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THE VALUE OF SEWAGE SLUDGE FOR TANNIA AND YAM PRODUCTION RESEARCH AND APPLICATIONS

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ABSTRACT

Low soil organic matter content appears to be one of the main causes of nia and yam problems in the West Indies. Among other methods of organic ilization, the use of sewage sludge seems of most interest. Experiments ducted by INRA (Guadeloupe) establish its value against Tannia disease, for vegetative propagation and for flowering intensity of yams.

RESUME

La faible teneur en matière organique semble être l'une des causes principales des problèmes du Malanga et de l'Igname aux Antilles. Parmi d'autres fertilisations organiques, les boues d'épuration s'avèrent du plus grand intérêt. Des experimentations conduites par l'INRA en Guadeloupe établissent leur valeurs contre le déperissement du Malanga, pour la multiplication végétative et l'intensité de floraison de l'Igname.

INTRODUCTION

In a number of underdeveloped tropical countries the following situation exists. On the one hand, ferralitic soils (60% of cultivated soils) are acid, often linked with aluminum toxicity, poor in all elements and having a low cation exchange capacity. The cultivation of these soils increases the mineralization of organic matter. Even within traditional agriculture the use of mineral fertilization is developing, and the restoration of organic matter is decreasing, thus reducing impeding the availability of elements for the plant.

On the other hand, residues of human activities, specially in urban areas, increase by 10-15% each year, raising serious difficulties in environmental protection. Particularly, the surrounding sea of the rather closed insular systems is threatened, having a much lower self-purifying capacity than the soils.

The residues of human activity can be used, due to their high content in organic fertilizing elements, for preserving or reclaiming a wide area of tropical soils. In Guadeloupe, where the soils which could be involved are more than a third of the cultivated land and where the treatment of urban water offers 20-22 t/day of sewage sludge, studies are being conducted to that end.

Clairon and Nagou (1978) show the superiority of sludge use in yield

achievement of *Zea mays*, compared to the use of an equivalent amount of annual mineral fertilization. A significant long-lasting increase in organic C and N and in P of the soils are demonstrated after a 100 t/ha. year amendment (Giboulot, 1984, Clairon and Nagou, 1984).

Some antagonistic effects against parasites soon appear with use of these sewage sludge. Susceptible varieties of tomato (*Lycopersicon esculentum*) can exhibit a resistant behavior against bacterial wilt (*Pseudomonas solanacearum*). Tomato also, appears less suitable as host for the nematode *Meloidogyne incognita*, the reproductive potential of which seem to be reduced (Castanone-Sereno, et al. 1988).

This paper reports two cases of general and particular effect of sewage sludge in root crops. The first is on yam yield, growth and development; the second one is on tannia yield, growth and disease resistance.

Few experiments have been conducted on the use of organic fertilization on these crops. While Clairon and Nagou (1980), and Etiffier-Chalono (1985) observed the high level of organic matter involved in traditional root crop cultivation in the West Indies, in yam cultivation Djokoto and Stephen (1961) observed a positive correlation between soil content in organic nitrogen and yield.

Degras (1986) mentioned an apparent effect of the level of nitrogen on the flowering behavior of a yam cultivar, but nothing seemed really known about flowering and soil fertility relation in yams.

The Tannia (*Xanthosoma sagittifolium*) decline which recently affected tropical countries appears determined by a number of factors, among which the soil fungi *Pythium myriotylum, P. splendens, Rhizoctonia solani, Fusarium solani* and the poor drainage of the soil seem the most important (Nzietchung, 1983; Laguna, et al., 1983; Adams and Patanjalidial, 1986). Hountoundji (1986) as well as Nzietchung (1985) consider *P. myriotylum* as the initial pathogen. Lyonga (1979) and Boli (in Hountoundji, 1986) has seen beneficial effects of potassium fertilization, where the decline is rather weak.

MATERIALS AND METHODS

A. Growth and Development of Yam

1. Plants

A tradltional cultivar and a selected clone of *Dioscorea cayenensis-rotundata* have been used. The first one, cv "Grosse Caille" is common in Guadeloupe and the type is known as Portuguaise in Martinique, and *D. rotundata* Portuguese and Lady's Yam in Dominica. It flowers rarely and then as female. The second, N 83005 T, has been obtained through four growth cycles of selection for yield, disease resistance and tuber quality, from a polycross introduced as sexual seeds of IITA (Ibadan, Nigeria). It flowers regularly as male.

2. Soil condition

The sewage sludge characteristics are given in Table 1.

TABLE 1. MAIN CHARACTERISTICS OF THE SEWAGE SLUDGE WITH SOME DATA FOR COMPARISON

A. ELEMENTS (% DM)

	SEWAGE SLUDGE		
	GUADELOUPE (JARRY)	EUROPE (POMMEL, 1979)	COW MANURE
CARBON (C)	31.3	33.5	36.2
NITROGEN (N)	4.9	3.9	2.2
C/N	6.1	8.6	16.5
PHOSPHORUS	2.1	1.24	0.2
POTASSIUM	0.15	0.2	1.1
CALCIUM	4.5	4.9	2.6
MAGNESIUM	0.8	0.6	0.3

B. OLIGO-ELEMENTS (TOTAL, PPM)

BORON	32.2	
COPPER	186.	1,650
IRON	17.513	
MANGANESE	777.	
MOLYBDENUM	4.6	
ZINC	1.032	5,500

C. HEAVY METALS (TOTAL, PPM)

CADMIUM	0.9	95
CHROME	5.1	925
LEAD	23.9	910
MERCURY	<1	10
NICKEL	6.3	106

D. pH (WATER) 6

An analysis of the soil type where trials have been conducted at Domaine Duclos, Petit-Bourg (2800 mm rain) is given in Appendix I. Ridgee of 40 cm high, 120 cm apart were made. Fertilizers were buried in furrows 10 cm deep on top of ridges a day before planting, and were immediately covered.

The following treatments were compared:

a. Control: no fertilization
b. NPK added: 347 Kg/ha ammonium nitrate; 122 kg/ha triple superphosphate; 233 kg/ha sulfate of potash
c. Sewage sludge: 10 t/ha dry matter plus 233 kg/ha sulfate of potash
d. Sewage sludge: 100 t/ha dry matter

Elementary plots were allocated to cultivars, with two ridges for "Grosse Caille" and one for N 83005 T (limited planting material available). Fertilizers were the main plots and they were settled in four randomized blocks.

Growth was estimated after staking (1.6 m high) at 1 1/2 and 4 months after planting (April 3rd) within a scale of 1-5 each time. Developmental stage noted by flowering: first date of budding and number of inflorescences more than 0.5 cm length, every week as from 10th of July.

Yield, obtained after a unique harvest, 299 days after planting, instead of the traditional sequential ware + seed tuber system, was considered as fresh weight converted into tons/ha.

B. Protection of tannia against root decline

1. Plant

Xanthosoma sagittifolium cv "Malanga violet", one of the most common tannias in Guadeloupe was used.

2. Parasites

The studies quoted, led to the use of local races of *Pythium myriotylum* mainly but also *Rhizoctonia solani*, and another soil organism.

3. Antagonistic microorganisms

Bacteria, a Mucorale and an Aspergillus extracted from sludge filtrate have been confronted with *P. myriotylum*

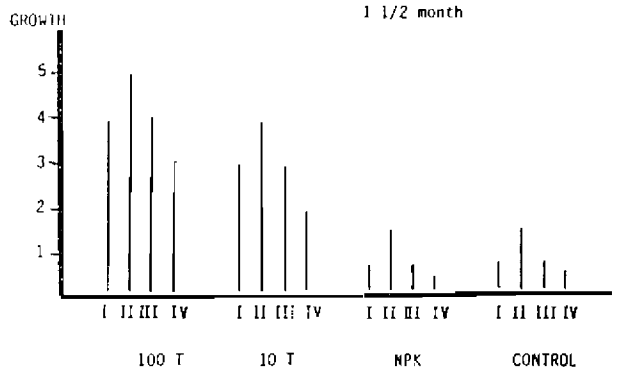
4. Organic matter sources

After preliminary use of several organic matter sources: compost, bagasses, sugar mill filter mud, and sewage sludge, the latter one was used as the basis for experiments reported.

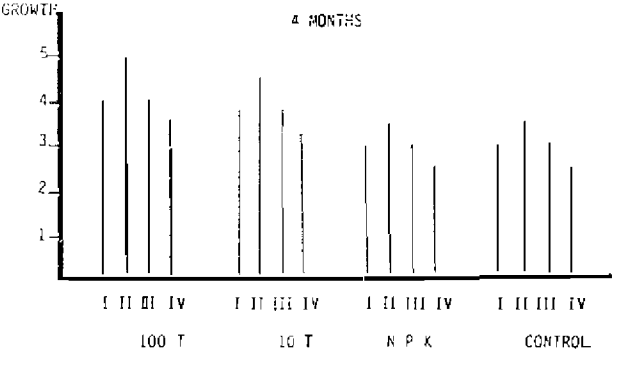
5. Methods of experimentation and observation

Graph 1. Growth Response of Yams to Sewage Sludge and NPK Fertilizer.

(a)



(b)



I, II, II, IV: BLOCKS

a. Field experiment on naturally infested soil

A trial with 3 replications was compared in blocks: compost, bagasse, filter press mud and sewage sludge to a control without organic matter amendment. Each treated plant received 2 liters of organic matter. Harvesting was done at 7 months. The control had equivalent NPK rates. Weight of petioles, mother tubers and daughter-tubers were evaluated and presented in t/ha.

b. Greenhouse experiments

Plastic pots were filled, from the bottom up, with 3 cm of non sterilized soil, the disc inoculum of *Pythium myriotylum* [1] organic matter (2.5 cm), non sterilized soil (2.5 cm) and around the healthy plantlet (see Appendix II) with ordinary soil over its roots up to its neck. Two control pots were established, one inoculated without organic matter added, the other not inoculated. All treatments were replicated six times. A thin water film was maintained in the tray under the pots to maintain soil water saturation favorable to infection. Temperature was about 27°C and relative humidity 75 to 100%.

In the first experiment, notations of diseased and healthy leaves have been done two weeks after plantlet establishment. In the second experiment, the height of plantlets on the day of planting, and on 25 days after, were added to similar notations. All these parameters have been found to be correlated with the behavior of roots when diseased (Hountondji, 1986).

c. Culture in Petri dishes

A filtrate (F1) of sludge was prepared with a mixer, diluted (150 g/350 ml of water), shaken, decanted and filtered of the overflow on filter paper. Filtrate F2 was obtained from F1 filtered on a millipore filter of 0.2 microns, which gives the filtrate for sterile media. An F3 filtrate was obtained by the same process as F1 but adding a 24 hour stay in an oven at 30°C, between shaking and filtration. These filtrates were prepared at variable ratio with S media (Messiaen & Lafon, 1970) poured in Petri dish and inoculated with a fungus implant 4 days old. Development of the colonies were monitored.

Selective media were used at various sludge dilutions for the isolation of bacteria, actinomycetales and fungi.

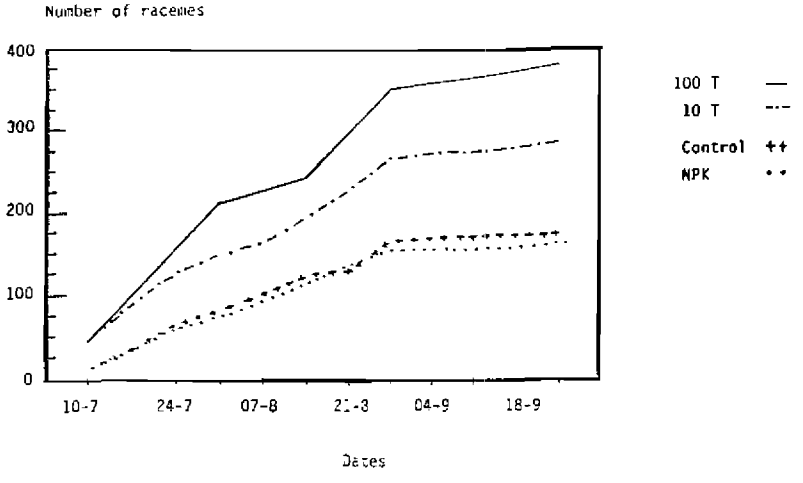
RESULTS

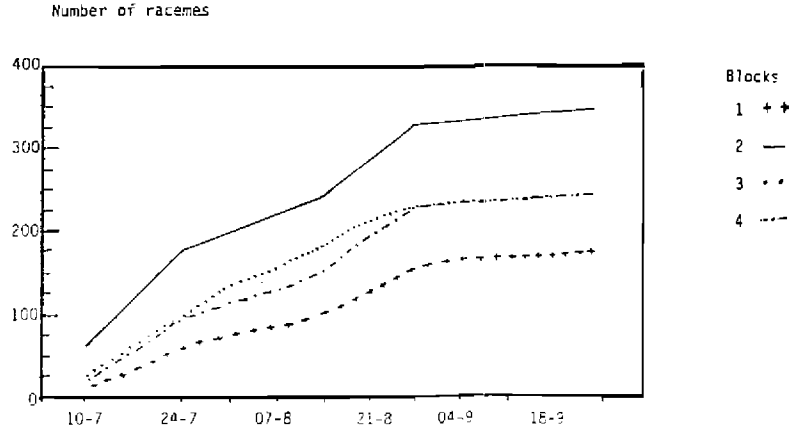
A. Growth and development of yam (*D. cayenensis-rotundata*)

Data are shown on graphs 1a and b. Sewage sludge, and especially at 100

[1] Fungus culture was done in 9 cm Petri dishes in non nutritive agar from a culture initiated in S media (Messiaen and Lafon, 1970).

Graph 2. Flowering Response of the Clone N 83005 T to Sewage Sludge and NPK Fertilizer: Treatments.





Graph 3. Flowering Response of the Clone N 83005 T to Sewage Sludge and NPK Fertilizer: Blocks

t/ha rate, give an earlier growth, though the advantage is reduced at 4 months. Leaves were also of a deeper green with sewage sludge.

Only the clone N 83005 T flowered. First buds appeared on both sludge treatments 69 days after planting and 84 days after planting in the other treatments. Graph 2 shows the evolution of the number of racemes. One hundred t./ha gives a higher level, followed by 10 t/ha, while NPK and control were identical at the low level. A block effect must be noted (graph 3). Statistical analysis of the final number of racemes shows a significant superiority of sewage sludge at 100 t/ha over all the other which are not statistically different between them at the 5% probability level.

Table 5 gives the mean yields of the two cultivars and each fertilizer treatment. For N 83005 T, only sewage sludge at 100 t/ha emerges among the four means. For Grosse Caille a significant superiority is admitted at the 5% point for 100 t/ha over 10 t/ha sewage sludge over NPK which did not differ from the control.

Statistical comparisons between the two cultivars need a further analysis, but the superiority of N 83005 T is likely. This was not an objectlve of the experiment. These yields repreeent coefficients of multiplication from seed material weight of 18.8 for N 83005 T and 10.6 for Grosse Caille on 100 t/ha sewage sludge against, respectively, 7.6 and 4.5 for the control.

B. Protection of tannia (*X. sagittifolium*) against root decline

1. Field trial on naturally infested soil

Table 2 gives the mean weight in ton x ha^{-1} equivalent for petioles, mother-tubers and daughter-tubers for each treatment.

As a general result, all organic fertilizers improve the weight harvested, compared to the control and specially the daughter-tubere, which represent the commercial production. But the effect of the sewage sludge is far more evident.

2. Pot experiments in green-house under *P. myriotylum* -controlled inoculation

The results of the two experiments are given in Tables 3 and 4. The data of the two tables confirm the protective effect of the sewage sludge against *P. myriotylum*, insuring healthy and fast growth of the plant in inoculated soil.

3. Microorganisms culture on filtrates of sewage sludge

With sterile media (filtrate F2) inoculated with *P. myriotylum*, the growth of the fungus is normal and even faster than the control on increasing ratio of the filtrate. Consequently, the effect of the sewage sludge cannot be linked with toxins, and in fact, some of its chemical components, may favor the growth of *P. myriotylum* mycelia.

From the F1 filtrate inoculated just after cooling, and at 36 hours, white, blue and red microorganisms began to develop and progressively reduce

the area of *P. myriotylum* mycelia towards the inoculated implant. The same applies to *F. solani*, *R. solani* and *S. rolfsii*.

With the F3 filtrate, subjected for 24 h to 30°C, no development of the implant occurred, while cream-colored bacteria invaded the media.

Among the microorganisms isolated from the filtrates, mucorale bacteria after 20 days maintained a free zone in front of *P. myriotylum*, while Aspergillus and the bacteria progressively invaded the pathogen area.

From all these data the effect of the sewage sludge appears as likely related to its content in microorganisms which act as antagonists of *P. myriotylum*, *R. solani* and *S. rolfsii* in the infected soils.

DISCUSSION

These results emphasize the wide range of profitable uses of organic matter, and especially of the sewage sludge available in Guadeloupe.

However some limitations can be found in the methods and materials. As was seen in the yam experiment, one cultivar did not express any degree of flowering, while the other increased significantly in its flowering with sewage sludge use. Varietal interaction could be an important component in the effect of sewage sludge. Therefore the results obtained against tannia root decline with one cultivar needs perhaps to be confirmed with several. But the fact that this result occurs through antagonistic processes against several genera of fungi leads one to be confident in the polyvalency of this property.

Another type of interaction should be examined in this research: between soil characteristics and sewage sludge. We have seen the rather wide differences between blocks for the mean level of flowering of yam. The field was known to vary for several physical basic characters. Multilocal trials would be necessary for a good appraisal of the efficiency of sewage sludge.

This last interaction must be compared with the well known multilocal variation in flowering level of yam over different locations. It must be also considered along with the similarity of tuber bulking from sewage sludge use and from long days application to plantlets of *D. cayenensis-rotundata* at their first months after in vitro culture micropropagation (Arnolin, personal communication).

Obviously much has to be investigated on the nature of the process involved in the polyvalent action of the sewage sludge and overall in growth and development increase.

However this organic matter resource emerges as a promising material for peri-urban agriculture, specially in tropical countries, where the constant high temperature could perhaps reduce the potential of sanitary problems. It must not be forgotten that such sludge can carry dangerous bacteria and even viruses (Gustave, 1987), which need sanitary protection for their manipulation in fresh or dry condition, and their burying or ploughing in, especially for vegetable production.

An effective means of protecting against the dangerous human parasites

which could be present, would be composting (Gustave, 1987). But the necessary large land requirements for compost processing,and high transportation costs involved in the method will narrow the prospects for wide utilization.

The benefits of sludge materials appear still to be underestimated. However, regardless of how high the level of sludge production may be, the supply will be rather insufficient for extensive application to all agricultural lands, even in Guadeloupe. The best option seems to be to develop methods of more efficient use of the sewage sludge and, while research continues, to apply it mainly to the nursery, for sexual and vegetative seed production in root crops, a key area in the modernization of this agricultural sector in our countries.

The research results obtained in yam flowering earliness and intensity, lead one to consider higher rates of sewage sludge application to non-flowering cultivars, to ascertain limitations in efficacy. A study of the internal chemical balance and its evolution with respect to plant behavior when growing on this type of organic matter should be also informative as to the biological processes of growth, development, yield and disease resistance.

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APPENDIX I.

MAIN CHARACTERISTICS OF THE SOIL USED AT DOMAINE OUCLOS (INRA, PETIT-BOURG, GUADELOUPE)

(ferralitic soil)

ORGANIC CARBON	C %	19.1
NITROGEN	N %	1.9
C/N		10
P_2O_5 (OLSEN)		0.001
C.E.C. m. eq/100g dry soil		14
Ca^{2+}	"	6
Mg^{2+}	"	0.9
K^{+}	"	0.02
Na^{+}	"	0.01
pH-water	4.7	

APPENDIX II.

PRODUCTION OF HEALTHY PLANTLETS OF TANNIA

A : DAUGHTER TUBER B : AXILLARY BUDS FROM A

C : HEAD OF MOTHER TUBER D : TRIMMING OF A OR C HEAD

E : DIPPING IN 5% SOLUTION OF CALCIUM HYPOCHLORITE

F : SAND POTS SOAKED WITH KNOP SOLUTION

G : PLANTLETS 20-30 DAYS OLD FROM D
OR 90 DAYS OLD FROM B