Mineralization and decomposition of four types of compost based on biomass of *Sida cordifolia* L. in a sandy soil in the semi-arid zone of Niger

Abstract

The low nutrient availability ~~of unpredictable~~and rainfall patterns ~~and~~ regimes are the main constraints to agricultural production in Niger. This is a food of the body of bio and compost. Generally, this use has been taken into account in the quality, decomposition and release of nutrients from these organic materials. This study of the decomposition and mineralization of nutrients of four types of composts (M1P, M2P, M1H and M2H) a dune soil, ~~. It~~ was carried out at the experimental N'Dounga station (CERRA Kollo) located about 15 km from Niamey. A randomized device with four blocks was used. For the evaluation of yield, two doses (1 t ha^{-1} and 1.5 t ha^{-1}) were applied per millet. Decomposition and mineralization were assessed in depth at 10 cm depth between the lines of the small bag containing 100 g of each compost. The characterization of the physico-chemical elements of composts has shown that composts are relatively rich in nutrients. Nitrogen ranged from 0.8% to 1.1%, phosphorus from 9.99 mg.kg^{-1} to 12.76 mg.kg^{-1} and potassium from 19.94 ~~meq~~ cmol$_c$ dm^{-3} ~~k / 100g~~ to 26.26 cmol$_c$ dm^{-3} ~~meq k / 100g~~. All four composts are basic (pH> 7). Compost M2H lost more than 80% of its weight during the 10 weeks of the experiment compared to 48% for the M1P. the mineralization of N, P and K is greater at compost M1P (83.6% N, 72.72% P and 89.5% K). This compost also gave the highest yield (1272.5 kg ha^{-1}). The decomposition and mineralization of the main elements (~~nitrogen~~N, ~~Pphosphorus~~ and ~~Kpotassium~~) allow the synchronization between the release of nutrients from these composts and the nutrient requirements of millet in a sandy soil.

Keywords: compost, mineralization, *Sida cordifolia*, millet, sandy soil

Introduction

Agricultural production in Sub-Saharan Africa is low and decling resulting from continued decline in soil fertility due to poor soil management and other biophysical factors (Voortman 2010).

In Niger, low crop yields are often explained by poor soil nutrient supply, unpredictable rainfall and low fertilizer use. This situation is aggravated by a population growth of about 3.8%, leading to frequent food shortages and persistent poverty in smallholder farming communities.

To increase yields and improve the efficient use of scarce rainfall in the Sahelian region of Niger, the use of mineral fertilizers is becoming increasingly necessary (Payne 2000). The

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fertilizer recommendation in Niger is 200 kg ha^{-1} of NPK compound (15-15-15) (Hayashi et al. 2008). However, most farmers cannot afford to buy that amount of fertilizer. The high price of inorganic fertilizers, and the risks associated with their use in dry areas are the key factors limiting fertilizer use in Niger (Abdoulaye and Sanders 2005).

The option of integrated use of mineral and organic fertilizers to improve crop yields and maintain soil fertility is well documented (Yamoah et al. 2002, Bationo et al. 2003, Akponikpe 2008). However, the main sources of organic amendments such as crop residues and animal manure, are not available in sufficient quantities.

It is therefore necessary to develop another alternative low-cost soil fertility management option. The use of *Sida cordifolia* L., an herbaceous plant of the Malvaceae family as an organic material for the production of compost, is one of the alternatives to explore. To do this, an experimental study of composting the biomass of Sida cordifolia (BSC) was conducted in 2018. Four types of composts were developed to be applied by hill on millet. To be used as an organic amendment, these composts must be rich in nutrients but also, the decomposition and mineralization of nutrients must synchronize with the need of the crop.

The objective of this work is to evaluate the decomposition and nutrient mineralization of four types of composts based on the biomass of *Sida cordifolia* and their effects on millet yield in sandy soil.

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Material and method

Study site

The trial was conducted during the rainy 2017 season at the experimental station of the Regional Agricultural Research Centre (CERRA) of Kollo located at N'Dounga 15 km southeast away from Niamey. The station is located at a latitude of 13° 29'088'North and a longitude 2° 07'535'East (Figure 1). The climate of the study area is of the Sahel-Sahelian type with an average annual rainfall of unclear. Average temperatures are around 30°C in the dry season (March, April) and fall to 10°C in the harmattan season (December to February).

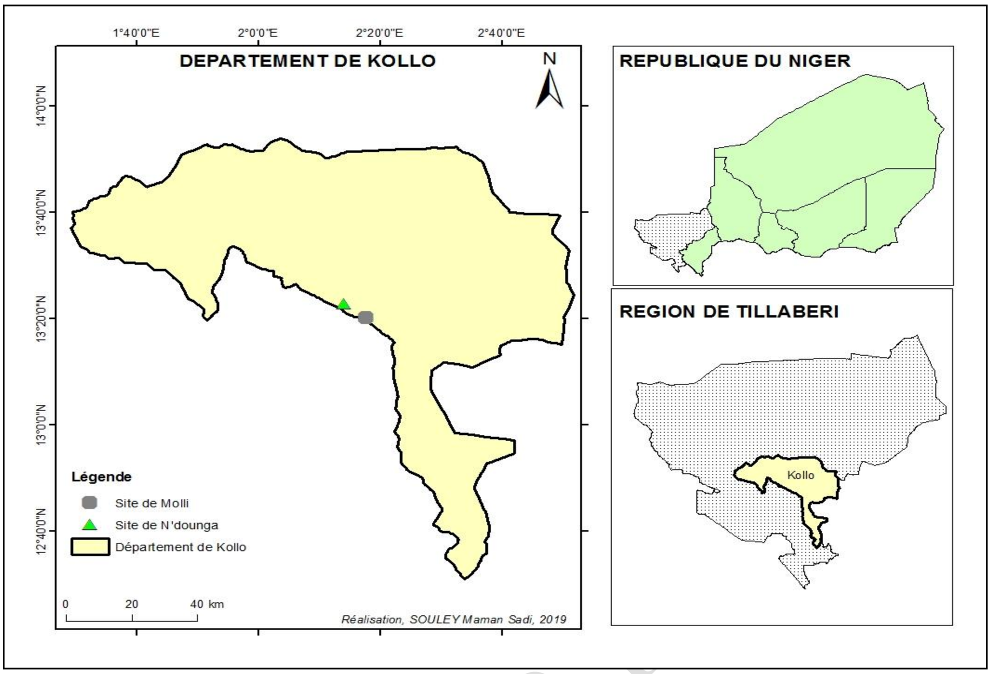

Figure 1: Study site location map

Preparation of compost

Four types of compost were developed in 2018: M1P = p~~P~~it composting with 75% biomass of *Sida cordifolia*, 20% of organic manure and 5% ~~Ash~~ash;~~,~~ M2P = ~~Pit~~ pit composting with 95% biomass of *Sida cordifolia* and 5% organic manure;~~,~~ M1H = ~~Heap~~ heap with 75% biomass of *Sida cordifolia*, 20% organic manure and 5% ~~Ash~~ash;~~,~~ M2H = ~~Heap~~ heap composing with 95% biomass of *Sida cordifolia* and 5% of organic manure. The biomass of *Sida cordifolia* was harvested between October and November 2017 at maturity stage. In terms of organic manure and ash, they were collected in the village of Molli near the station where the composts were made.

Physico-chemical characterization of composts and soil

The physico-chemical characterization of the composts and soil was carried out by analyzing the physico-chemical elements on a composite sample of each compost. This analysis included ~~the elements~~ pH, ~~carbon~~C, ~~nitrogen~~N, P~~phosphorus~~, and K~~potassium~~.

The pH was measured according to the international standard ISO 10390 (1994), while the total organic carbon (TOC) was determined by the method (Walkley and Black 1934). The

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Kjeldahl method (NT 76.05, 1983) was used assessing ~~nitrogen~~ N content. The method of (Murphy and Riley 1962) was used to determine available ~~phosphorus~~ P content.

Potassium ~~(K+)~~ was determined using a flame photometer. ~~The analytical solution is prepared using the Kjeldahl method (NT 76.05, 1983).~~ The K^+ content was read directly into the mineralization.

Exchangeable bases (Na^+, Ca^{++}, Mg^+) were extracted by the ammonium acetate (NH4OAc) solution at pH 7 using the extraction method described by (Van Reeuwijk 1993). To determine the soil particle size, the Robinson pipette sampling method was used.

Experimental Design

The bag method was used to study decomposition of the compost. ~~The 1.0mm nylon.~~ The litter bags measured of 20 cm x 15 cm and were produced from 1.0 mm nylon mesh. The design was coupled with an experimental trial to evaluate the effects of *Sida cordifolia* -based composts on the yield of HKP millet. They were installed on 02 July 2018. Five (5) bags containing 100g of each compost repeated 4 times were buried 10 cm deep. Before design installation, Physico-chemical ~~elements~~ characteristics of each compost were determined: dry weight, ~~nitrogen~~N, P~~phosphorus~~, K~~potasuim~~ and pH. Soil sampling was conducted to characterize the soil sites composition.

Data collection

Random sampling of one bag of each compost and in each block was performed at 2, 4, 6, 8 and 10 weeks. At each sampling, the remaining compost from each bag was manually cleaned and a fresh weight was recorded before drying it in an oven at 65°C for 48 hours to take the dry weight.

The site's automated agro-metrological station was used to collect: moisture, temperature and rainfall data covering the trial period.

Statistical Analysis

A variance analysis at the 5% threshold was performed on data from the physico-chemical elements of composts. Each time a significant difference ~~is~~ was detected, ANOVA ~~is~~ was accompanied by the Fisher test (LSD). Excel 2016 and GENSTAT 9th edition software were used for all these analyses. The percentage of dry weight after sampling was determined using the formula:

(1) $\boldsymbol{Ps\ (\%) = 100 \times \frac{P_t}{P_0}}$ where:

Ps (%) = Dry weight percentage;

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Pt = Compost weight at t time;

P0 = Initial weight of compost in the bag.

The rate of release of nutrients following decomposition was calculated using the following formula:

(2) $T_n\ (\%) = 100\ x\ \frac{C_0\ P_0 - C_t\ P_t}{C_0\ P_0}$ where:

Tn (%)=Nutrient Release Rate,

C0=Initial Concentration of Chemicals (N, P, K) from Compost,

Ct=Concentration of chemicals (N, P, K) compost at t time,

Pt=Weight of compost at t time, P0=Initial weight of compost in the bag.

The decomposition model and decomposition rate constant (k) of each type of compost were determined through the data that were ~~modelled~~modeled using a single exponential model described by (Olson 1963):

(3) $M_t = M_0 e^{-kt}$ where:

Mt = dry weight remaining of the compost at time t,

M0 = initial dry weight of the compost.

The time required for the compost to lose half its initial weight (t_{50}) was calculated using the formula described by (Fening et al. 2010):

(4) $t_{50} = \frac{-\ln(0,5)}{k}$, where ~~K~~ k is the decomposition factor.

Results

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Humidity, temperature and rainfall

At the beginning of the experiment, the maximum mean temperature was 33°C and the minimum value of 22.4% was obtained 65 days after the test was installed.

Site moisture content ranged from 41.8% to 97.7% during the 10 weeks of the trial The cumulative rainfall during the growing period was 579.4 mm. The highest rainfall (73 mm) was recorded on the 80th day after planting. Between the 30th and 59th day after the semi (JAS), a small dry spell was observed. During this dry spell of 29 days the total rainfall was only 12mm.

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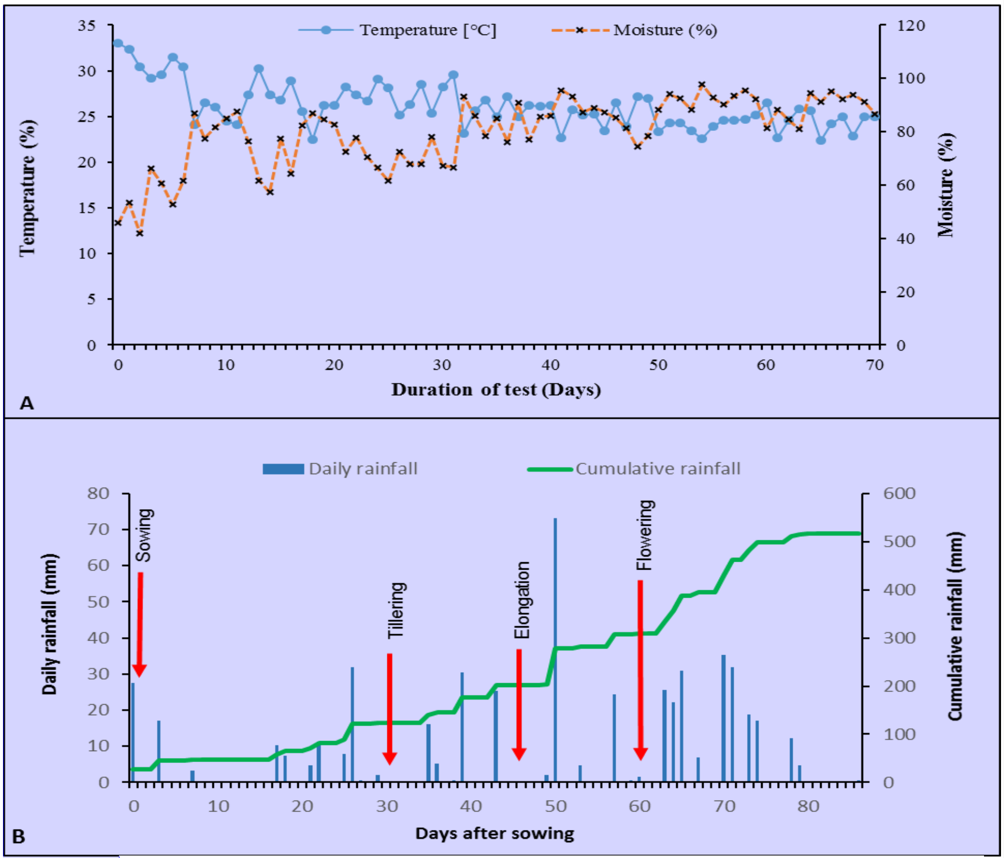

Figure 2: Moisture and soil temperature (A) and rainfall distribution during the test period (B) at the site level

Source: http://www.fieldclimate.com INRAN REDSA ACC-3, Serial number 0020366.

Physical and chemical composition of soil at the experimental site

The results of the analysis of the soil samples (0-20 cm depth) collected at the site prior to the installation of the test (Table 2) showed that this is a sandy soil. The pH value was 6.77 available ~~phosphorus~~ P content remaineds average (26.81 mg dm^{-3} ~~ppm~~). The ~~nitrogen~~ N and C~~carbon~~ content of the soil ~~is~~ was very low, 0.02% and 0.16%, respectively. The low ~~carbon~~ C and ~~nitrogen~~ N content indicate that this soil has very soil fertility status~~.~~ (Table 1).

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Table 1: Physical and chemical characteristics of the test site soil (n=4)

Measured parameters	Unit	Mean of values (depth 0-20 cm)
pH-H_2O (1 :2.5)		6.77±0.1
MO	%	0.28±0.02
C	%	0.16±0.01
Total N	%	0.02±0.002
Available P	~~ppm~~mg dm^{-3}	12.81±8.11
Exchangeable bases		
~~CA~~Ca^{++}	~~Méq/100g~~cmol$_c$ dm^{-3}	0.19±0.02
Mg^{++}	cmol$_c$ dm^{-3}~~Méq/100g~~	0.03±0.01
Na^{+}	cmol$_c$ dm^{-3}~~Méq/100g~~	0.31±0.04
K^{+}	cmol$_c$ dm^{-3}~~Méq/100g~~	1.02±0.47
Granulometry		
Clay	%	0.72±0.04
Silt	%	4.78±0.41
Sand	%	94.5±1.3

Legend: MO – organic matter.

Physio-chemical characteristics of composts

The analysis showed clear differences with the composts with regard to ~~organic matter~~OM ($p<.001$), ~~nitrogen~~ N ($p = 0.008$), and ~~potassium~~ K ($p= <.001$). No significant difference was observed for total and assimilated ~~phosphorus~~ P and pH. The richest compost was the M1P compost containing 12.31% C, 1.11% N content and 26.6 cmol$_c$ dm^{-3}~~meq K/100g~~. The pit method gave a better quality than heap composting as this compost was richer in ~~carbon~~C, ~~nitrogen~~ N and available ~~phosphorus~~ P than the heap compost.

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Table 2: Mean composition in physio-chemical elements of composts (± SE)

Physico-chemical element	Types of composts				F.pr (0.05)	CV (%)	Norme	
	M1P	M2 P	M1H	M2H			FAO	AFNOR
pH-H2O (1 :2.5)	7.95 [a] (± 0.26)	7.58 [a] (± 0.85)	8.09 [a] (± 0.53)	8.15 [a] (± 0.51)	0.467	6.7		
Organic matter (%)	21.21 [b] (± 1.13)	19.16 [b] (± 0.88)	13.61[a] (± 1.07)	14.21[a] (± 1.33)	<.001	6.9	10-30	> 5
C (%)	12.31 [b] (± 0.65)	11.12 [b] (± 0.51)	7.90 [a] (± 0.62)	8.25 [a] (± 0.77)	<.001	6.9		
N (%)	1.11 [b] (± 0.14)	0.88 [a] (± 0.07)	0.80 [a] (± 0.08)	0.83 [a] (± 0.06)	0.008	11.3	0.4-0.5	> 0.25
~~tot~~ Total P (mg.~~.~~ kg^{-1})	122250 [a] (± 6850)	118000 [a] (± 4690)	125500 [a] (± 577)	126250 [a] (± 500)	0.086	3.5		
Available P (mg.~~.~~ kg^{-1})	11.25 [a] (± 1.48)	12.76 [a] (± 1.46)	9.99 [a] (± 1.58)	10.07 [a] (± 1.55)	0.112	29.8		
K^+ (cmol$_c$ dm^{-3} ~~meq k/100g~~)	26.26 [b] (± 0.32)	24.95 [b] (± 1.09)	19.94 [a] (± 1.31)	20.83 [a] (± 0.38)	<.001	4.2		
C/N	11.25 [a] (± 1.48)	12.76 [a] (± 1.46)	9.99 [a] (± 1.58)	10.07 [a] (± 1.55)	0.112	14.4	10-15	< 20

M1 P *= Compost in pit with 75% SCB +20% OM+5% Ash,* ***M2P*** *= Compost in pit with 95% SCB +5% OM.*
M1 H *= Compost in heap with 75% SCB +20% OM+5% Ash,* ***M2 H*** *= Compost in heap with 95% SCB+5% OM.*
FAO: *World organization for agriculture and the food,* ***AFNOR****: Association French of Normalization.*
tot P*= total P and available* ***P*** *= Available phosphorus.*
Same letters within columns indicate no significant differences

Decomposition model for different types of composts

The decomposition pattern of different types of composts based on the *Sida cordifolia* biomass during the 2018 rainy season ~~is~~ was shown in Figure 2. The remaining weight of each decomposing compost ~~is~~ was expressed as a percentage of the initial weight of the compost. The composts lost in averegae 59.4% its initial value after 10 weeks. Throughout the study, the M2H compost (~~Heaps~~ heaps compost with 95% of SC+5% FM) decomposed faster than the others with a weight loss of 26% to 79% from the first month to the fourth

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month, respectively?. There ~~is~~ was little variation in the percentage of decomposition between the other composts (M1P, M2P, M1H). Within 30 days of the experiment, M1P, M2P and M1H composts lost 21%, 14% and 5% of their initial weights, respectively. At the end of the fourth month study the remaining amount of compost 48%, 52.6% and 58 % for the M1P, M2P and M1H, respectively.

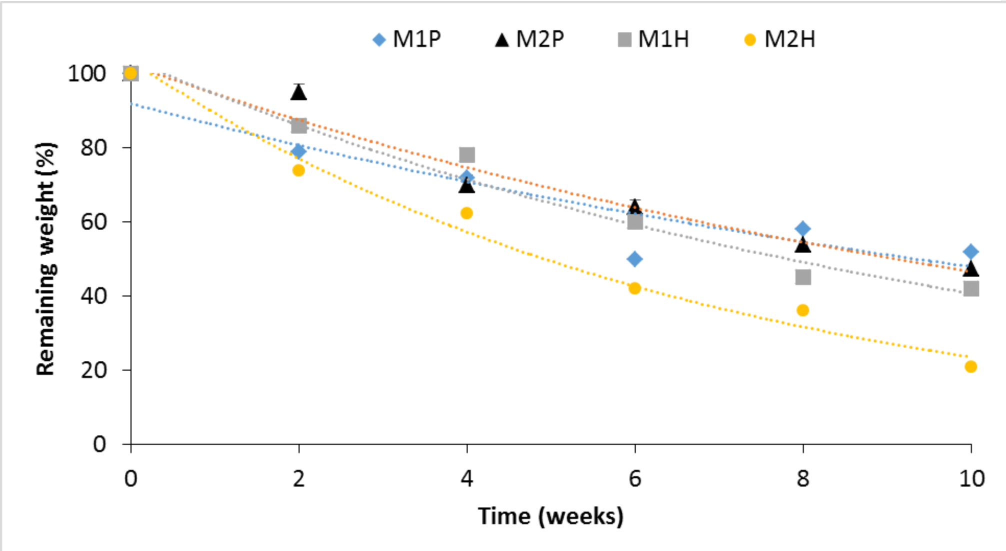

Figure 3: Percentage of weight remaining in the litterbag

__M1P__ =Compost in pit with 75% SCB +20% OM+5% Ash, __M2P__=Compost in pit with 95% SCB +5% OM.

__M1H__=Compost in heap with 75% SCB +20% OM+5% Ash, __M2H__=Compost in heap with 95% SCB+5% OM
Trend lines are the best fit.

The composts differed greatly in number of weeks to ~~loose~~lose half of its initial weight (t50). The two heap compost M2H and M1H had a t50 value of 2.33 and 3.85 weeks while the two peat compost M1P and M2P had t_{50} values of 5.33 and 4.33, respectively. The higher k value of the heap compost also reflect~~s~~eds the higher decomposition rates for the heap composts as compared to the pit composts.

Table 3: Decomposition rate constant (k), coefficient of determination (R2) and (t50) of composts

Type of compost	Regression equation	K (day^{-1})	R²	T_{50}
M1P	M_t = 104,79e$^{-0,13t}$	0,13	0,81	5,33
M2P	M_t = 119,99e$^{-0,158t}$	0,16	0,97	4,33

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M1H	$M_t = 125{,}22e^{-0{,}187t}$	0,18	0,97	3,85
M2H	$M_t = 139{,}42e^{-0{,}296t}$	0,29	0,97	2,39

***Mt** = compost remaining weight at t time.*
***M1P** =Compost in pit with 75% SCB +20% OM+5% Ash, **M2P**=Compost in pit with 95% SCB +5% OM.*
***M1 H**=Compost in heap with 75% SCB +20% OM+5% Ash, **M2 H**=Compost in heap with 95% SCB+5% OM*

Model for nutrient liberalization of different composts

Mineralization of nitrogen

None of the compost reached a 50% ~~nitrogen~~ N liberalization during the first two weeks of the experiment, but the M1P compost which is ~~relative~~ richer in ~~nitrogen~~ N release a larger part of its ~~nitrogen~~ N than the other composts. This trend continued until the end of the experiment. At the end of the trial the compost at lost in average 76.5% of its initial value.

At the end of the study period, M1P compost released 83.6% of its N, while M2P, M1H and M2H composts released 66.6%, 74.8% and 81.02% of the N content, respectively.

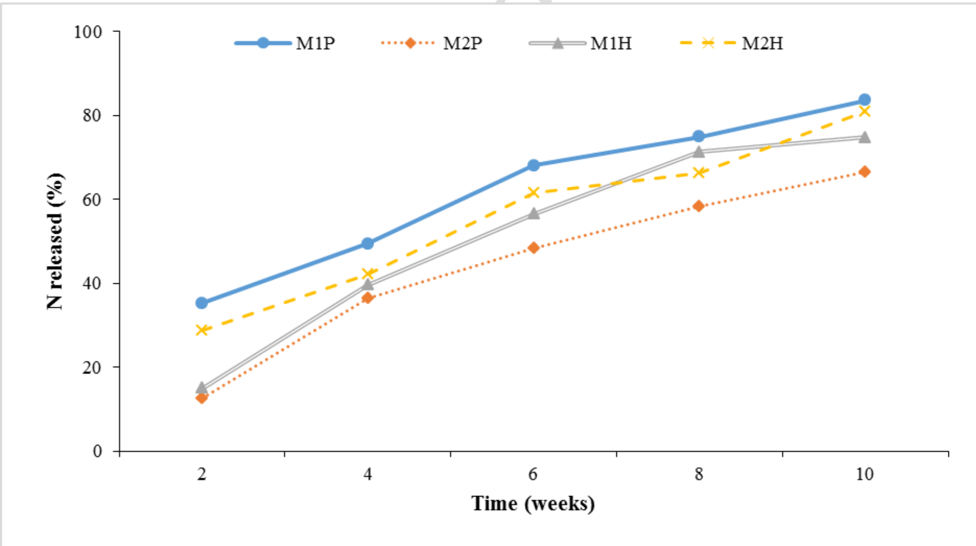

Figure 4: Proportion of nitrogen released from different composts over time

Comment [H13]: Idem.

***M1P** =Compost in pit with 75% SCB +20% OM+5% Ash, **M2P**=Compost in pit with 95% SCB +5% OM.*
***M1 H**=Compost in heap with 75% SCB +20% OM+5% Ash, **M2 H**=Compost in heap with 95% SCB+5% OM*

Mineralization of available phosphorus

During the first four weeks, the release of available ~~phosphorus~~ P was slow. None of the compost released 50% of its available ~~phosphorus~~P.

~~It was only a small difference in P release between the composts after 10 weeks~~ Within 10 weeks, 72.72%; 69.17%; 68.47% and 67.68% of available ~~phosphorus~~ P were released from M1P, M2P, M1H and M2H composts giving and average loss during the 10-week period of 69.5%.

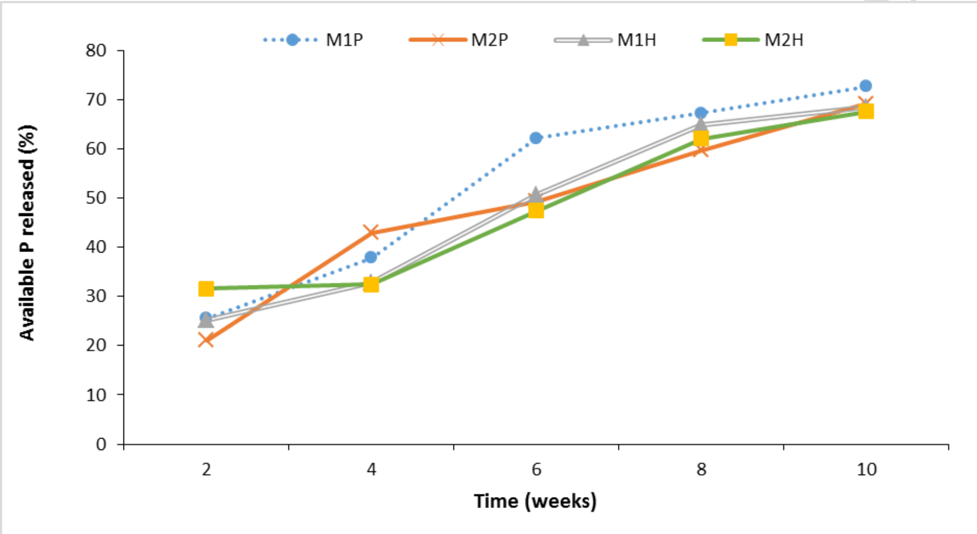

Figure 5: Proportion of available phosphorus from different composts released over time

M1P *=Compost in pit with 75% SCB +20% OM+5% Ash,* ***M2P****=Compost in pit with 95% SCB +5% OM.*
M1 H*=Compost in heap with 75% SCB +20% OM+5% Ash,* ***M2 H****=Compost in heap with 95% SCB+5% OM*

Mineralization of potassium

Comment [H14]: Idem.

In this study, ~~potassium~~ K mineralization was rapid as early as the second week for M1P and M2P compost, which released 56.98% and 52.02% of ~~potassium~~ K, respectively. The average loss in ~~potassium~~ K during the 10-week period was 77.3%.

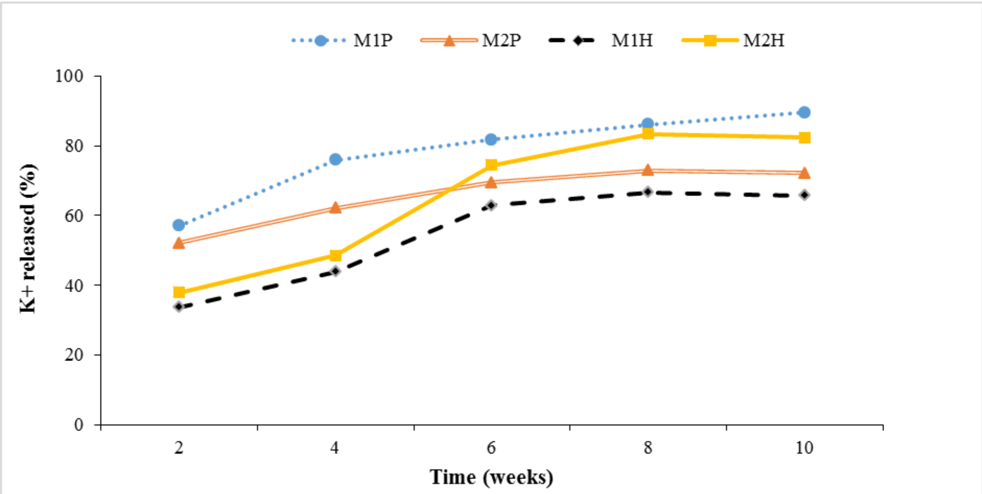

Figure 6: Proportion of potassium released from different composts released 10 weeks

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M1P *=Compost in pit with 75% SCB +20% OM+5% Ash,* ***M2P****=Compost in pit with 95% SCB +5% OM.*
M1 H*=Compost in heap with 75% SCB +20% OM+5% Ash,* ***M2 H****=Compost in heap with 95% SCB+5% OM*

Mineralization of carbon

The release of ~~carbon~~ C from the different composts ranged~~s~~ from 18% to 35% in the second week of the experiment. Only the composts M2H and M1H released more than 50% of the ~~carbon~~ C during the first 6 weeks. After10 weeks, the compost M2H had the highest release of ~~carbon~~ C and for this compost 84.2% of the ~~carbon~~ C was released The compost M2P had the lowest loss of ~~carbon~~ C and this compost lost 58.4% of its ~~carbon~~ C after 10 weeks. The compost lost in average 69.~~,~~0% of its initial value during the 10 weeks' period.

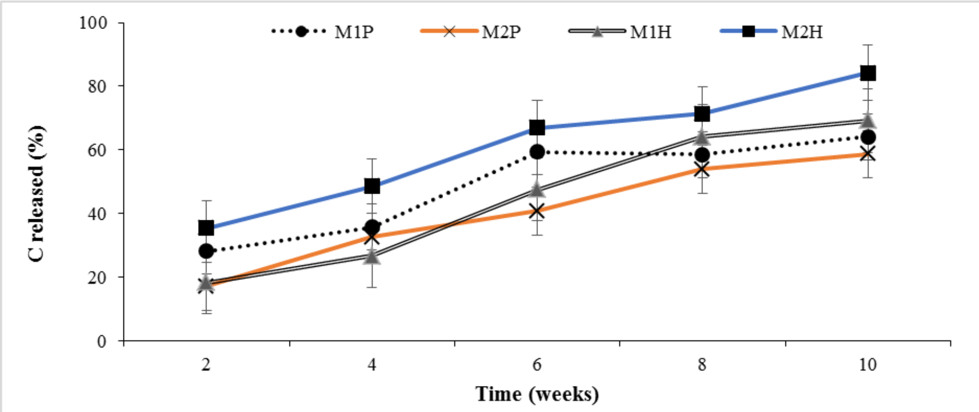

Figure 7: Proportion of total carbon from different composts released over time

M1P *=Compost in pit with 75% SCB +20% OM+5% Ash,* ***M2P****=Compost in pit with 95% SCB +5% OM.*
M1 H*=Compost in heap with 75% SCB +20% OM+5% Ash,* ***M2 H****=Compost in heap with 95% SCB+5% OM*

Comment [H16]: Idem.

Effects of composts on millet grain yield and biomass

Analysis of variance showed significant effects of treatments on grain and biomass yields (P=<.001). The highest grain yields were obtained with the 1 t ha^{-1} and 1.5 t ha^{-1} doses of the M1P compost. This compost applied at the 1 t ha^{-1} dose increased the grain yield by 652 kg ha^{-1} (105.2%) compared to the control.

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For biomass yield, only M1P compost at 1 t ha $^{-1}$ significantly increased the yield compared to the control (1,377 kg ha $^{-1}$).

Table 4: Mean yield in grains and in stover of HKP millet according to treatments and sites

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Treatments	**yield (kg ha^{-1})**	
	Grain	**Stover**
Control	620 a	1776 a
1t ha^{-1} M_1P	1272.5 e	3153 b
1.5t ha^{-1} M_1P	1127.5 e	2836 b
1t ha^{-1} M_2P	856 cd	1500 a
1.5t ha^{-1} M_2P	790 bcd	1565 a
1. ha^{-1} M_1H	832.8 bcd	1563 a
1.5t ha^{-1} M_1H	871.8 cd	1635 a

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1t~~.~~ ha^{-1} M_2H	692 abc	1835 a
1.5t~~.~~ ha^{-1} M_1H	685 ab	1517 a
Probability	**<.001**	**<.001**
CV	**12.1**	**25.3**

M1 P *= Compost in pit with 75% SCB +20% OM+5% Ash,* ***M2P*** *= Compost in pit with 95% SCB +5% OM.*

M1 H *= Compost in heap with 75% SCB +20% OM+5% Ash,* ***M2 H*** *= Compost in heap with 95% SCB+5% OM.*

Same letters within columns indicate no significant differences

Discussions

The study assessed the decomposition and nutrient mineralization of four types of compost based on the biomass of *Sida cordifolia* under field conditions and their effects on millet yield. In general, the composts are of good quality because their ~~nitrogen~~ N and ~~potassium~~ K contents were much richer than in the soil they are supposed to fertilize. Soil analysis showed that the soil ~~nitrogen~~ N content was 0.016%, while the composts had a ~~nitrogen~~ N content of between 0.8 and 1.1% (Table 2). The low soil ~~nitrogen~~ N content indicates that the soil has a very low capacity to supply ~~nitrogen~~N.

The decomposition study showed that between 50 and 80% of the plant nutrients contained composts in the were released within the 10 weeks' period. This shows that these composts can be used a fertilizer as this period corresponds to the period with high nutrient demand of the cereal crops. In this study pearl millet flowered after 8.5 weeks (Figure 2b). Cereals take up most of the nutrients during the period from sowing to flowering. There was a gradual release of plant nutrients during the 10 weeks' period even though there was considerable variation in soil water during the period of the experiment (Figure 2). Even though these composts may not release their plant nutrients very early in a growing season, this may not be of great importance since it has been previously shown that fertilization in pearl millet in Niger can be delayed until 20 days after sowing without causing a yield penalty (Hayashi et al. 2008). It is likely that nutrients reserve in the seed, are sufficient in the first days after germination.

There was a variation in release pattern of the plant nutrients contained in the composts and the weight loss did not correspond to the nutrient release. The average loss with regard to weight, ~~nitrogen~~N, available ~~phosphorous~~P, K~~potassium~~ and C~~carbon~~ was in average 59.4, 76.5, 69.5, 77.3 and 69.0%, respectively. The weight loss of the composts was therefore less than the nutrients loss. The mechanisms causing weight loss and nutrient loss are different explaining there was discrepancy between weight loss and nutrient loss. The losses were

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Comment [H20]: Which corresponds to how many days?

highest for ~~nitrogen~~ N and K~~potassium~~. This can be explained by the fact that these cations (NH^{4+} and K^{+}) are easily leached from the soil while the particles in the compost are likely to be more resistant degrading forces. Because, NH^{4+} and K^{+}~~Ammonium and potassium~~ are not strongly chemically bound in the soil~~.~~ (Andrist-Rangel et al. 2007). ~~Ammonium and potassium are therefore strongly exposed to leaching~~

The heap composts have higher weight losses than the composts produced in the pit as the heap composts lost half its weight in 3.12 weeks while the corresponding figure for pit compost was 4.83 weeks. The physical structure and resistance to degrading forcing may not be the same in pit and heap composting as there will be difference in temperature and water conditions between pit and heap composting.

The ~~carbon~~ C loss during the 10 weeks' period was in average 69%. Even though the ~~carbon~~ C decomposition will still continue for a few weeks, it is likely that not all the carbon supplied in the compost will be lost. The remaining carbon is of great value for building the soil organic carbon content.

Comment [H21]: And what does it cause?

The composts produced can supply considerable amount of ~~nitrogen~~N. If the composts are applied a micro dosing in the form of 100 g compost $hill^{-1}$, the amount of compost applied will be 1000 kg ~~/~~ha^{-1} if there are 1000 hills ha^{-1} as commonly practiced in Niger. The average ~~nitrogen~~ N content in the compost was 0.90% corresponding to ~~n nitrogen~~N input of 9 kg ~~N~~ ha^{-1}. The litter bag study showed that 78.5% was released during the first 10 weeks. If this is taken into consideration the amount of easily available N will be 6.8 kg ~~N~~ ha^{-1}. The recommendation by (Tabo et al. 2007) is to apply 2 g diammonim phosphate $hill^{-1}$ corresponding to an N input of 3.6 kg ~~N~~ ha^{-1}. It is therefore clear that the N input from micro dosing of compost will be higher than the N input from micro dosing diammoium phospate.

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With regard to ~~phoshorous~~ P input the *Sida cordifolia* compost can also provide a substantial amount of P. The average available ~~phosphorous~~ P content was 11.0 mg ~~p~~ kg^{-1} compost (Table 2). Application of 1000 kg compost ha^{-1} (100 g per hill) will apply 7.6 kg ~~P~~ ha^{-1} (1000kg*0.011*69.5%) (69.5% is percent P released during the decomposition process) (Figure 5). ~~—~~Application of 2 g diammonim $hill^{-1}$ as fertilizer will apply 4.0 P ha^{-1} (20 kg fertilizer ~~/~~ha*46% P_2O_5*0.436) which is almost half the ~~amound~~ amount of ~~phosphorous~~ P appliqued with 100 g compost $hill^{-1}$.

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The study also showed that ~~a compost~~compost containing 95% and 5% manure can produce a compost of good quality as shown in the nutrient analysis of compost (Table 2). This is an

Comment [H22]: ????

indication that it will be easy to produce a compost were the main ingredient is *Sida cordifolia*~~SC~~ since ~~SC~~ it is easily available in the agro-pastoral areas in Niger. This can also stimulate the farmers to use *Sida cordifolia* as a weed control. The C/N ratio of the four composts were close to 10 which is ideal value for a compost according to the norms of FAO. A C/N ratio of 10 implies that this is ~~a~~ well decomposed compost than can be applied to the soil without causing ~~nitrogen~~ N immobilization.

The application of composts improved millet yield over controls. The largest grain and biomass yield increase was achieved with M1P compost. The study of the mineralization showed that this compost released 83.6% of N, 72.72% of the available ~~phosphorus~~ P and 89.5% of the ~~potassium~~ K in 3 months. This could explain the increase in yield seen with this compost. Improved crop yield resulting from composting may be related to better crop development due to increased availability of nutrients from compost (Suge et al. 2011, Badar et al. 2015). Studies by (Esse et al. 2001, Fatondji et al. 2009) have also highlighted improved grain and biomass yields of millet under organic fertilization due to the progressive availability of nutrients for plants. In addition, M1P compost was the richest in nutrients compared to other composts. The dose of 1t. ha^{-1} compost M1P ~~is~~ was equivalent to the application of 1.11g N per pouch corresponding to 11.1 kg of N ha^{-1} calculated on the basis of the density of the seedling of 10,000 feet / ha. This compost is also richer in ~~organic matter~~OM (21.21%) and ~~carbon~~ C (12.31% ?). The use of this compost could durably improve the physical properties of the soil. (Bationo et al. 2007) reported that soil organic carbon is a sustainable land management index.

Conclusion

The study show~~s~~eds that the composts produced from *Sida cordifolia* are rich in plant nutrients and the plant nutrients were release gradually after incorporation in the soil. The weight loss of the composts were in average 59.4% during the 10-week test period while the corresponding release of N, P, and K was in 76.5, 69.5, and 77.3 respectively. This show that the release of these nutrients are well synchronized with nutrient demand in pearl millet as this crop reached flowering after 8.5 weeks. The plant nutrient release from the composts were highest for ~~nitrogen~~ N and ~~potassium~~ K as these plant nutrients are not strongly chemically bound in the soil. The composts can be a good source of plant nutrients as 1000 kg compost ha^{-1} applied as micro dosing will apply more ~~nitrogen~~ N and ~~phosphorous~~ P than applied in 2 g diammonium phosphate hill^{-1} corresponding to 20 kg DAP ha^{-1}. The *Sida cordifolia* mulch will over time improve soil ~~organic matter~~OM a considerable amount of

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~~carbon~~ C remained at the end of the test period. Use of *Sida cordifolia* for compost production will not only increase soil fertility, but will also stimulate the farms to cut this invasive weed species.

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