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Effect of type and level of roughage offered to sheep and urine addition on compost quality and millet growth and production in the Sahel

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Abstract

A greenhouse trial was carried out at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), at Sadoré (13°15′ N, 2°18′ E), Niger. Experiments were conducted in conjunction with a feeding trial. The feeding trial yielded eight types of compost made from faeces and leftovers with or without urine addition from sheep fed either bush straw or millet stover offered at 60 or 80 g dry matter (DM) kg^{-1} live weight (LW). In the second trial the agronomic value of composts to a millet crop was evaluated. The level of roughage on offer did not affect compost quality. Urine addition increased N content in composts ($P < 0.05$), but had no effect on P. Millet stover based composts contained 24% more N and 42.5% more P than composts made with bush straw ($P < 0.05$). Urine addition enhanced millet growth between 15 and 60 days after planting (DAP), increased millet aboveground mass by a factor 2.8, and increased the efficiency of N and P use by 100% and 50%, respectively. Millet response (growth, phytomass, N and P uptake, apparent efficiency of N and P use) to urine addition was higher with millet stover based composts than with bush straw based composts ($P < 0.05$). It was concluded that addition of urine during composting of roughage leftovers and faeces from stall-fed animals could significantly improve nutrient recycling and consequently the productivity of mixed farming systems of semi-arid West Africa.

Résumé

Cette expénence a été superposée à une expénence d'alimentation au cours de laquelle les ovins étaient nourris avec différents niveaux d'apport (g MS kg^{-1}% Pv) de chaume de mil et de paille de brousse. Le premier essai de l' expérience consistait à évaluer les effets du niveau d'apport (60 et 80 g) et du type de fourrage offert, et de l'ajout d'urine sur la qualité des composts produits. Le second essai consistait à déterminer à partir des performances d'une culture de mil, les effets de ces paramétres sur la valeur agronomique des composts produits. Le niveau de fourrage offert n'a eu aucune influence sur la composition chimique des composts. L'ajout d'urine a augmenté la teneur des composts en N de 100%, mais n'a pas eu d'effet sur leur teneur en P ($P < 0.05$). Les composts faits à base de refus de chaume de mil contenaient 24% plus de N et 42.5% plus de P que ceux faits à base de paille de brousse ($P < 0.05$). L'ajout d'urine a augmenté la vitesse de croissance du mil entre 15 et 60 jours après semis et multiplié la phytomasse épigée du mil par 2.8. L'ajout d'urine aux composts à base de chaume de mil a permis de multiplier la production de phytomasse de mil par 3.5 contre 2.3 pour les composts à base de paille de brousse par rapport aux composts sans urine. L'ajout d'urine a augmenté le prélèvement de N et P ($P < 0.05$), et les coefficients d'utilisation apparente de N (100%) et de P (50%). Il en était de même pour l'effet des composts à base de chaume de mil par rapport à ceux à base de paille de brousse. Il est conclu que la collecte et l'ajout de l'urine lors du compostage des refus et des féces est une option susceptible d'améliorer de façon significative le recyclage des éléments nutritifs excrétés par le bétail dans l'agrécosystème.

Introduction

Manure constitutes an important source of nutrients for agricultural production in mixed farming systems of semi-arid West Africa (Powell et al. 1998), and could remain so because of the low income of agro-pastoralists and the lack of a public aid policy for the sale of imported inorganic fertilizers. Unfortunately, current manure production in the region is insufficient to sustain crop yield on a long-term basis (Fernández-Rivera et al. 1995; Williams et al. 1995). However, efficient management of crop residues and available animal excreta has potential to reduce imported inorganic fertilizer requirements.

In the predominant extensive management system, feeding relies on poor quality pasture during most of the manuring season (dry season). Night corralling of livestock on cropland on bare soil (Powell et al. 1998), or on mulched soil, significantly increases acid sandy soil fertility and millet yield. In stall feeding systems, animals often receive diets of high digestibility and high N content, and therefore, excrete more urinary and soluble faecal N. In this system all of the faeces are available for restitution to the cropland. But, the urine which may contain more than 50% of the N ingested by the animal (Henzell and Ross 1973) and could improve P availability (Somda et al. 1997; Powell et al. 1998), infiltrates, and the urinary N is lost by volatilization (Stillwell and Woodmansee 1981; Vallis et al. 1982). Therefore, for increasing the productivity of this crop/livestock production system of semi-arid West Africa, improved management of faeces, urine and feed refusals, to enhance nutrient cycling, is needed (Williams and Powell 1995).

The objective of this experiment was to evaluate the effects of type and level of roughage offered to sheep, as well as of the addition of urine on compost quality and growth and production of millet.

Materials and methods

Study site

The study was conducted from April to December 1997 at the International Crop Research Center for the Semi-Arid Tropics (ICRISAT), at Sadoré (13°15′ N, 2°18′ E), located 45 km south of Niamey, Niger, West Africa.

Treatments, experimental procedures and measurements

The study was conducted in conjunction with a feeding trial, in which the basal roughage leftovers, faeces and urine of four groups of six sheep each, were collected and stored per group. Two trials were carried out. The first part of the study comprised eight treatments that resulted in eight types of compost made from faeces and leftovers, with or without addition of urine from sheep fed either bush straw or millet stover, offered at 60 or 80 g dry matter (DM) kg^{-1} live weight (LW) d^{-1}. Urine was collected at the end of the feeding trial, in plastic buckets placed under the metabolic crate of each animal, and then bulked per group and stored. Leftovers and faeces of each group were bulked and split in two. One half was composted with urine from sheep of the corresponding group, the second half was composted without urine. The first phase of composting lasted 90 days in (8) holes (2.3 m $\times$ 1.4 m $\times$ 1 m) dug in bare soil. Composts (8 types) were watered twice a week and mixed fortnightly. After 90 days, composts were removed, and a sample of each type of compost was split into five and composted again for 30 days in plastic pots (8 $\times$ 5 pots = 40 pots). Composts were watered and mixed twice a week. Composts prepared with urine, were wetted exclusively with urine during this phase. After 30 days, composts were dried at 55 °C and stored for analyses and an agronomic trial.

In the second part of the study, the agronomic value of the composts was tested on a millet crop (*Pennisetum glaucum* L.) in a greenhouse experiment. An improved variety (GB-85-35) was planted (three plants per pot) in freedraining plastic pots containing 50 kg sandy soil, fertilized with 250 g DM (0.5%) of one of the eight types of compost (four replicates). Four liters of water were provided per pot twice a week from fifteen day post-emergence. Millet height was measured at 15, 30, 45 and 60 days after planting (DAP). Millet was harvested at 70 DAP. Aboveground organs and roots were separated, dried and weighed. Nitrogen and phosphorus uptake was calculated based on N and P concentrations (g kg^{-1} DM) in aboveground organs and roots. The uptake efficiency of compost N and P (apparent efficiency of use) was determined as:

$$[\text{Total N or P in the plant}/\text{N or P applied through compost}] \times 100$$

Laboratory analyses

A sample of each type of compost, aboveground organs and roots of millet were oven-dried at 55 °C for 48 h, ground to pass a 1 mm screen and analysed for Kjeldahl N and total P.

Statistical analyses

General Linear Model (GLM) of SAS (1987) was used to assess the analysis of the effects of type and level of offered roughage and urine addition on N and P contents of composts, millet yields, N and P uptake, and apparent uptake efficiency by millet. The model used was:

$$\mathrm{Y}ijk = \beta_0 + \beta_1\mathrm{F} + \beta_2\mathrm{L} + \beta_3\mathrm{U} + \beta_4\mathrm{FL} + \beta_5\mathrm{FU} + \beta_6\mathrm{LU} + \beta_7\mathrm{FLU} + ijk$$

where Y*ijk* = dependent variable; β_0 = intercept; $_{1...7}$ are regression coefficients; F = effect of roughage type (1, 2); L = effect of level offered (1, 2); U = effect of urine addition (1, 2); = error term.

Results

The concentrations of N and P in millet stover leftovers were about 2.5 times those in bush straw leftovers. The N concentration in the faeces of sheep fed millet stover was 30–40% higher, while the P concentration in faeces and the N concentration in urine from sheep fed the two forages were practically similar (Table 1).

Effect of type and level of roughage offered and addition of urine on N and P level of compost

The level of roughage on offer had no effect on compost N and P contents. Addition of urine increased N contents (g kg^{-1} DM) on average by 100% ($P < 0.05$), but had no effect on P contents (Table 2). Type of roughage had a significant effect on N and P level of composts ($P < 0.05$). Millet stover leftovers based composts contained 24% more N and 43% more P than composts based on bush straw leftovers. Urine addition and roughage type interaction significantly affected N level of composts, but had no effect on P.

Effect of roughage type and level on offer and urine on millet yield

Millet growth from 15 to 60 DAP was positively affected ($P < 0.05$) by both type of roughage and urine addition (Figure 1). Millet, fertilized with millet stover based composts grew faster than that fertilized with composts based on bush straw. Millet growth was positively influenced ($P < 0.05$) by roughage type and urine addition interaction, from 45 DAP.

Millet grown on composts made with urine produced 3.8 times the aboveground phytomass and 4.7 times the root mass ($P < 0.05$) of millet grown on composts without urine (Table 3). The response of millet aboveground mass to urine addition was stronger for composts made with millet stover than for those with bush straw (3.5 times and 2.3 times more than composts without urine, respectively). Millet root mass was positively affected by roughage type and urine addition interaction (Table 3).

Nitrogen concentration (g kg^{-1} DM) in the whole millet plant did not vary significantly among types of compost applied. On the other hand, P contents (g kg^{-1} DM) were lower when composts with urine were applied, and higher for millet based composts (Table 3). N and P uptake ($P < 0.05$) for both compost with urine addition and compost based on millet stover was higher. Interaction between these two factors also affected these parameters. Urine addition resulted in higher efficiency of N and P use by millet, on average with more than 100% and 50%, respectively. Millet based composts yielded ($P < 0.05$) efficiencies of N and P use that were higher by 93 and 175%, respectively than those based on bush straw. Roughage type and urine addition interaction significantly affected these characteristics.

Discussion

It is likely, that most of the urinary N was lost through volatilization (Woodmansee 1978; Stillwell and Woodmansee 1981; Vallis et al. 1982; Somda et al. 1997) before its use for composting. This would suggest that the sole direct effect of urinary N could not

Table 1. Nitrogen (N) and phosphorus (P) contents of roughage leftovers, faeces (g kg^{-1} DM), and urine (g l^{-1}) used in composting.

Roughage type	Level on offer	Roughage		Faeces		Urine
N	P	N	P	N		
Bush straw	60	2.7	0.5	13.3	3.4	3.8
Bush straw	80	2.7	0.3	14.0	3.0	4.4
Millet stover	60	6.9	1.1	19.4	3.2	3.1
Millet stover	80	6.8	1.1	18.6	2.9	4.6

explain the dramatic increase in N content of the composts sprayed with urine. Indeed, during composting, N is the major nutrient required by microorganisms to assimilate carbon (C) substrate (Taquia et al. 1998). This implies that any additional N input would stimulate microbial growth and consequently decomposition of C and other compounds during the composting process. These reactions (C oxidation) yield energy and release carbon dioxide (CO_2). Given that 60 to 80% of C in the compost mass may be released in the form of CO_2 (Alexander 1961; Golueke 1977), the decrease in total C in the compost mass resulted in an increase in N (Golueke 1977) and P (Mato et al. 1994) concentrations. It could moreover be assumed that the amount of organic N and P mineralized augments with microbial activity in the compost.

Nitrogen concentration of millet stover leftovers and faeces of sheep fed millet stover was higher than that of bush straw leftovers and faeces of sheep fed bush straw. This may have resulted in higher microbial activity, with its associated CO_2 release, leading to higher concentrations in N and P of millet stover based composts. Also, the spongy structure of millet stover may have allowed it to absorb and fix volatile N and some exchangeable cations from faeces and urine. That would provide additional nutrients to the micro-organisms and improve compost quality. The significant effect of roughage type and urine addition interaction on millet growth and production (Table 3)

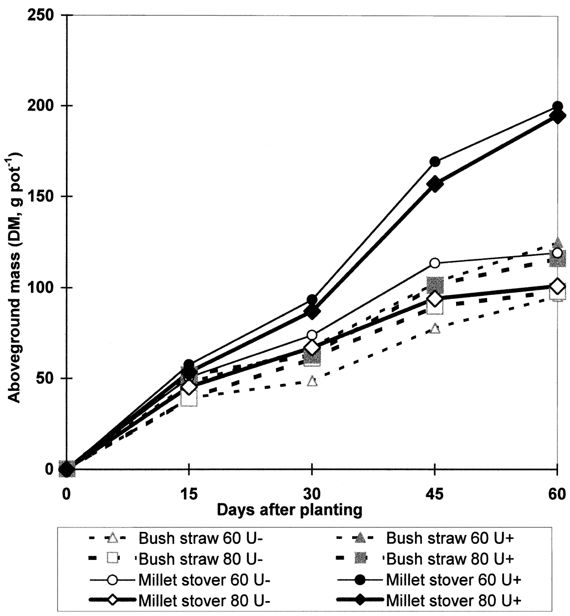

Figure 1. Effect of roughage type and level on offer and urine addition (U+/U−) on millet growth.

Table 2. Effect of roughage type and level (DM g kg^{-1} LW) on offer, and urine addition on compost N and P (g kg^{-1} DM).

Roughage type	Level on offer	Urine	Compost N[bcd]	Compost P[ab]
Bush straw	60	−	5.5	1.1
Bush straw	60	+	10.4	1.1
Bush straw	80	−	5.7	1.7
Bush straw	80	+	10.1	1.4
Millet stover	60	−	5.4	2.1
Millet stover	60	+	15.1	2.1
Millet stover	80	−	6.9	1.4
Millet stover	80	+	11.9	1.4
sem			0.5	0.1

− = Compost without urine; + = Compost with urine;[a] = Effect of roughage level on offer;[b] = Effect of roughage type;[c] = Effect of urine addition;[d] = Effect of roughage type × urine addition interaction; sem = Standard error of treatments means; $P > F = 0.05$

Table 3. Effect of roughage type (RT) and level (L) on offer, and urine addition on millet aboveground (AM) and root (RM) mass (g DM pot^{-1}), N and P concentration of millet (g kg^{-1} DM), N (N_{up}) and P (P_{up}) uptake (mg pot^{-1}) and efficiency of N (N_{ef}) and P (P_{ef}) use (%).

RT	L	Urine	AM^{bcd}	RM^{bcd}	N	P^{bc}	N_{up}^{bcd}	N_{ef}^{bcd}	P_{up}^{bcd}	P_{ef}^{bcd}
Straw	60	−	10.5	1.2	6.1	1.6	64	4.7	17	6.1
Straw	60	+	39.6	11.6	7.3	0.5	299	11.5	18	6.6
Straw	80	−	13.6	3.9	5.9	1.4	95	6.6	24	5.5
Straw	80	+	38.7	14.2	7.4	0.8	284	11.2	27	7.8
Millet	60	−	29.5	12.2	6.2	2.1	171	12.7	59	11.2
Millet	60	+	132.7	39.5	6.6	0.9	838	23.4	118	22.5
Millet	80	−	25.2	14.8	5.9	2.1	144	8.3	50	14.2
Millet	80	+	97.8	31.3	6.6	0.8	632	21.2	81	23.0
sem			6.0	1.8	0.4	0.1	39	1.1	5	1.2

Straw = bush straw; Millet = millet stover; Level on offer DM, g kg^{-1} LW; [a] = Effect of roughage level on offer; [b] = Effect of roughage type;[c] = Effect of urine addition;[d] = Effect of roughage type × urine addition interaction;[e] = Effect of roughage level on offer × urine addition; sem = Standard error of treatments means; P > F = 0.05

supports this hypothesis. The lack of significant effect of interaction of urine addition and type of roughage on P content of composts suggests that roughage did not absorb P from urine, which seems logical, since very little P is excreted via urine (Powell et al. 1994). On the sandy acid soils of semi-arid West Africa, it has been shown that P is the most limiting nutrient for millet production (Bationo and Mokwunye 1991; Payne et al. 1991; Bationo et al. 1992, 1993). This implies that, under adequate water supply, millet responds to N supply only when P is not limiting. Our results show that urine did not provide additional P to the compost. However, the effect of urine on pH (Somda et al. 1997; Powell et al. 1998) resulted in increased P availability in the soil (Buerkert et al. 1996; Powell et al. 1998). Thus, the higher growth rate and production (aboveground and root mass) of millet might be attributed to increased availability of P in the soil and higher N content of composts sprayed with urine. The stronger response of millet (growth rate, uptake and apparent uptake efficiency of N and P) to composts with urine, suggests that urine addition during composting synchronized the availability of N and P in the compost with millet requirements. The same synchronization effect of urine addition may explain the stronger response of millet to millet stover based compost than to bush straw based compost.

Conclusion

Ours results show, that urine addition significantly affects compost quality and subsequent nutrient availability as measured through millet production, despite the fact that most urinary N is likely to be lost during storage. The strong effect of urine on millet stover based composts, suggests that, in addition to the effects of its pH on P availability, urine could have a catalytic effect on the composting processes, and also could provide exchangeable cations fixed by millet stover. The study has shown that possibilities do exist to significantly improve recycling of nutrients excreted by livestock in mixed crop/livestock systems of the Sahel. The impact of such improvements will be stronger the higher the quality of animal diets, as in intensive stall feeding systems (fattening animals, dairy cattle, etc.). However, a major constraint to this practice could be urine collection devices. This problem could be resolved by using leftovers as litter for animals before composting them.

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