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Management of available phosphorus in tropical ferruginous soils through the application of « Neyma » compost in the northern Sudanese zone of Burkina Faso

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ABSTRACT: The lack of available phosphorus in Burkina Faso's tropical ferruginous soils led us to produce an organic fertiliser called «Neyma compost» using local materials. The Fischer block system of 4 treatments with 3 replicates was implemented during the 2023 growing season at the Kamboinsé Centre for Environmental, Agricultural and Training Research to evaluate the performance of compost on the availability of assimilable phosphorus in cowpea crops. The treatments were the control (T0); 2 t/ha of Neyma compost incorporated during ploughing (T1); 2 t/ha of Neyma compost applied to the seed holes 15 days after sowing (T2) and 1 t/ha of Neyma compost incorporated during ploughing followed by 1 t/ha applied to the seed holes 15 days after sowing (T3). The objectives of the study were to evaluate the rate of available phosphorus in soils according to application methods, determine the most efficient application method in terms of available phosphorus content, and determine the soil properties that control phosphorus availability. The results showed that the assimilable phosphorus content was improved by approximately 21% overall through the application of Neyma compost, with the assimilable phosphorus content varying from 3.5 ppm to 6.1 ppm under the different compost application methodsThe greatest improvement in assimilable phosphorus content (56%) was achieved with the T1 application method. The availability of phosphorus varied according to the physical and chemical parameters of the soil. The methods of application and doses of Neyma compost were the main factors influencing the availability of phosphorus in the soil. Neyma compost may be a promising alternative for sustainable soil management in Burkina Faso by small-scale producers.

KEYWORDS: Neyma compost, management, available phosphorus, Burkina Faso.

1 INTRODUCTION

In tropical soils, like nitrogen and potassium, phosphorus plays a crucial role in plant nutrition and agricultural productivity. It is involved in several physiological functions and promotes nitrogen fixation by plants ([1], [2]). However, the soils of Burkina Faso, dominated by leached tropical ferruginous soils ([3], [4], [5]) are deficient in available phosphorus, as are tropical soils in general ([6], [7], [8]). Phosphorus has variable chemical speciation ([9], [10]), which can influence its accessibility to crops. According to [11], the proportion of phosphorus in its chemical forms that can be assimilated by crops is not widely available in soils, due to its strong interactions with soil colloids and the low solubility of phosphate minerals ([12]). According to [13], up to 98% of total phosphorus is inaccessible to plants. This deficiency is a constraint likely to limit the agricultural productivity of tropical soils ([14], [15]). This limiting factor may influence food security, which is the main challenge targeted by many leaders in semi-arid countries.

In order to correct the deficiency of assimilable phosphorus in tropical soils, phosphate soil improvers and/or synthetic phosphate fertilisers have been used, usually in combination ([6], [16]). Numerous studies have shown that natural phosphates have low solubility ([17], [18]), which limits their direct application by many growers. They are often incorporated into composting substrates to improve their solubility ([19]). Research has shown that adding rock phosphate to basic composting substrates improves the phosphorus content of the compost, but influences the quality of the organic matter [18]. Enriching mature compost with natural phosphate can be an alternative way of obtaining high-quality organic compost capable of improving the soil's assimilable phosphorus content.

On the other hand, high-solubility phosphate fertilisers have been used to improve soil fertility in terms of available phosphorus ([20]), but can lead to a long-term deterioration in soil fertility. A variety of composts have also been used in Burkina Faso to improve the soil's pool of available phosphorus by many farmers, but with limited available phosphorus quality ([21]).

It is therefore necessary to find an ecological intensification alternative to improve phosphorus availability in tropical ferruginous soils in Burkina Faso for sustainable agricultural production. As a result, compost from the biodigester has been enriched with rock phosphate to enhance the value of these two local products and to produce an improved organic fertiliser known as « Neyma » compost for the efficient management of tropical soils in general and Burkina Faso in particular. Several methods of applying this compost will be applied in order to assess their performance in improving the assimilable phosphorus content of soils. The general objective of this study is to understand the dynamics of assimilable phosphorus in tropical soils under the effect of different methods of applying « Neyma » compost to cowpea crops. Specifically, the aim was (i) to assess the rate of assimilable phosphorus as a function of the different methods of applying « Neyma » compost to the soil, (ii) to determine the most efficient method of applying « Neyma » compost in terms of the availability of assimilable phosphorus in the soil and (iii) to determine the edaphic properties controlling assimilable phosphorus in the soil.

2 MATERIALS AND METHODS

2.1 SITE DESCRIPTION

The study was conducted during the 2023 agricultural season at the Centre de Recherches Environnementales, Agricoles et de Formation de Kamboinsé of the Institut de l'Environnement et de Recherches Agricoles. The centre is located in Kamboinsé on the Ouagadougou-Kongoussi axis on National Road No. 22, north of the Ouagadougou municipality in the Centre region. The geographical coordinates of the site are latitude: 12° 27'10.26"N and longitude: 1° 32'10.88"W.

Its climate is North Sudanian, characterised by a long dry season and a short rainy season. A total of 737.4 mm of rainfall spread over 47 days was received during the 2023 wet cropping season. The area is characterised by heterogeneous soils, dominated by leached tropical ferruginous soils ([22]). At a depth of 0-30 cm, the soils have a silty-sandy texture (52% sand, 31% silt and 17% clay), a slight acidity (6.8), a low bulk density (1.5) and a low level of organic matter (0.5%). In addition, they are on average low in assimilable phosphorus (5 ppm), nitrogen (434 ppm), available potassium (56 ppm) and average cation exchange capacity (11 meq/100 g) ([23]). The physico-chemical characteristics are presented in Table 1. Their interactions can influence the availability of assimilable phosphorus in the soil.

Table 1. Physicochemical characteristics of cowpea-grown soils

Parameters		Average	Extents
Physics	Bulk density (g/cm³)	1,5±**0,1**	1,4-1,6
	Clay (%)	17±10	6-39
	Silt (%)	31±17	14-63
	Sand (%)	52±**25**	10-76
Chemicals	Organic matter (%)	0,5±**0,2**	0,3-0,8
	pH	6,8±0,3	6,3-7,3
	Total nitrogen (ppm)	434±**125**	285-680
	Available phosphorus (ppm)	5±1	2-7
	Available potassium (ppm)	56±17	18-79
	Total iron (ppm)	**4329±3414**	**1087-10760**
	Cation exchange capacity (meq/100 g)	11±5	6-20

Source: Field data; BAZEMON, 2023

2.2 EXPERIMENTAL SET-UP

The experimental set-up was a completely randomised Fisher block design covering an area of 210 m^2 (15 m x 14 m) and consisting of 4 treatments with 3 replications. The individual plots covered an area of 12 m^2 (4 m x 3 m). The aisles between the blocks and treatments were 1 m. The different treatments were T0: Absolute control; T1: 2 t/ha of « Neyma » compost added during plowing; T2: 2 t/ha of « Neyma » compost applied to the holes 15 days after sowing and T3: 1 t/ha of « Neyma » Compost ploughed in followed by 1 t/ha planted 15 days after sowing. These doses were chosen on the basis of previous work.

2.3 PLANT MATERIAL AND FERTILISATION

The plant material used was the cowpea "Komcallé", with a sowing-maturity cycle of 60 days and an upright plant habit, with a potential grain yield ranging from 1.5 to 2 t/ha. The fertiliser used was « Neyma » compost. The « Neyma » compost was made by enriching 900 kg of compost from the biodigester with 100 kg of Burkina phosphate, which was homogenised, moistened, windrowed and covered with a plastic sheet for 10 days, with periodic turning for 3 days. After the 10 days of covering, the compost was air-dried in the shade for a week, then sieved using a 5 cm mesh sieve. A sample was analysed, and its agronomic characteristics are presented with international standards in Table 2.

Table 2. Chemical characteristics of « Neyma » compost

Parameters	Units	Values	FAO standard	AFNOR standard NFU 44- 051
pHeau	-	7,3	7-8	6-8
Organic matter	%	41,5	10-30	>20
Rapport C/N	-	17,5	10-15	>8
Total nitrogen	%	1,4	0,4-0,5	< 3
Total phosphorus	%	1,3	0,1-1,6	< 3
Total potassium	%	1,5	0,4-2,3	< 3

2.4 CULTURAL OPÉRATIONS

The experimental plot underwent shallow ploughing using a 20-horsepower sprayer before the trial was set up. Ploughing was followed by harrowing to level the plot. After harrowing, a wedge plough was used to mark out the rows of seedlings, which were planted at a distance of 80 cm between rows and 40 cm between seedpots at a rate of three (3) seeds per seedpot. One week after sowing, a weeding operation was carried out to keep 2 vigorous plants per stake, followed by an initial weeding. Given the 60-day sowing-maturity cycle of cowpeas, a second weeding was carried out 5 weeks after sowing.

2.5 SOIL SAMPLING AND CHEMICAL ANALYSIS

A total of 12 composites soil samples for all treatments were taken from a depth of 0-30 cm using a hand auger, 4 samples before planting, 4 samples 45 days after sowing and 4 samples after harvesting. Composite samples were taken from replicates of the same treatments. Analyses were carried out at the laboratory of the National Soil Office (BUNASOLS) in Burkina Faso to determine the following physico-chemical parameters:

- pHwater was measured using an electronic pH meter ([24]);
- 3 fraction particle size distributionbased on the international method adapted to the "Robinson Khöln" pipette ([25]);

Cation exchange capacity was determined using the silver thiourea centrifugation method, based on the extraction of cations with a silver thiourea solution. After centrifugation, the cation exchange capacity (CEC) was measured directly by atomic absorption spectrophotometer. Organic carbon by [26] method, which consists of oxidising the soil sample with a mixture of potassium dichromate and sulphuric acid, assuming that the oxygen consumed is proportional to the carbon to be measured. And the rate of matter was determined by the following formula: Organic matter= C (%) x 1.72;

Available phosphorus using the Bray-I method. This combines the extraction of phosphorus in an acid medium with the complexation, by ammonium fluoride, of the aluminium bound to the phosphorus [27]; the determination was carried out by colorimetry with a spectrophotometer.

Available potassium was determined using the method of [28], which involves measuring potassium in a suspension of 1g of soil per 15 ml of ammonium acetate using a flame photometer.

2.6 STATISTICAL ANALYSIS

The various data obtained were entered using Excel 2019 and subjected to analysis of variance (ANOVA). The Fischer test was used to separate the means when there was a significant difference at the 5% probability threshold, using XLSTAT 2025 software. The correlation matrix was used to determine the various soil factors correlated with soil available phosphorus.

3 RESULTS

3.1 EFFECT OF « NEYMA » COMPOST APPLICATION METHODS ON THE AVAILABILITY AND VARIATIONS IN THE LEVELS OF ASSIMILABLE PHOSPHORUS IN SOILS.

Figure 1 shows that, on average, the use of « Neyma » compost (CN) improved the availability of assimilable phosphorus by around 21% compared with the level in soils without « Neyma » compost (SCN).

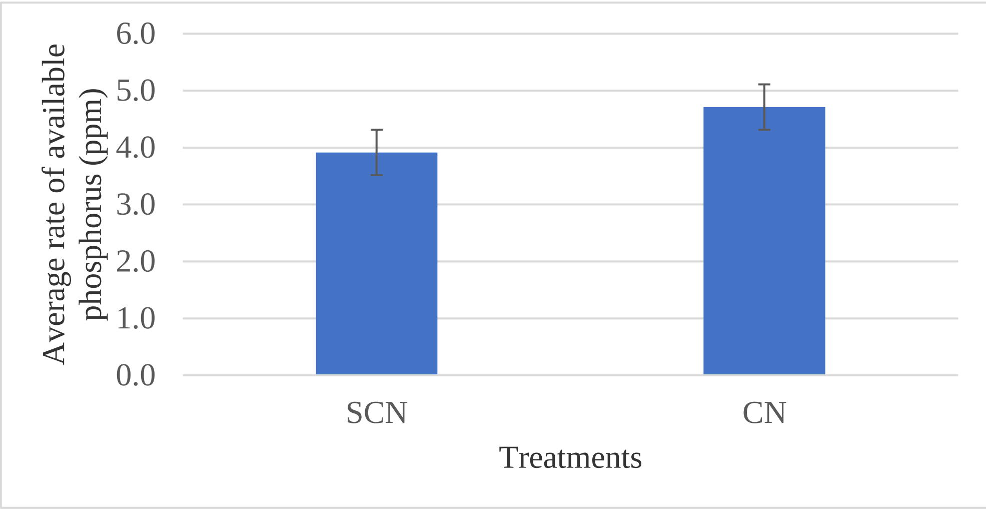

Fig. 1. Effect of « Neyma » compost on the average assimilable phosphorus content of the soil

Legend: SCN: without « Neyma » compost; CN: « Neyma » compost and ppm: parts per million.

Figure 2 shows that in soils without the addition of « Neyma » compost (SCN), the assimilable phosphorus content fell progressively under cultivation. On the other hand, with the addition of « Neyma » compost, the assimilable phosphorus content of the soil fell by around 34% 45 days after sowing and 27% after harvesting, compared with the initial soil level (5.9 ppm).

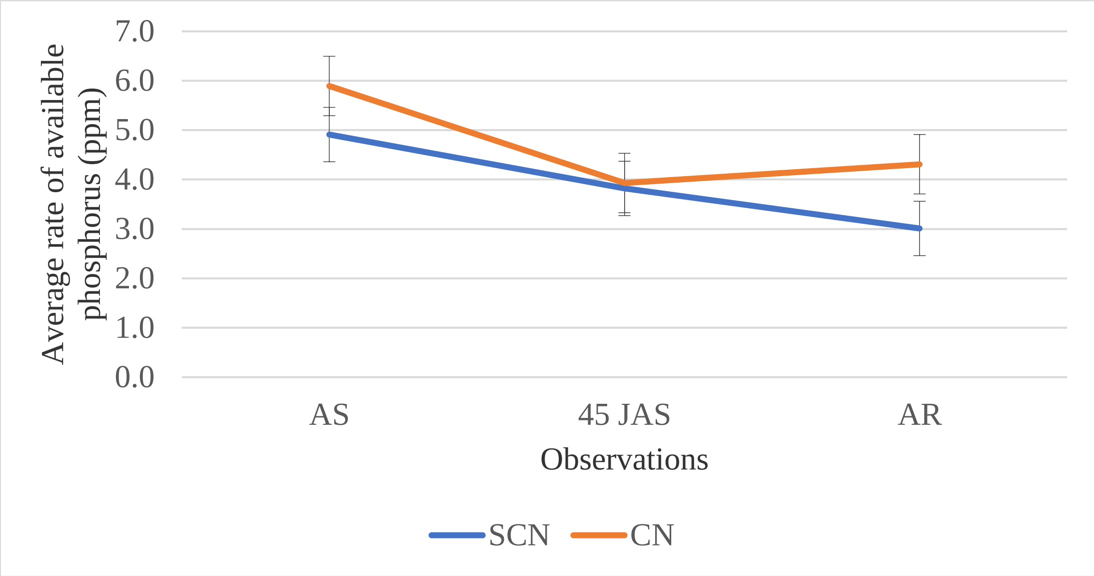

Fig. 2. Variation in the average level of assimilable phosphorus in the soil under cultivation

Legend: AS: before sowing; JAS: days after sowing; AR: after sowing; SCN: without « Neyma » compost; CN: « Neyma » compost and ppm: parts per million.

The results (Figure 3) showed that the average level of assimilable phosphorus in the soil varied from 3.5 ppm when « Neyma » compost was applied at a rate of 2 t/ha to the stakes 15 days after sowing (T2) to 6.1 ppm when it was applied at a rate of 2 t/ha spread uniformly during ploughing (T1). Only the average content of available phosphorus under the application of compost at a rate of 2 t/ha to the stakes 15 days after sowing (T2), was lower than that of the control soils (T0). In fact, the application of « Neyma » compost at a rate of 2 t/ha during ploughing (T1) improved the soil's assimilable phosphorus content by an average of around 56% compared with control soils (T0). In addition, the fractioned application of « Neyma » compost at a rate of 1 t/ha spread uniformly during ploughing, followed by 1 t/ha in the poquets 15 days after sowing, increased the level of assimilable phosphorus in the soils by around 15% compared with the level in the control soils (T0).

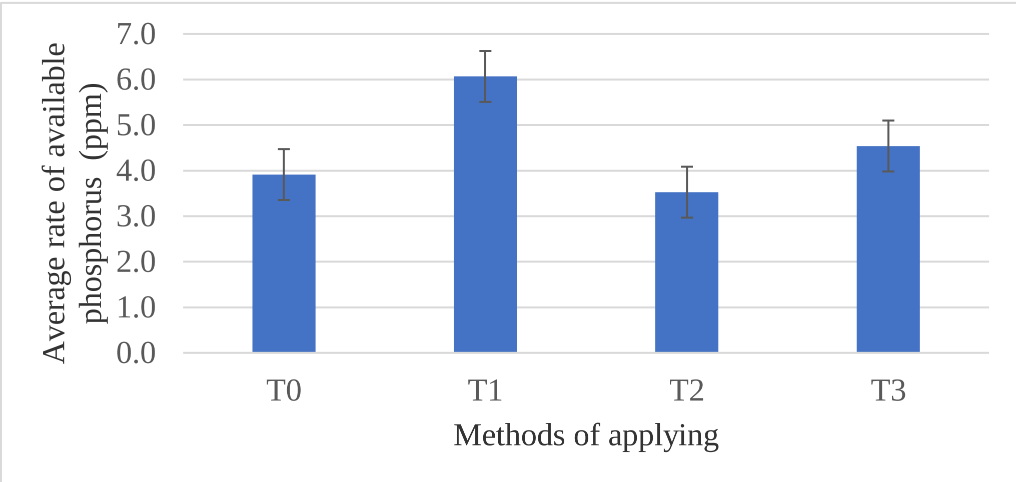

Fig. 3. Effect of « Neyma » compost on the average assimilable phosphorus content of the soil

Legend: T0: Absolute control; T1: 2 t/ha of « Neyma » compost added during plowing; T2: 2 t/ha of « Neyma » compost applied to the holes 15 days after sowing and T3: 1 t/ha of « Neyma » Compost ploughed in followed by 1 t/ha planted 15 days and ppm: parts per million

During the observations, the analysis of variance (Table 3) revealed no significant difference in the level of available phosphorus in the soils before sowing (p=0.57), 45 days after sowing (p=0.32) and after harvesting (p=0.54). Assimilable phosphorus levels were relatively higher before sowing (6.5 ppm), 45 days after sowing (5.6 ppm) and after harvest (6.1 ppm) when 2 t/ha of « Neyma » compost was spread uniformly during ploughing (T1). In addition, the low level of assimilable phosphorus in the soil varied relatively according to the input methods used during the soil sampling periods. It was obtained in the control soils (T0) before sowing (4.9 ppm), under the application of « Neyma » compost at a dose of 2t/ha to poquets 15 days after sowing (T2) for soil sampling 45 days after sowing (2.1 ppm); then treatments T0 and T2 for soil sampling after harvesting (3.0 ppm).

It can be seen that the sharp drop in the level of assimilable phosphorus in the soil under cultivation was observed under the T2 application method; on the other hand, the slight drop in the level of assimilable phosphorus was observed under the T1 application method. However, the assimilable phosphorus content of the soil was intermediate under the split application of « Neyma » compost at a rate of 1 t/ha spread uniformly during ploughing, followed by 1 t/ha in the stakes 15 days after sowing (T3).

Table 3. Effect of « Neyma » compost application methods on variations in soil phosphorus levels

Input methods	**Rate of available phosphorus before sowing (ppm)**	**Assimilable phosphorus level 45 days after sowing (ppm)**	**Post-harvest assimilable phosphorus levels (ppm)**
T0	**4,9**	3,8	3,0
T1	**6,5**	**5,6**	**6,1**
T2	5,5	**2,1**	3,0
T3	5,7	4,1	3,9
Probability	**0,57**	**0,32**	**0,54**
Meaning	**I**	**I**	**I**

Legend: ppm: parts per million; I: insignificant; T0: Absolute control; T1: 2 t/ha of « Neyma » compost added during plowing; T2: 2 t/ha of « Neyma » compost applied to the holes 15 days after sowing and T3: 1 t/ha of « Neyma » Compost ploughed in followed by 1 t/ha planted 15 days

3.2 Edaphic Properties Controlling The Availability Of Assimilable Phosphorus In Soils

The physico-chemical characterisation of the soils showed that the availability of assimilable phosphorus is controlled by numerous edaphic properties (Table 4). Two groups of soil properties were found to control variations in available phosphorus. Firstly, those properties for which an increase in their values leads to a decrease in the level of assimilable phosphorus in the soil, and vice versa.

These interactions are indicated by relatively high negative correlation coefficients. Among these edaphic properties, assimilable phosphorus shows a strongly negative correlation with apparent density (r= - 0.61), sand content (r= - 0.59) and cation exchange capacity (r= - 0.69). On the other hand, there are soil properties for which an increase in their values leads to an increase in the level of assimilable phosphorus in the soil.

These interactions were indicated by highly positive correlation coefficient values. Assimilable phosphorus, however, shows a strong positive correlation with clay (r= 0.65), silt (r= 0.50), organic matter (r= 0.55), pH (r= 0.57) and available potassium (r= 0.80).

Table 4. Correlation between soil physicochemical properties and available phosphorus

Properties	Da (g/cm³)	A (%)	L (%)	S (%)	MO (%)	pH	N (ppm)	Pa (ppm)	Kd (ppm)	Fe (ppm)	CEC (méq/ 100 g)
Da (g/cm³)	**1**	-0,92	-0,94	0,99	-0,92	-0,43	-0,21	**-0,61**	-0,51	-0,38	0,70
A (%)	-0,92	**1**	0,75	-0,90	0,77	0,41	0,30	**0,65**	0,54	0,23	-0,54
L (%)	-0,94	0,75	**1**	-0,97	0,92	0,40	0,04	0,50	0,44	0,43	-0,66
S (%)	0,99	-0,90	-0,97	**1**	-0,92	-0,43	-0,14	**-0,59**	-0,51	-0,38	0,66
MO (%)	-0,92	0,77	0,92	-0,92	**1**	0,57	0,32	**0,55**	0,41	0,54	-0,77
pH	-0,43	0,41	0,40	-0,43	0,57	**1**	0,41	**0,57**	0,35	0,43	-0,55
N (ppm)	-0,21	0,30	0,04	-0,14	0,32	0,41	**1**	0,47	0,30	0,69	-0,30
Pa (ppm)	**-0,61**	**0,65**	**0,50**	**-0,59**	**0,55**	**0,57**	0,47	**1**	**0,80**	0,35	**-0,69**
Kd (ppm)	-0,51	0,54	0,44	-0,51	0,41	0,35	0,30	**0,80**	**1**	0,32	-0,36
Fe (ppm)	-0,38	0,23	0,43	-0,38	0,54	0,43	0,69	0,35	0,32	**1**	-0,364
CEC(méq/100 g)	0,70	-0,54	-0,66	0,66	-0,77	-0,55	-0,30	**-0,69**	-0,36	-0,36	**1**

Legend: Pa: available phosphorus; Da: bulk density; OM: organic matter; pH: hydrogen potential; N: total nitrogen; Kd: available potassium; CEC: cation exchange capacity; A: clay; L: silt; S: sand; Fe: total iron; ppm: parts per million; meq: milliequivalent and %: percentage

4 DISCUSSION

4.1 EFFECT OF « NEYMA » COMPOST APPLICATION METHODS ON THE AVAILABILITY AND VARIATIONS IN THE LEVELS OF ASSIMILABLE PHOSPHORUS IN SOILS

The improvement in the soil's assimilable phosphorus content by approximately 21% through the addition of 'Neyma' compost can be explained by its quality and agronomic performance. The work of [29] also found a significant availability of assimilable phosphorus in the soil under the application of compost alone at an average rate of 6.22 ppm which is much higher than that found under the application of « Neyma » compost alone, which is 4.7 ppm. This difference could be explained by the quality of the composts and the doses applied. Some authors have shown that inputs of organic resources can improve soil fertility in terms of available phosphorus ([30], [31]). For [32], the characteristics of phosphorus transfer kinetics from organic compounds to the soil solution can explain the level of available phosphorus in soils. According to [33], assimilable phosphorus is one of the chemical indicators of soil fertility that can vary rapidly over time.

Many authors have also noted that compost is an essential resource for improving the flow of available phosphorus in soils ([34], [29]). The nature of fertilisers and soil management methods are important factors likely to influence soil assimilable phosphorus levels ([35], [36]). According to [34], several mechanisms can explain the availability of assimilable phosphorus in the soil, including the intensity of mineralisation of organic matter, the fixation mechanisms for this element, the nature and quality of the compost used, as well as the nature of the soil and climatic conditions. Similarly, the work of [37] adds that the dose of fertilisers applied contributes to fluctuations in the assimilable phosphorus content of soils.

In soils where no « Neyma » compost has been added, the gradual fall in the level of assimilable phosphorus over time can be explained by continuous export of phosphorus by the cowpea. These results show that the use of tropical soils without exogenous phosphorus sources contributes to their continuous degradation in assimilable phosphorus. However, with the addition of « Neyma » compost, the decrease in the average level of available phosphorus 45 days after sowing, followed by a slight increase after harvesting, can be explained by the use of phosphorus during the intense activity of the microorganisms for the synthesis of their ATP molecules and the release of phosphorus after the death of certain microorganisms after harvesting. Cowpea is a legume capable of fixing atmospheric nitrogen in the soil through its roots, which are equipped with rhizobacteria ([38]; this can create acidic conditions in the soil that can lead to phosphorus precipitation and adsorption by metal oxides in the soil. The very low level of assimilable phosphorus (5.6 ppm) can be a limiting factor for crop growth ([39]). In Burkina Faso soils, many authors have found assimilable phosphorus levels below 15 ppm ([29], [2], [40]). These low levels of assimilable phosphorus can be explained by the nature of the soils and the reactivity of their mineralogical components to fertilisers. For many authors, these soils are deficient in assimilable phosphorus ([41], [42]).

[43] explains the low level of assimilable phosphorus in tropical soils by its energetic adsorption by iron and aluminium oxides, which are present in very large quantities in these soils. However, [32] found 26 ppm of assimilable phosphorus in a soil before cultivation. This difference can be explained by the way the soil was previously used. In Côte d'Ivoires soils, studies have found assimilable phosphorus levels ranging from 12 ppm to 71 ppm in soils without any inputs ([44], [45]). Similarly, [46] found assimilable phosphorus levels ranging from 5 to 13 ppm in Benin soils. This difference is thought to be linked to the

nature of the soil and the type of climate likely to favour the alteration and solubility of phosphate materials capable of releasing assimilable phosphorus into the soil solution. It was found that the level of assimilable phosphorus in the soil fell continuously over time under cultivation. This continuous drop in the soil's assimilable phosphorus content could be explained by its continuous uptake by cowpeas, as well as by the mechanisms of fixation by colloids and metallic elements in the soil.

Under cowpea cultivation, the level of available phosphorus in the soil was improved by about 56% by applying « Neyma » compost at a rate of 2 t/ha spread uniformly during ploughing (T1), followed by a split dose of 1 t/ha spread uniformly during ploughing and 1 t/ha applied in patches 15 days after sowing (T3), which increased the soil's available phosphorus by about 15%. This difference shows that the compost dose is an essential factor in improving the level of available phosphorus in the soil. The application of compost at a rate of 2 t/ha to the pots 15 days after sowing (T2) caused a reduction in the level of available phosphorus of less than 10%. This loss of assimilable phosphorus can be explained by the time and intensity of mineralisation of the « Neyma » compost, which would be linked to its quality. Authors have demonstrated that soils contain phosphorus-solubilising bacteria capable of improving the content of assimilable phosphorus in soils ([47]). The application of 2 t/ha of « Neyma » compost during ploughing (T1) and the timing of its application can promote the development of large population of phosphorus-solubilising bacteria, which can improve the flow of available phosphorus in the soil. Furthermore, for compost fractionation (T3), the dose of 1 t/ha at ploughing may be insufficient to stimulate the intense activity of phosphorus-solubilising bacteria. However, the application time for the 2 t/ha dose of compost to the seed holes 15 days after sowing (T2) may be too short to promote the intensity of these bacteria's activity. This may explain the low content of assimilable phosphorus under the T2 application method.

The variable availability of assimilable phosphorus in soils, depending on how compost is added, may also be linked to the intensity of activity of living soil organisms, capable of promoting the decomposition of organic forms of phosphorus ([31]). [48] have shown that soil macrofauna contribute to the improvement of soil richness in assimilable phosphorus. This improvement may be linked to the degradation of organic matter by these living soil organisms, releasing the phosphorus trapped and adsorbed by the latter. The « Neyma » compost has a C/N ratio of 17.5, which complies with international standards (Table 2). « Neyma » compost can be applied as a bottom dressing to take full advantage of its performance in improving the flow of assimilable phosphorus in soils. Numerous studies have shown the effect of organic fertiliser doses on soil phosphorus bioavailability ([48], [49]), but there is still a lack of studies on application dates. Among the input methods, the evaluation of the assimilable phosphorus content of the soils under cowpea cultivation during the observations showed that the available phosphorus rate remained higher before the soils were cultivated and after the harvests in the soils that had received « Neyma » compost at a dose of 2 t/ha spread uniformly during ploughing (T1). On the other hand, it was lower in soils that had received a dose of 2 t/ha in pots 15 days after sowing (T2) during cultivation; then intermediate under the fractioned application of « Neyma » compost (T3). The time and dose at which compost is incorporated into the soil can affect the quality of the soil's organic matter, which can lead to hydration of the soil, which can encourage the dissolution of phosphates. These results show that the availability of assimilable phosphorus in tropical soils can be influenced by the natural richness of these soils in this valuable fertiliser. Fractioning organic fertilisers can help mitigate the decline in soil fertility in terms of available phosphorus. Numerous authors have shown that fluctuations in soil assimilable phosphorus levels reflect land use patterns ([47]). The content of available phosphorus in the soil varied relatively depending on the methods used to apply « Neyma » compost, but no significant differences were found. These results can be explained by the small number of samples.

4.2 EDAPHIC PROPERTIES CONTROLLING THE AVAILABILITY OF ASSIMILABLE PHOSPHORUS IN SOILS

Physico-chemical characterisation of soils has shown that the level of assimilable phosphorus depends on edaphic physico-chemical properties. According to [47], variations in the availability of assimilable phosphorus reflect soil properties and use patterns. The results showed that increasing the bulk density, sand content and cation exchange capacity of the soil leads to low availability of assimilable phosphorus in the soil, and vice versa. A high bulk density and a high sand content in the soil can make the availability of assimilable phosphorus in the soil vulnerable.A high bulk density can reduce the activity of living soil organisms likely to mineralise organic matter to make available assimilable phosphorus. Work by [50] has shown that the level of assimilable phosphorus varies according to the value of bulk density. Similarly, a high sand content can encourage the loss of assimilable phosphorus through leaching or run-off in the event of high rainfall in the agro-ecological zone.

On average, the soil contains a high sand content of 52%. Soil with a high sand content has a high porosity ([51], which is likely to affect the availability of available phosphorus. Work by [6] has shown that a soil with a high sand content is low in available phosphorus. Cation exchange capacity corresponds to the soil's ability to retain exchangeable cationic elements such as potassium, sodium, calcium and magnesium. The results showed a strong negative correlation between cation exchange capacity and assimilable phosphorus. In fact, a high value for cation exchange capacity resulting in low availability of assimilable phosphorus can be explained by the presence of a large quantity of Ca^{2+} and Mg^{2+} ions, which can precipitate with the available phosphorus in the form of calcium and magnesium phosphates respectively, which are insoluble forms of phosphorus.

The work of many authors has shown that low values of cation exchange capacity lead to high levels of available phosphorus ([52], [46]). Furthermore, work by [53] in western Burkina Faso has shown that low cation exchange capacity values lead to low available phosphorus levels. This difference can be explained by the type of climate, where heavy rainfall can lead to the leaching of exchange bases and the loss of labile phosphorus through run-off.However, there is a strong positive correlation between the levels of clay, silt, organic matter, pH and available potassium, respectively, and the amount of available phosphorus in the soil. High values for these parameters increase the soil's available phosphorus content, and vice versa.Authors have shown that pH is essential for the availability or poverty of assimilable phosphorus in the soil ([54]). A pH close to neutrality leads to maximum availability of assimilable phosphorus in soils ([54]). On the other hand, an acid pH reduces the availability of available phosphorus by increasing phosphorus fixation by metal oxides ([55]). There is a strong positive correlation (0.56) between organic matter and assimilable phosphorus, showing that a high level of organic matter in the soil favours the significant availability of assimilable phosphorus. The same observation has been made in the work of numerous authors ([56]). This correlation can be explained by the capacity of organic matter to adsorb phosphorus and make it available in the soil solution after mineralisation. According to [34], the rate of assimilable phosphorus varies according to the mineralisation of organic matter.In addition to organic matter, numerous studies have shown that the level of available phosphorus in the soil increases with the level of clay and silt ([57], [58], [59]). This correlation could be explained by the capacity of these fine soil particles to adsorb assimilable phosphorus.The cultivation of these soils can lead to a strong fixing power of these particles when the soils contain high levels of clay and silt. It should be noted that this effect can vary depending on the type of clay. Clay and silt can contain iron and aluminium sesquioxides that can bind assimilable phosphorus, where an increase in pH can favour the availability of phosphorus in the soil solution.It can be seen that the level of available phosphorus in the soil also increases with the level of available potassium. This correlation can be explained by the fact that assimilable phosphorus and available potassium are almost equally important for plant nutrition. Similarly, the availability of these two macroelements in the soil can be controlled by the same soil factors. [2] have shown that this correlation increases with depth.

However, other authors have not found a correlation between the rate of available phosphorus and that of available potassium [60]. This difference is thought to be linked to the nature of the fertilisers applied, which are likely to have a variable influence on soil properties.

5 CONCLUSION

The fixation of assimilable phosphorus in soils by metal oxides and the low solubility of phosphate minerals are the main causes of the deficiency of assimilable phosphorus in tropical soils. But the nature, quality and methods of fertiliser application can also affect the availability of assimilable phosphorus. Improving the management of assimilable phosphorus in soils would require fertilisation techniques based on methods of supplying organic sources capable of provoking interactions between soil particles and its phosphorus-fixing capacity, in order to improve its availability. The general objective of this study was to understand the dynamics of assimilable phosphorus in tropical soils as a result of the use of « Neyma » compost, made from biodigester compost enriched with Burkina phosphate under cowpea cultivation. The use of Burkina phosphate and biodigester compost in the production of « Neyma » compost, made from these local substrates, improved the average level of assimilable phosphorus by around 21%. In addition, soil cultivation without the use of « Neyma » compost has led to a steady decline in the assimilable phosphorus content of the soil.

However, the assimilable phosphorus content of the soil was influenced by the way the compost was added. The greatest improvement (56%) in soil available phosphorus was obtained when « Neyma » compost was applied at a rate of 2 t/ha, spread uniformly during ploughing (T1). The assimilable phosphorus content of the soil was higher when the « Neyma » compost was applied at a rate of 2 t/ha during ploughing (T1) and lower when the same rate was applied to the poquets 15 days after sowing. The small number of soil samples affected the significance of the results for the different methods of application under crops. In addition, the study showed that an increase in clay, silt, organic matter, pH and available potassium leads to an increase in the level of assimilable phosphorus in the soil. On the other hand, bulk density, sand and cation exchange capacity are the edaphic parameters whose increased content leads to a decrease in the soil's assimilable phosphorus content, and vice versa. Organic soil fertilisation strategies using plough inputs and managing the degradation of tropical soils would make it possible to improve the availability of assimilable phosphorus and the performance of phosphate fertilisers. The T1 fertilisation method, which improved the soil's assimilable phosphorus content the most, can be used by small and medium-sized producers for sustainable soil management. Indeed, repeating the trial and applying these different fertilisation techniques based on « Neyma » compost to other crops is necessary to better understand the agronomic performance of this organic fertiliser.

DECLARATION OF COMPETING INTERESTS

No competing interests have been reported.

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