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Effect of organic and inorganic supply on Al detoxification and sorghum crop yield in ferralitic soils from Burundi.

C. Van den Berghe*+, P. Sota* & A. Mujawayezu*

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Summary

A methodology has been tested to evaluate the agronomic effectiveness of organic fertilizers in combination or not with chemical fertilizers and lime on a ferralitic soil in Burundi.
The experiments have shown that the samples obtained by weighing the mixed organic matter with water to obtain a paste are representative and the method by comparison of the regression coefficients after linear transformation of the response curve can also be applied on organic sources, when freshly applied.
There were no significant differences at the 5% level at 1 or 3 months between the sources for dry matter production of sorghum with and without fertilizer. Only when lime was applied these differences existed.
For farmyard manure the effects of farmyard manure and farmyard manure+ fertilizer on Al detoxification were significantly different at the 10% level. All sources showed only differences on Al detoxification at the 5% level when lime was applied.

Samenvatting

In deze studie werd een methodologie getest om de invloed na te gaan van de toevoeging van meststoffen en bekalking op de droge stofproductie van sorghum en de zuurheid van een ferralitische bodem in Burundi.
Deze studie heeft aangetoond dat de methode van monstername van de organische bronnen en de evaluatie door vergelijking van de regressiecoëfficiënten bruikbaar zijn voor vers organisch materiaal. Na drie maanden incubatie was het model minder bruikbaar.
Er waren geen verschillen voor de droge stof productie van sorghum op het niveau 5% op 1 en 3 maanden. Voor de Al detoxificatie was het verschil significant op het 10% niveau voor stalmest, wanneer stalmest en stalmest+ meststof werden vergeleken. Enkel wanneer bekalking werd toegepast werden significante verschillen op het 5% niveau tussen de behandelingen bekomen.

1. Introduction

The improvement of soil productivity by the utilisation of local fertilizers becomes a priority in many developing countries. In Burundi many soils are acid and are characterised by toxic Al levels, nutrient deficiencies in Ca and P. These contraints can be obviated by addition of organic matter. The decomposition process of organic matter releases organic acids that can detoxify the exchangeable Al (5).
The association of organic matter with chemical fertilizers may have beneficial effect (2,7,10,15). Many questions remain unsolved: the mode of action, the duration of the efficiency, the optimal doses of this organic amendments applied alone or in combination with chemical fertilizers and lime. The present study introduces a method to compare different fertilizer sources used in integrated fertilisation (mineral fertilizers, organic fertilizers and lime).

2. Materials and methods

The trial was conducted in the greenhouse using 3 litre pots and with sorghum as test plant.

a. Soil material

The soil is an acid ferralitic soil from Gisozi and 1.5 kg per pot is used. Soil characteristics are given in table 1, using the methods of soil analysis of the Institute of Agronomic Sciences in Burundi (9).
The soil is characterised by a high C/N and organic matter content, pH values, exchangeable Al content (>1 meq/100g) and a toxic Al saturation (65%) (12).
The soil is very poor in Ca (<1 meq/100g) and Mg (<0.4 meq/100g) but medium in K (0.2 – 0.4 meq/100g). The Ca/Mg ratio is adequate (1 – 10), but the Mg/K is low (2 – 20) (13). The phosphorus content as determined by Olsen-Dabin

TABLE 1
Physico-chemical status of the soil of Gizosi (0-25 cm).

% C	% N	C/N	Texture				pH		P 0-D
			200-2000μ	20-200μ	2-20μ	<2μ	H_2O	KCl	ppm
4.55	0.17	26.8	43.08	12.70	8.72	35.50	4.5	4.0	6.20

Exchange complex (meq/100g)

Ca	Mg	K	Na	Al	H	S	CEC	ECEC	V	Al/ECEC %	Veff (%)
0.30	0.17	0.23	0.05	3.4	1.02	0.75	21.6	5.17	3.47	65.76	14.51

* Faculty of Agricultural Sciences, Bujumbura, Burundi.
+Correspondance: B.P. 143 Bujumbura, Burundi.
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(< 40 ppm P) (14) and Bray 1 (< 10 ppm) (6) is low.

b. Farmyard manure (FYM) and compost

The farmyard manure came from the Zootechnic station of Mahwa and the compost from the Seed multiplication centre in Rwira. The compost was made from sarasen leaves (30%) and potatoes leaves (70%). The dry matter contents were 23.9 and 34.7% respectively.
The composting process took 7 months. The amounts of fertilizer NPK (F) added to the soil corresponded to 0, 10, 20 and 60 t/ha of the original farmyard manure (FYM) and compost (C). The treatments were as follows:

1. FYM: 10, 20 and 60 t/ha.
2. FYM + F: 5, 10 and 30 t/ha + NPK corresponding to 5, 10 and 30 t/ha.
3. FYM + F + L: Idem (2) + lime according to dose of Kamprath.
4. C: see (1) but compost instead of FYM.
5. C + F: see (2) but compost instead of FYM.
6. C + F + L: see (3) but compost instead of FYM.

Taking a representative sample is one of the major problems in compost or FYM sampling. To take a representative sample the compost and FYM was mixed well with a hand mixer for 10 minutes after water addition to obtain a paste whose consistency allowed the application in the pots by weighing. In this case respectively 1500 and 100 ml of water were added to 1.5 kg of FYM and 1.5 kg of compost. The results of three samples expressed on the original dry matter content of the compost and FYM are given in table 2. The methods of analysis are given by Kiberiti et al. (10).
The FYM used has higher N, P and K contents (% DM) than the compost. The diluted FYM and compost have a content of resp. 0.527% N, 0.089% P, 0.498% K and 0.462% N, 0.056% P and 0.198% K. The real amounts of diluted compost and fertilizers added per pot are given in table 3.

TABLE 2

Total nutrient content of the diluted compost and FYM (%) for 3 samples taken at different times during application.

	Ca	Mg	K	Na	P	N
Compost	0.204	0.132	0.193	0.0068	0.039	0.452
	0.217	0.133	0.196	0.0075	0.055	0.471
	0.213	0.129	0.204	0.0084	0.075	0.463
Mean			0.198		0.056	0.462
FYM	0.181	0.106	0.475	0.022	0.099	0.534
	0.184	0.107	0.496	0.021	0.104	0.502
	0.180	0.109	0.508	0.026	0.064	0.544
Mean			0.498		0.089	0.527

TABLE 3

Amounts of N, P, K in resp. 10, 20 and 60 t/ha of FYM and compost added to the pots and half doses of fertilizer salts (*) added to the FYM and the composts for the treatments with fertilizer addition.

	Dose t/ha Real	Dose g/pot dil.	N mg/pot	NH4NO4 mg/pot *	P mg/pot	Dose NaH2PO4 mg/pot *	K mg/pot	KCl mg/pot *
Compost	10	12.5	57.8	82.6	7.0	13.56	24.75	22.87
	20	25.0	115.5	165.1	14.0	27.12	49.50	45.74
	60	75.0	346.5	495.3	42.0	81.36	148.50	137.22
FYM	10	15.0	79.1	113.0	13.4	26.0	74.70	71.19
	20	30.0	158.1	226.0	26.8	52.0	149.40	142.37
	60	90.0	474.3	678.0	80.4	156.0	448.20	427.11

c. Liming

The lime of Verrundi (2.8% Ca and 13.1% Mg) was applied two weeks before the application of the nutrients and water was added to equilibrate the soil. The amount added was calculated following Kamprath (8): 1.5 meq bivalent for 1 meq Al. The amount was 1.451 g of $Ca(OH)_2$ and 0.794 g of MgO, which corresponds to 4739 kg of lime/ha.

d. The test plant used

After application of the fertilizers, 10 pregerminated sorghum seeds var DX360 (tetraploid) from Uganda per pot were planted.

e. Experimental setup and statistical analysis

Two series of pots were used. In one the sorghum was planted immediately and harvested after one month. It indicates the original exchangeable Al contents and the original fertility of the soil. In a second serie 10 wetting and drying cycles of four days each were introduced, the first one was started after harvesting in the first series.

The scheme is as follows:
P ... H
O ... < > < > < > cycles < > < > < > P ... H
P: Planting of sorghum
H: Harvesting of sorghum

After the second serie the soil was analysed for Al and the dry matter of sorghum determined to indicate the final fertility after the wetting and drying cycles. Water was added each time to field capacity by weighing.

After harvesting the exchangeable Al in the soil and dry matter (roots + leaves) of sorghum were determined.
The design was completely randomised and statistical analysis (ANOVA) and comparison of the regression coefficients using multiple linear regression were performed on the dry matter.

The advantage of the method is that sources are compared for the whole response curve. The same methodology was used by (12) to compare phosphatic rocks with TSP in P availability and by (5) to compare phosphatic rocks with $CaCO_3$ in Ca availability.

A semilog function was used to describe the relationship between yield and rate of organic matter applied in the different sources, as follows: $Yi = bo + b \ln \times i$. A t-test was used to state statistical differences between the sources. The relative agronomic effectiveness of the various sources with respect to the best one can be defined as the ratio of two slopes:

$$RAE\% = \frac{bi}{b\ best} \times 100$$

For the exchangeable Al contents of the soil after the harvests the analysis of variance and the method of contrasts were used to study the effect of fertilizer addition to the organic sources applied at 10 t/ha (Table 4).

TABLE 4

Analysis of variance Al

Source	df	1 month ss	1 month ms	1 month F	3 months ss	3 months ms	3 months F
Treatments	18	77.29	4.29	13.42**	125.54	6.97	10.18**
Error	57	18.23	0.32		39.04	0.69	
Strat. tot.	75	95.52			164.58		
FYM vs FYM + F				2.96ns			3.22ns
FYM + F vs FYM + F + L				31.65**			33.26**
C vs C + F				0.39ns			1.14ns
C vs C + F + L				35.26**			28.51**

The method of multiple linear regression allows to compare different sources for the whole response curve. It is very useful for analysis of data where for example the dry matter of organic fertilizer sources differs. In this case the comparison can be made by introducing the DM of the organic sources in the equation for the calculation of the response curve.

3. Results and discussion

3.1. Dry matter production

TABLE 7

Relative agronomic effectiveness of the organic sources based on total dry matter production, as compared to the best treatment: FYM + F + lime.

Source	RAE (%) 1 month	RAE (%) 3 months
FYM + F + L	100.0a	100.0a
C + F + L	95.3a	90.3a
FYM	28.6b	0.0b
FYM + F	21.8b	0.0b
C	18.7b	0.0b
C + F	8.5b	0.0b

a,b: significant differences, had no statistical differences at level 5%.

TABLE 5

Dry matter yield of sorghum (g/pot) and Al after 1 and 3 months (means of 4 replications).

Source	dose T/Ha	Dry matter (g/pot) 1 month	Dry matter (g/pot) 3 months	Al content (meq/100 g) 1 month	Al content (meq/100 g) 3 months
	0	0.264	0.089	3.75	3.88
FYM	10	0.431	0.139	2.94	2.83
	20	0.763	0.227	2.25	3.13
	60	1.921	0.848	2.38	2.63
FYM + F	5	0.356	0.150	3.13	3.50
	10	0.442	0.211	3.13	3.88
	30	1.296	0.687	2.38	2.50
FYM + F + L	5	1.791	0.946	0.63	0.50
	10	2.276	0.971	0.88	0.50
	30	2.947	1.187	0.75	0.62
C	10	0.271	0.142	2.88	3.38
	20	0.479	0.378	3.25	3.63
	60	1.333	0.600	2.38	3.38
C + F	5	0.276	0.397	2.75	3.75
	10	0.315	0.156	3.13	4.00
	30	0.767	0.236	2.38	2.62
C + F + L	5	1.504	0.918	0.63	1.00
	10	1.533	0.810	0.75	0.88
	30	2.619	1.193	1.00	0.75

The mean dry matter production after 1 and 3 months (mean of 4 replicates) and the analysis of variance are given in table 5 and 6. Table 7 gives the relative agronomic efficiency (RAE) of the sources as compared to the FYM + F + lime treatment.

Although nutrient contents for P and K were higher in the FYM than in the compost samples, for each of these sources fertilizer addition had no effect on the RAE values based

TABLE 6

Analysis of Variance dry matter (roots + leafs)

Source	1 month df	1 month ss	1 month ms	1 month F	3 months ss	3 months ms	3 months F
Treatments	18	55.86	3.10	35.50**	1162.34	64.57	12.87**
'error'	57	4.98	0.09		286.01	5.02	
Strat. tot.	75	60.84			1448.35		

TABLE 8

Multiple linear analysis dry matter after 1 and 3 months

Term	1 month Coef.	1 month Stan error	1 month T.stat.	1 month part corr.	1 month Contr R^2	3 months Coef.	3 months Stand error	3 months T.stat.	3 months part corr	3 months Contr R^2
B0	0.42	0.102	4.11	—	—	0.32	0.072	4.48	—	—
B1	0.36	0.076	4.75	0.50	0.082	0.08	0.072	1.53	0.18	0.02
B2	0.28	0.105	2.67	0.31	0.026	0.09	0.074	1.15	0.14	0.01
B3	1.23	0.106	11.68	0.82	0.494	0.44	0.074	5.94	0.58	0.27
B4	0.24	0.090	2.70	0.31	0.026	0.06	0.063	1.04	0.12	0.01
B5	0.12	0.128	0.92	0.11	0.003	−0.06	0.090	−0.71	−0.08	0.00
B6	1.28	0.128	10.02	0.77	0.363	0.48	0.090	5.39	0.54	0.22

	1 month Sum sq	1 month deg fr	1 month mean sq	3 months Sum sq	3 months deg fr	3 months mean sq
Due regr.	46.81	6	7.60	6.99	6	1.16
About regr.	15.59	69	0.23	7.56	69	0.11
Total	62.39	75	0.83	14.54	75	0.19
R squared	0.48	corr R squared	0.43			
F-test	10.61	std error of regr.	0.33			

on dry matter content after 1 or 3 months as shown in table 8. Only in the combination with lime significant differences existed.
The results confirm the findings that crop responses to FYM or compost may be explained in terms of their nutrient composition, particularly P and K contents (2,16).
As all applications of compost and manure with and without fertilizer in the absence of lime contained were identical in NPK contents, no differences in dry matter production were observed.
In the case where fresh organic matter was added the multiple linear regression model was highly significant as indicated by the respective F values and the R^2 value which was 0.75. The model is less suitable for comparisons at three months (R^2 = 0.48).

3.2. Exchangeable Al

The analysis of variance as given in table 4 indicated highly significant differences between the various sources. The method of contrasts showed that fertilizer addition to the organic sources had no significant effect on exchangeable Al at the dose of 10 t/ha of FYM or compost. For FYM the difference between FYM and FYM+ fertilizer was significant at the 10% level. Only when lime was added significant differences with the no-lime treatments existed.

Conclusions

The methodology of sampling of FYM and compost and the experimental procedure used is very sensitive and allows to study the effect of doses and sources of organic matter on Al detoxification and dry matter production of these sources. The study shows that no differences existed in dry matter production for FYM or compost non-treated and treated with fertilizers in the absence of lime after one and three months. In all cases liming the soils at the dose of Kamprath had a significant effect and when limed no differences existed between the two organic sources when dry matter production is considered.

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C. Van den Berghe, Belgian, Dr ir (Lille, Gent) Project leader FAVA/BM/FACAGRO, Burundi
P. Sota, Burundese Agricultural Engineer (Bujumbura) Researcher FAVA/BM/FACAGRO, Burundi
A. Mujawayezu, Burundese Agricultural Engineer (Bujumbura), Researcher FAVA/BM/FACAGRO Burundi