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Effect of crop waste composts on millet production

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Abstract

The decline in soil fertility had a strong impact on agricultural productivity and therefore on farmers' income. The use of mineral fertilizers improves soil fertility and quality, thus promoting an increase in agricultural productivity and better soil biodiversity. It was in this perspective that the present study was. The objective of this study was to evaluate the agronomic efficiency of composts obtained from crop residues, on the production of millet.

The work undertaken was aimed at studying the agronomic efficiency of composts obtained from crop residues, on millet production. Thus, the effect of two types of composts (a simple compost made from millet husk, cow manure and rice husk ash, and a phosphocompost made from millet husk, cow manure, rice husk ash and Tahoua rock phosphate) on millet yields was monitored at the INRAN agronomic station located in N'Dounga, 20 km from Niamey in the department of Kollo, Tillaberi region. The experimental set-up used was a complete randomized block with three replications of microdose treatments. The results obtained showed that the addition of composts increased grain yield by 146.77%, 135.48%, 74.19% and 74.19% respectively for treatments T22 (150 g/packet of phosphocompost), T12 (150g/packet of simple compost), T21 (100 g/packet of phosphocompost) and T11 (100/packet of simple compost) compared to the control. The same trend was observed for total biomass yield (76.13% for T22, 68.38% for T12, 46.17% for T21 and 34.49% for T11 compared to the control).

The results showed that the best yields were obtained with the phosphocompost amendment (150g/packet), so it can therefore be recommended to producers to improve their millet production. These results showed that the composts produced were mature and of acceptable quality. So, they could be used as soil amendments.

Keywords: phosphocompost, crop waste, microdose, millet grain yield.

Introduction

Environmental degradation and declining soil fertility do not spare Sahelian countries like Niger. These problems contribute strongly to the decline in agricultural productivity, which leads to persistent and growing food insecurity as highlighted by Payne, (2006), quoted by Souley, (2021). Soil degradation leading to falling yields is a major concern for the agricultural production system in Niger as a result, the country imports synthetic fertilizers, which are generally recommended to correct short-term soil nutrient deficiencies. However, these mineral fertilizers are still not widely available and their costs are quite high for small-scale producers. Yet there are several production alternatives and/or combinations of certain agricultural practices that are being developed and promoted for sustainable production (Boni et al. 2017; Amoatey and Acquah, 2010). Among these, agroecological production via the value of different forms of organic matter (compost, manure...), natural biopesticides (Weber et al. 2007), and the use of effective microorganisms that can significantly reduce the pressure of bioaggressors, while contributing to the health of ecosystems (Houenou, 2013). Indeed, studies conducted around the world on organic amendment practices obtained interesting results where soil fertility was sustainably improved and yields comparable to chemical fertilization were achieved (John, 2019; Vanden Nest et al. 2014; Ezzo et al. 2012). However, these results varied from year to year and influenced by a number of factors such as, compost type, crop species, soil type, and rainfall patterns in the study regions. Compost applications in soils allow a reduction of leachable mineral fertilizers. They improve soil fertility in a sustainable and efficient manner (Guittonny-Larchevêque, 2004), promote reforestation processes by improving plant nutrition and growth, increase their survival potential during periods of drought, and increase the buffering capacity and exchange capacity of soils, two parameters that condition the mineral nutrition of plants (Mustin, 1987). A natural way to value crop wastes with many advantages is composting. Composting has the advantage of reducing the environmental risks associated with waste management by reducing the volume of waste and destroying pathogenic organisms (Saebo & Ferrini, 2006). In addition, composting provides a stable, humified organic material containing nutrients. The incorporation of compost into the soil is effective in combating the degradation of the soil surface (Bresson et al., 2001) and in improving its porosity and structure (Pagliai et al. 2004). The use of compost, which is a fertilizer rich in organic matter, allows the soil to acquire a buffering capacity against the modifications induced by the application of mineral fertilizers. In addition to improving physical and biological properties (Aggelides et al. 2000; N'Dayegamiye et al. 2005), compost also provides the soil with mineral elements such as phosphorus, nitrogen and trace elements (McDowell et al. 2004).

Depending on their origin, composts can have different fertilizing qualities. Composts from agri-food waste are free of pathogens, heavy metals, and therefore are of better quality compared to composts from urban waste (Koledzi et al. 2011). Thus, the development of new types of composts based on organic matter and materials such as manure, rock phosphates and ash become a priority for organic agriculture (Tchegueni, 2011). Phosphocomposting leads to a nutrient-rich organo-mineral fertilizer and could reduce the depressive effects on yields by ensuring sustainable soil fertility management (Ousmane M S et al. 2016). The objective of this work was therefore to assess the effects of the use of composts, developed from crop residues (millet husk and rice husk) on millet production.

Materials and Methods

Fertilizers

A phosphocompost elaborated from organic matter with Tahoua rock phosphate powder (granulometry 125µm), a simple compost elaborated from 100% organic matter and the chemical fertilizer NPK were used in this study.

These were:

✓ Simple compost C1: 100% organic matter containing 45.72% millet husk + 37.14% cow manure + 17.14% rice husk ash.

✓ Phosphocompost C2: 95% organic matter (42.86% millet husk + 35% cow manure + 17.14% rice husk ash) and 5% Tahoua rock phosphate.

Table 1 presents the quantities in kg of material used to prepare these composts.

Table 1: Composition of the mixtures used during composting

Composition	Millet husk (Kg)	Rice husk ash (Kg)	Cow manure	Phosphate
Simple compost C1	32	12	26	-
Phosphocompost C2	30	12	24.5	3.5

The mixtures are put in aerobic fermentation during 3 months with regular turnings every week until maturation (complete decomposition)

Experimental site

The agronomic tests on millet production were carried out on the experimental plots of the INRAN agronomic station located in N'Dounga, 20 km from Niamey (13°56'29" N and 2°14'51" E) in the department of Kollo, Tillaberi region during the 2019 rainy season.

Plant material

The plant material was the millet variety *Pennisetum glaucum [L] R.Br*. called Haïni Kiré Précoce (HKP) developed by the National Institute of Agronomic Research of Niger in 1987 which has an average cycle of 90 days. This variety was chosen because of its adaptation to different agro-ecological zones, including the study area.

Technical material

The technical equipment used was composed of a graduated tape measure for the measurement of the dimensions of the trial, traditional dabas for ploughing, labels for the distinction of the treatments, electronic scales for the different weight measurements. The auger for the collection of soil samples, plastic bags for the conservation of samples.

Experimental device

The trial design was a completely randomized Fischer block with 5 treatments and 4 replications, that is a total of 20 plots for the whole trial. Each block was composed of 5 plots of 6m x 5m each spaced 2m apart, and 3m separates the blocks.

The treatments used are as follows:

T11 = 100g of C1 Simple Compost per plot applied at microdose
T12 = 150g of C1 Simple Compost per pile applied at microdose
T21 = 100g of Phosphocompost C2 per pellet applied at the microdose
T22 = 150g of Phosphocompost C2 per microdosed pile
T0 = Control (without any compost application) corresponds to the absolute control.

Physico-chemical analysis of the study site soils and the composts produced

Before the commencement of the test, soil samples were taken with an auger at depths of 0 - 20 cm for physicochemical characterization. After drying the samples in the ambient air, they were crushed and sieved to 2 mm. The analysis of the soil samples taken on site were carried out at the National Institute of Agronomic Research of Niger laboratory.

Physico-chemical analysis made it possible to determine: the granulometry, the pH-water, the total organic carbon (C), the total nitrogen (N), the total phosphorus and the exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}). The granulometry was determined by the Robinson pipette method. The pH was measured with a pH meter (soil/water ratio 1/2.5), the organic carbon was measured by the method described by Walkley and Black. The Kjeldahl method was used to determine the nitrogen content. For the determination of total phosphorus, the modified Dabin method was used at the wavelength of 882 nm using a JENWAY 6300 spectrophotometer. Potassium was determined using a flame photometer. Potassium K^{+} was read directly from the mineralization. Exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}) were extracted by ammonium acetate solution at pH 7. In addition, samples of the composts were taken and analyzed in the same laboratory. These analysis included pH, potassium, total phosphorus, carbon, nitrogen and calcium.

Evaluation of agronomic parameters

To determine the effect of composts on millet production, the following parameters were evaluated:

- Percentage of emergence: It was evaluated for the whole plot, and expressed in percentage of emerged clusters. It was assessed seven (7) days after sowing;

- Number of ears per cluster: The number of ears per cluster was determined at the stage of maturity and consisted of counting the number of ears in each cluster on the treatment;

- Grain yield per plot in Kg: After harvesting, threshing and weighing of the production was done. The yield in Kg/ha of each treatment was determined.

Determination of the agronomic efficiency of the composts

The agronomic efficiency (AE) of the composts allowed a better comparison of the composts. The absolute control was considered as the reference with an efficiency of 0%. The AE of composts was calculated in reference with the absolute control using the following formula:

E A (%) = (Yield Compost-Yield Control) / (Yield Control) × 100

Statistical analysis of data

The data for each variable was tested for normal distribution with the Ryan Joiner test. Results for the millet yield study were subjected to an analysis of variance (ANOVA) at the 5% level. All these analysis were done using MINITAB software version 14.1. Some graphs were developed with EXCEL 2016.

Results

Physico-chemical characterization of the study site soil

The analysis of soil samples from the experimental site before the installation of the millet crop allowed the preparation of Table 2 in which the main physico-chemical parameters were recorded.

Table 2: Physico-chemical parameters of the soil at the study site

Physical characteristics								
Clay (%)			Fine silt (%)		Fine sand (%)			
20.22			30		47.4			
Chemical characteristics								
	Organic matter			Phosphorous (mg/kg)	Changeable bases (mg/kg)			
pH	C (%)	N (%)	C/N	Pt	Ca^{2+}	Mg^{2+}	K^+	Na^+
6,77	0.16	0.02	8	12.81	0.19	0.03	1.02	0.19

The results of the analysis of the soil samples taken before the test at a depth of 0-20 cm (Table 2) showed that the soil had a grain size dominated by sand, giving it a sandy texture. Chemically, the soil pH was acidic, organic carbon (0.16%), total nitrogen (0.02%) and total phosphorus (12.81 mg/kg) were very low. Exchangeable bases are dominated by potassium. It was therefore a soil with low agronomic potential.

Physico-chemical characterization of the composts produced

The physicochemical characteristics of the composts obtained are shown in Table 3.

Table 3: Chemical composition of the composts produced

Compost	**Simple compost C_1**	**Phospho compost C_2**	**Simple compost ***	**Phospho compost***	**Simple compost ****	**Phospho compost****
pH	7.86	7.9	9.38	8.07	7.90	7.99
%C	11.115	15.405	20.450	19.750	20	17.070
%N	1.12	1.14	1.34	1.37	0.49	1.43
C/N	9.92	13.41	15.26	14.41	40.81	11.93
P_2O_5 mg /kg	2867.92	3866.67	340.59	826.89	2938.98	5949.4
K_2O mg /kg	8886.79	6400	-	-	5543.5	2138.8
CaO mg /kg	385.35	851.46	-	-	-	-

*Ousmane Mahamane Sani, 2018 ; ** Abdou Gondah, 2021

The pH of the composts produced varies between 7.8 and 7.9. The C/N ratios of the different composts varied between 9 and 14 and were consisted with those found in the literature (Table 3).

The analytical results of these nutrients showed that the composts contained high levels of P, K and Ca (Table 3). The total phosphorus content in mg/kg was 2867.92 in the simple compost C1 and 3866.67 in the phosphocompost C2 (Table 3).

The potassium content was 8886,79 mg/Kg in the C1 simple compost and 6400 mg/Kg in the C2 phosphocompost (Table 3).

Content of metallic trace elements

The purpose of these analysis was to know their content in the compost before its use to evaluate their toxic potential.

Table 4: Content of trace elements in the composts produced

TME (mg/Kg MS)	Compost C1	Phosphocompost C2	Standard limit France
Cu	1.98	2.74	300
Zn	4.5	9	600

The analysis of the TMEs (Cu and Zn) carried out on the composts gave very low values (Table 4): less than 3 mg/kg DM for Cu and less than 10 mg/kg DM for Zn.

Effects of treatments on millet yield

Effect of treatments on emergence rate

The results concerning emergence are given in Table 5. The millet variety HKP used in this experiment germinated well with a uniform germination rate of almost 100% on all plots. Statistical analysis showed that there was no significant difference between treatments ($F < 0.05$).

Effects of treatments on the number of harvested ears/plots

The average number of harvested ears per bunch was shown in Table 5.

The analysis of variance showed that there was a significant difference between the treatments at the 5% threshold. It varied from 5 for the control T0, 6 for treatments T11 and T21 and 7 for treatments T12 and T22.

Table 5: Effect of composts on millet vegetative growth

Treatment	Survey	No. of ears per cluster
T0	98.7a	5a
T11	99.6a	6ab
T12	99.8a	7b
T21	99a	6ab
T22	99.4a	7b

Effects of treatments on grain and biomass yields

The results of the statistical analysis for the comparison of means are presented in Table 6. A highly significant difference at the 5% threshold was obtained between composts (p=< 0.0001) and doses (p=0.0003). On the other hand, no significant difference at the 5% threshold was obtained in the interaction composts doses (p=0.70).

Table 6: Effect of treatments on grain and total biomass yields

Treatments	Grains yield (kg/ha)	Biomass total yield (kg/ha)	EA (%)
T0	620c	2116b	0
T22	1530a	3727a	146.77
T12	1460ab	3563a	135.48
T11	1080b	2846b	74.19
T21	1080b	3093a	74.19
Probability			
Composts	< 0.0001		
Doses	0.0003		
Composts*Doses	0.7025		

Means followed by the same letter are not statistically different

Phosphocompost and compost doses applied at the microdose had a significant effect (at the 5% threshold) on grain and total biomass yields of millet (Table 6). Grain yield was 620 kg/ha for the T0 control compared to 1530, 1460, 1080 and 1080 kg/ha for the T22, T12, T11 and T21 treatments, respectively (Figure 1).

The agronomic efficiency (AE) of composts (Table 6) varied with the dose applied. The analysis of the average efficiencies shows that treatment T22 had the highest agronomic efficiency (146.77%) exceeding the other treatments.

The treatment effects also induced a significant increase in millet biomass yield (Table 6). Biomass yield was 2116 kg/ha for the T0 control compared to 3727, 3563, 2846, 3093 kg/ha for the T22, T12, T11 and T21 treatments respectively (Figure 2). We observe an increase over the control of: 76.13; 68.38; 34.49 and 46.17% for treatments T22, T12, T11 and T21 respectively (Table 6).

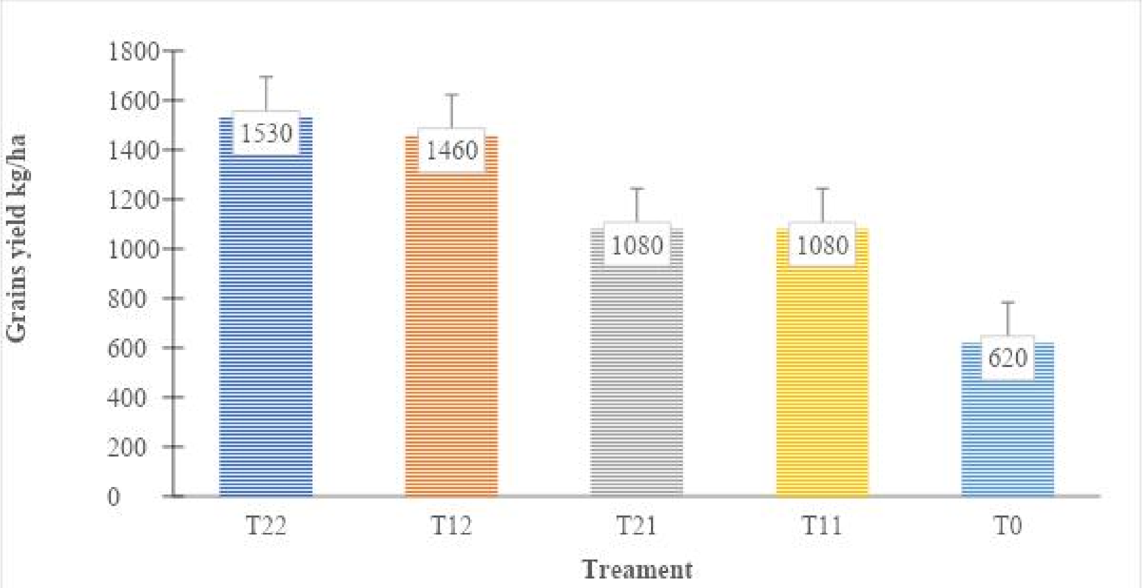

Figure 1: Grain yield of different treatments

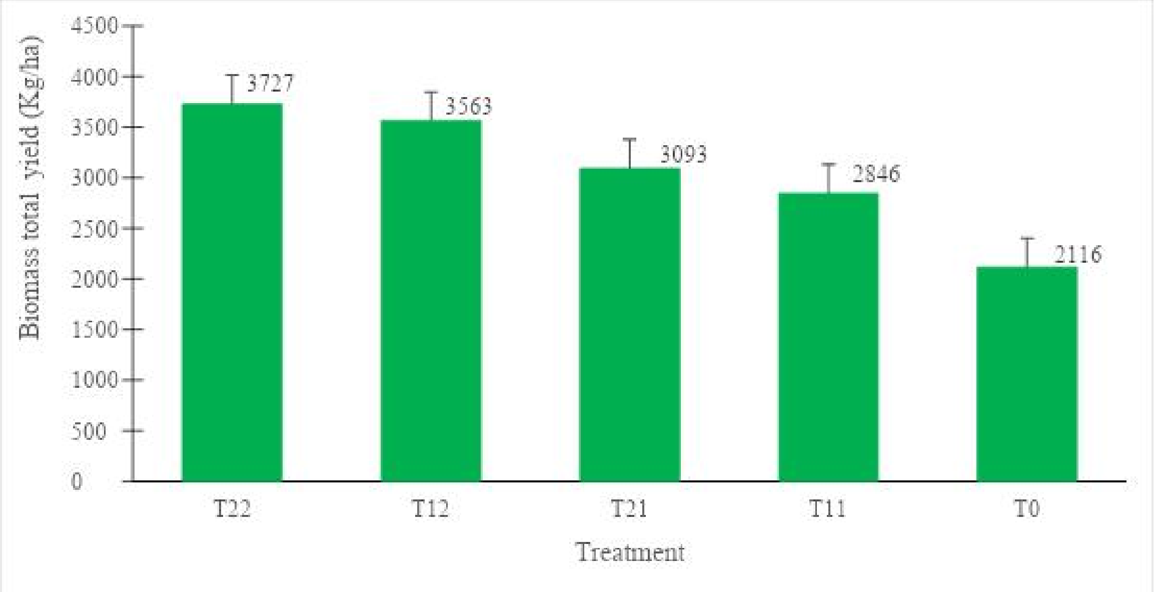

Figure 2: Total biomass yield of different treatments

Discussion

Physico-chemical characterization of the composts produced

The pH of the composts produced was found to be basic. This alkalinity was related to the proportion of rice husk ash. These results were in agreement with those of Tchegueni (2011) and those of Abdou Gondah (2021). The C/N ratios of the different composts varied between 9 and 14, and were consistent with those found in the literature (Table 3) (Abdou Gondah, 2021; Tchegueni, 2011).

These results showed adding rock phosphate to organic matter increased the total phosphorus content of composts (Table 3). According to Moursalou et al. (2010), the bioavailability of phosphorus was attributed to the biological oxidation of organic matter and to the process of humification which promotes the dissolution of natural phosphates. These results were comparable to those obtained by Ousmane M.S. (2018) during the composting of crop residues plus water hyacinth where the addition of Tahoua natural phosphate in the mixture improved the phosphorus content of the composts. The total potassium content decreased with addition of phosphate in the compost (Table 3). This showed, on one hand, that the main source of potassium in our mixtures was organic matter and, on the other hand, that since phosphate was not a good source of potassium, its addition leads to a decrease in potassium content within the medium.

Our results were in agreement with those of Zaguina A. (2011) who worked on the composting of lawn mowing in the presence of Tahoua natural phosphate from which the total potassium content of the composts was found to decrease with the addition of phosphate in the mixture.

The presence of these elements in composts was an advantage for soil amendment. Their fertilizing nature allowed them to act like chemical fertilizers, not only by enriching the soil with N, P, K, but also through their main effect as an organic amendment that acts on the physical, biological and chemical stability of the soil (Bertoldi et al. 1983).

These results were in agreement with those obtained by Naima Tahraoui (2013) in Algeria.

Complying with the limit values set by the French standard NFU 44051, the contents of trace metal elements (Cu and Zn) analyzed of simple compost C1 and phosphocompost C2 were found to be within the set limit values. Therefore, these composts could be used as organic amendments.

Effect of treatments on millet yield

The contribution of composts allowed a good stimulation of the vegetative growth of millet crop (Table 5). The high rate of emergence recorded could be due to the good quality and coating with fungicides of the seeds used. Aune et al. (2019) showed that seed coating with fungicides increased millet yield by 15% in Mali. These results were in line with those of studies carried out in Niger by Zeinabou et al. (2013) and Nourou et al. (2020) showing that the combination of the quality and coating of the seeds used and the contribution of organic manures had allowed to increase the vegetative growth of millet crop (Nourou et al. 2020; Aune et al. 2019; Zeinabou et al. 2013).

The doses of phosphocompost and compost applied at the microdose had a significant effect (at 5% threshold) on grain yields and total biomass of millet (Table 6). These results showed that the T22 treatment was more effective in increasing grains, followed by the T12 treatment, indicating that the treatment of the natural phosphate powder with organic matter significantly increases millet yields. These results corroborated the physico-chemical study of these composts in particular the phosphorus content which was higher in the phosphocompost. Similar results were obtained during a study of the agronomic effectiveness of phosphocomposts based on natural phosphate from Tahoua (Niger) applied at a microdose in comparison with the control, simple compost and natural phosphate from Tahoua, the results of which were 450 Kg/ha, 1217 Kg/ha and 1506 Kg/ha respectively (Ousmane M.S. et al. 2016).

This improvement could be explained by the organic matter content which would have improved the biological and physical properties of the soil (Takeda et al. 2009, Zeinabou et al. 2014, Ousmane M.S. et al. 2016, Dabré et al. 2016). Ouattara (2007) cited by Saba et al. (2017) showed that most soils with natural poverty react positively to different fertility improvement practices. This improvement had led to good nutrition of the plants, hence, the increase in yields.

Treatment effects also induced a significant increase in millet biomass yield (Figure 2). These results indicated that the higher the compost dose, the greater the biomass yields. The results followed the same trend as those in the case of grain yields. These results were in agreement with those obtained by Palé et al. (2021) in Burkina Faso.

The results could be explained by the fact that localized fertilizer application (microdose) makes it possible to cover much more of the nutrient requirements of millet crop. Indeed, the method was particularly well suited to millet and sorghum crops and allows more efficient use of fertilizer and increased agricultural yields in a sustainable manner (FAO, 2012). Many studies have highlighted the positive role of the microdose in reducing the various losses of nutrients (Demers, 2008), improving the efficiency of nutrient use by its concentration in the root system (Tabo et al. 2007; Palé et al. 2009). These results in rapid root and plant growth (Aune and Bationo, 2008; Saba, 2011) improved yields (Tabo et al. 2007; Hayashi et al. 2008; Taonda et al. 2008; Bagayoko et al. 2011; Traore et al. 2012; Ibrahim et al. 2015; Somda et al. 2017).

The same results were found in studies carried out in Niger on HPK millet by Maman Sadi et al. (2020) and Nourou et al. (2020) which showed that the more the doses of manure increased, the more the grain and total biomass yields of millet crop were high.

Conclusion

This study assessed the performance of crop waste composts on millet. The application of the method to microdose was used. Compost inputs increased millet grain yield by 74.19%, 74.19%, 135.19% and 146.47% respectively for treatments T11, T21, T12 and T22 compared to the control. The same trend was observed for total biomass yield (76.13% for T22; 68.38% for T12; 46.17% for T21 and 34.49% for T11 compared to the control). The results obtained allowed the best treatment that optimizes yield. The best grain yield (1530 kg/ha) was obtained in treatment T22, which was about three times higher than the control (620 kg/ha). The results of this study show that crop waste composts have a beneficial effect on millet yield. This study highlighted the potential of crop waste composting for sustainable agriculture. This is an opportunity for small-scale producers as it is a product that could be used to reduce production costs.

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