.

Family name	Scientific name	Common name	Soil-improvement materials and weed species dry matter accumulation				
			No filter cake	10,000 kg ha^{-1} filter cake	20,000 kg ha^{-1} filter cake	40,000 kg ha^{-1} filter cake	600 kg ha^{-1} fertilizer
Amaranthaceae	*Amaranthus hybridus* L.	Common pigweed	A	A	A	7.9	A
Asteraceae	*Galinsoga parviflora* Cav.	Gallant soldier	26.4	47.9	17.5	64.5	7.3
Asteraceae	*Bidens pilosa* L.	Black jack	551.6	309.6	415.3	281.4	613.8
Asteraceae	*Acanthospermum hispidum* DC.	Upright starbur	A	A	A	A	22.6
Capparaceae	*Cleome gynandra* L.	Spider flower	A	A	A	A	6.2
Commelinaceae	*Commelina benghalensis* L.	Benghal wandering Jew	92.0	88.0	26.9	57.8	7.2
Convolvulaceae	*Convolvulus arvensis* L.	Field bindweed	0.4	A	A	A	10.5
Cyperaceae	*Cyperus rotundus* L.	Purple nutsedge	11.5	13.2	21.7	4.0	19.8
Labiataceae	*Leucas martinicensis* (Jacq.) R. Br.	Bobbin weed	A	6.1	82.4	4.8	A
Malvaceae	*Sida cordifolia* L.	Heartleaf Sida	A	1.6	A	A	18.2
Oxalidaceae	*Oxalis latifolia* H.B.K.	Red garden sorrel	10.7	5.5	17.3	13.2	2.6
Poaceae	*Elusine africana* L.	African goose grass	46.7	0.4	37.4	74.9	32.4
Poaceae	*Panicum maximum* Jacq.	Common buffalo grass	29.7	71.3	A	7.2	A
Poaceae	*Digitaria senquinalis* L.	Crab finger grass	16.2	A	6.3	11.4	13.3
Poaceae	*Echinochloa crus-galli* (L.) Beauv	Barnyard grass	A	5.5	A	A	A
Poaceae	*Cynodon dactylon* L.	Bermuda grass	A	7.7	A	A	A
Poaceae	*Chloris virgata* Sw.	Feather-top chloris	A	A	A	10.7	A
Polygonaceae	*Rumex crispus* L.	Curly dock	9.9	A	A	A	A
Rubiaceae	*Richardia brasiliensis* Gomes.	Tropical Richardia	379.0	403.7	139.7	247.0	137.8
Solanaceae	*Nicandra physalodes* (L.) Gaertn.	Apple of Peru	4.1	38.1	28.6	43.9	17.5
Weed density	NA	NA	3.2	3.9	3.1	3.7	3.6
[1]LSD $_{(0.05)}$ density	NA	NA	---------- 0.82 ----------				

[1]Least significant difference; A, species absent;
NA, Not applicable

Table 4. Effects of soil-improvement materials on yield and yield components in sweetpotato.

Type of fertilizer material	Tuber yield (kg ha^{-1})	Number of tubers $plant^{-1}$	Mass of tuber $plant^{-1}$ (g)	Petiole length (cm)	Tuber length (cm)	Tuber diameter (cm)
No filter cake	12017.4	3.8	650	16.2	18.7	4.3
10,000 kg ha^{-1} filter cake	13427.4	4.4	674	16.9	20.6	4.0
20,000 kg ha^{-1} filter cake	11973.1	4.5	918	18.5	18.7	4.0
40,000 kg ha^{-1} filter cake	11686.0	4.0	730	17.0	19.7	4.1
600 kg ha^{-1} fertilizer	13320.2	3.8	696	16.9	19.2	4.0
Means	12484.8	4.1	734	17.1	19.4	4.1
[1]LSD $_{(0.05)}$	3010.73	0.89	274	2.70	3.07	0.41
Significance ($P < 0.05$)	Ns	Ns	Ns	Ns	Ns	Ns
Correlation coefficient with tuber yield	-	0.419	0.530	0.607	0.186	0.335
R^2	-	17.6	28.1	36.8	3.5	11.2

[1]Least significant difference;
Ns, Not significant at $P > 0.05$;
R^2, Coefficient of determination for tuber yield (%).