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RESEARCH PAPER

Assessment of the effect of the input of cattle and small ruminant manure and Tilemsi Natural Phosphate on the productivity of soils and crops in the Sahel: Case of the region of Mopti

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Abstract

The present study aims to contribute to the fight against the decline of soil fertility and low millet yields in the Mopti region through the application of cattle manure, and small ruminants at different doses and 300kg. ha^{-1} 3 years-1 from PNT. A Fisher block was used in the three agro-ecological zones from 2005 to 2007. The results showed that with the application of 2t. ha^{-1} an^{-1} of cattle manure and 300kg. ha^{-1} 3 years-1 of PNT obtained an increase in production of millet grain compared with the control of 57.59%, and 52.8% with the application of 5t. ha^{-1} 3years-1 of cattle manure and 300kg. ha^{-1} 3 years-1. The contribution of 2t.ha^{-1} an^{-1} manure of small ruminants and 300kg. ha^{-1} 3 years-1 of PNT allows the increase of grain yield of 60, 11% and 63, 8% with 5t.ha-13ans -1 manure of small ruminants and 300kg. ha^{-1} 3 years-1 of PNT, compared to the control. Finally, the application of 300kg. ha^{-1} 3 years-1 of PNT allows an increase in grain yield of 0 to 16%. In the second year, soil analyzes showed an increase in the pH value and soil concentration of organic matter and a decrease in the third year.

Key words: Small ruminants, cattle, production, soil

Introduction

In the countries of the Sahel, in West Africa, in particular in the region of Mopti, millet is an important food crop for the food security of the populations. Its production often represents more than 30% of the total cereal production. Millet is eaten in the form of porridge and pancakes. The protein content of different mils, and their quality, compare to that of wheat or corn. It is an energetic and nutritious food. However, in the region of Mopti, the yields of this crop are very low, and range between 200 and 500 kg per hectare. Indeed, it is generally an extensive crop, cultivated without irrigation or fertilizer. The use of mineral fertilizers and organic manure is an effective way to help restore soil fertility and increase crop yields (Bationo et al. 1998; Piéri, 1989). Mineral fertilizers are used to provide essential nutrients such as nitrogen and phosphorus. The evolution of cropping systems has brought about changes in the quantities applied (N'Diaye et al., 1994).

According to Kieft et al., 1994, mineral fertilizers in Mali are mainly used in cotton growing areas (± 75%) and irrigated rice growing areas (± 10%) with an average and effective dose of around 80 kg of nutrients per hectare. fertilized and which goes to a maximum of 300 kg per hectare. It is clear that the introduction of mineral fertilizers has increased production, but the necessary cultural measures, especially to guarantee the same productivity in the future, will be more and more necessary. In Mali, cereal growing areas that use little or no mineral fertilizers are important.

Pieri (1989) notes that while the use of fertilizers for cotton crops continues to increase, it must be recognized that the application of fertilization for dry-grown cereals is not experiencing the same boom. These are mainly millet and sorghum crops. Indeed, this situation can be explained by the extremely unfavorable price relationship that exists in Mali between mineral fertilizers and agricultural products. This weighs heavily on the cost of imported products on which production depends. However, apart from Tilemsi Natural Phosphate (PNT), Mali depends on the outside for its supply of chemical fertilizers, and this requires significant currencies which the country does not have due to its economic situation (unfavorable balance of payments) (Gerner., 1993).

Studies carried out by Bationo, 1998 demonstrated that PNT could be applied directly and that its effectiveness depends on its chemical and mineralogical composition, soil factors, and the crops grown. According to Kamara et al., 1994, research on PNT led to fairly satisfactory agronomic results in Mali. According to Veldkamp, 1991, agronomic experience showed a measurable effect of Tilemsi Natural Phosphate (PNT) from the first year of its application on the plot. PNT contains according to Bationo (1998) 12.5% of P_2O_5, (phosphorus oxide) 1.84% of citrate-soluble P, 14.4% of CaO (calcium oxide), 3.1% of fluorine (F), 2.1% aluminum oxide or alumina (Al_2O_3), 6.1% Fe_2O_3, MgO (iron and magnesium oxide), 0.37% Na_2O (sodium oxide), 0.1 % K_2O (potassium dioxide), 0.007% SiO_2 (silicon oxide), and 9.4% carbon dioxide (CO_2). The solubility of PNT is low compared to phosphate fertilizers, Diammonium phosphate (DAP) and Super Simple Phosphate (SSP), but it is a soft rock phosphate, which gives it better solubility, compared to other natural phosphates. The basic dose of 300kg.ha-1 can provide phosphate feed to crops for about three years. The neutralizing power of Tilemsi's natural phosphate is low, it has been evaluated in the laboratory at 20% compared to calcium carbonate ($CaCO_3$).

This action of PNT is very interesting, especially for crops sensitive to aluminum toxicity. Another important aspect of NTP is that the high calcium level, especially on acidic soil, is especially beneficial for legumes such as peanuts. PNT is most effective in wet areas. Its effect is mixed in dry areas (Pichot et al., 1981). Tilemsi rock phosphate will be more effective if used with organic yard manure, there will be a better effect of PNT in a rotation on legumes when applied before plowing. A background dose would be 300kg of PNT / ha every 3 years or 500kg.ha-1 every 5 years (Veldkamp et al., 1991). In general, PNT should be considered as an important local source of phosphorus for improving soil productivity in Mali.

Morel et al., 1990, find that the application of phosphate fertilizers increases the use of phosphorus by plants in soils poor in available phosphates, but decreases the use of phosphate in soils with a high level of available phosphorus. The phosphorus contained in Diammonium phosphate (DAP) and Super Simple Phosphate (SSP) is soluble. The effectiveness of such types of fertilizer is rated between 10 and 15%. It depends on the texture and acidity of the soil, the more acidic the soil, the higher the requirements for phosphate fertilizers will be. Depending on the existence of more or less intense erosion, an annual input could be more effective than a massive phosphorus input all at once and for several years.

A change in the basic recommendations available to small producers goes in the direction of reducing chemical fertilizer doses (and costs). The application of phosphorus in the pocket allows to a certain extent to limit this problem by minimizing the doses of phosphorus to be applied while having an acceptable gain in return compared to the investment. The increase in straw and millet grain yields can reach 70%. For normal and regular rainfall the risks are negligible. Moreover, the phosphorus applied but not used by crops following a bad season remains largely available for the following season.

The objective of this study was to assess the effect of the supply of manure from cattle and small ruminants and Natural Phosphate of Tilemsi on the productivity of soils and crops in the Mopti region in the Sahelian zone of Mali.

Materials and methods

Equipment

The study was conducted in the region of Mopti. The sites selected were the village of Koporo-pen in the Commune of Koporopen, in the agro-ecological zone of Séno, the village of Tougoumé, in the rural Commune of Docoumbo on the Dogon Plateau, and in the village of Madiama, in the Municipality of Madiama, in the Delta area near the bush fields. These three sites were chosen because they are both representative of the three agro-ecological zones of the Mopti region and they are accessible. The Séno corresponds to a collapsing ditch between the Mossi

Plateau and the Dogon Plateau. The plains are made up of sand and clayey sandstone topped with an armored slab. The Séno is dominated to the south by banks of hills and to the north by dunes. The whole Séno is quite contrasted in terms of soil type; there are essentially three types of soils: light sandy soils (50%), heavy clayey soils (35%) and sandy loam soils (15%) (DRSPR, 1992).

Like the rest of the Dogon Plateau, the Rural Municipality of Docoumbo is characterized by a very rugged relief, made up of a 600 m altitude massif surrounded by low areas. These are siliceous sandstones, characterized by great heterogeneity. Here and there we can see hills and rocky expanses made up of a stack of sandstone banks. The geomorphological situation of the town justifies the scarcity of cultivated soils, which represent only 22% of the total area of the circle, the rest being occupied by rocky outcrops. The land is degraded because of insufficient vegetation cover and because of runoff (DRSPR, 1992).

The commune of Madiama is located in the Central Delta of the Niger River in the sedimentary basin of the Middle Bani, which was filled in by Quaternary alluvium. The oscillations of the sea level and the climatic variations during the Quaternary caused several phases of fluvial digging and alluvialization which gave deposits very varied by their granulometry and their topographic position. According to the work of Badini, 2001, the textural series of soil types of morphopedological units listed includes: sand, silty sand, gravelly silt, sandy loam, silt, silt and clay.

The climate of the region is Sahelian, it has a dry season that extends from October to May and a rainy season from June to September. Rainfall averaged 468 mm from 1977 to 2005, with a minimum of 273 mm received in 2002 and a maximum of 643 mm in 1999 (Traoré et al., 2002). It is characterized by an annual average temperature of 29.1 ° C with a maximum in April and May and a minimum in January; by an average annual relative humidity of 44%, the maximum of which is in the months of August, September, October and the minimum in the months of January, March, April; by a minimum of six hours of sunshine per day in July, which increases to reach its maximum in February with 8 hours per day and per rainy season (Traoré et al., 2002).

Methods

The study was conducted in the region of Mopti. The three sites selected for the experiment were the agricultural research sub-station of Koporo-pen (commune of Koporo-pen) in the agro-ecological zone of Séno, the village of Tougoumé in the rural commune of Docoumbo on the Dogon Plateau and the village of Madiama in the Delta area at the level of the bush fields. These three sites were chosen because they are both representative of the three agro-ecological zones of the Mopti region and accessible. According to the Regional Agronomic Research Center of Mopti, the farmers are volunteers and they show their interest in technological innovations. The sites have the following characteristics:

The rural commune of Koporo-pen is located in Séno which, as a whole, corresponds to a collapsing ditch between the Mossi plateau and the Dogon plateau. The plains are made up of terminal continental materials (sand and clayey sandstone) topped with an armored slab. The Séno is dominated to the south by banks of hills and to the north by dunes. The study area is located in this dune area. The whole Séno is quite contrasted in terms of soil type; in fact, there are essentially three types of soil: light sandy soils (50%), heavy clayey-silty soils (35%) and sandy loam soils (15%) (DRSPR, 1992). The Sahelian-type climate includes a dry season from October to May and a rainy season from June to September. Rainfall is on average 468 mm (from 1977 to 2005), with a minimum of 273 mm received in 2002 and a maximum of 643 mm (Traore et al., 2005).

Like the rest of the Dogon plateau, the rural commune of Docoumbo is characterized by very rugged relief, made up of a 600 m altitude massif surrounded by low areas. These are siliceous sandstones, characterized by great heterogeneity. Here and there we can see hills and rocky expanses made up of a stack of sandstone banks. The geomorphological situation of the town justifies the scarcity of cultivated soils, which only represent an estimated 22% of the total area of the circle, the rest being occupied by rocky outcrops. As it stands, the land is degraded due to insufficient vegetation cover and runoff (DRSPR, 1992). The climate is characterized by a wet season from May to October and a dry season from November to April. It is characterized by an annual average temperature of 29.1 ° C with a maximum in April and May and a minimum in January; by an average annual relative humidity of 44%, the maximum of which is in the months of August, September, October and the minimum in the months of January, March, April; by a minimum of six hours of sunshine per day in July, which increases to reach its maximum in February with 8 hours per day and per rainy season (Traore, 2005).

The commune of Madiama is located in the Central Delta of the Niger River, in particular in the sedimentary basin of the Middle Bani which was filled in by Quaternary alluvium. The relatively high relief at the edge was shaped in the infracambrian sandstone of Bandiagara. The middle valley of the Bani and the Niger began to form at the start of the Quaternary with the notch of infracambrian sandstone, topped with a ferruginous breastplate, the remains of which can be found on the edges of the town. The oscillations of the sea level and the climatic variations during the Quaternary caused several phases of fluvial digging and alluvialization which gave deposits very varied by their granulometry and their topographic position. According to the work of Badini, 2001, the textural series of soil types of morpho-pedological units listed includes: sand, silty sand, gravelly silt, sandy silt, silt, silt-clay and clay.

The choice of farmer collaborators was the guiding principle in the conduct of the tests. It was carried out in a village assembly in June 2005 in the presence of agents from the local technical support service and some members of the Regional Commission for Users of Research Results (CRU). The criteria for this choice were mainly focused on the will, the availability of the producer and the accessibility of the test plot.

The experimental set-up was Fisher's block with 6 treatments in 4 repetitions in each agro-ecological zone. The area of the elementary plot was 150 m^2.

In the first year, the T0 treatment is a continuous cultivation of millet without any fertilizer input. T1 received only the dose of 300 $kg.ha_{-1}$ of PNT, per elementary plot during plowing. T3 and T4 received respectively: $2t.ha^{-1}$ yr-1 and $5t.ha^{-1}$ 3yrs-1 of cattle manure per elementary plot during plowing and the dose of $300kg.ha^{-1}$ of PNT, per elementary plot. Treatments T5 and T6 received respectively a dose of $2t.ha^{-1}$ yr-1 and 5t.ha-13yr-1 of small ruminant manure, and the dose of $300kg.ha^{-1}$ of PNT, per elementary plot during plowing. . In the second and third years, the treatments which received $5t.ha^{-1}$ $3ans^{-1}$ of manure with PNT were repeated without any other contribution. While the treatments which received $2t.ha^{-1}$ $3ans^{-1}$ of cattle and small ruminant manure were repeated without PNT.

The local variety of millet, Pennicetum glaucum (L.), well adapted to the area, was sown with several seeds (minimum 8 seeds) per pocket at a spacing of 1 m between rows and 1 m between the pockets and spaced at 2-3 plants per pocket 15 days after emergence. Sowing was done when the soils were sufficiently moist after a rainfall of at least 15 mm. The first weeding took place 15 days after emergence while the second weeding was carried out 20 days after the first. The other weeding's were done as needed.

The determination of soil organic carbon (modified Anne method) was carried out using the following principle: the carbon in the soil is oxidized by a mixture of potassium dichromate and sulfuric acid. The excess K2Cr2O7 is removed by a solution containing Fe2 + (as Mohr's salt or iron sulfate). Phosphoric acid is used to complex the Fe ion for a more distinct end point. The difference in meq. Fe used for the sample and for the blank test is used to calculate the carbon content in the soil. Elemental analyzes have shown that 97% of the carbon in the soil is oxidized in this way. The percentage of organic matter in the soil can be calculated on the basis of the carbon content according to the formula below (Nelson and Sommers, 1982). % C = 0.24 x (ab) x (13 / V) / g Where a = volume poured for the blank b = volume poured for the sample. V = volume poured for the control of the Fe solution G = weight of the sample% MO = 1.72 x% C Accuracy of 0.01. Calculation of the means of the soil element levels, and analyzes of variance for the yields were performed to determine the difference between the effects of the treatments and the Duncan's test was used to separate the means of the different treatments.

Results

Effect of adding cattle and small ruminant manure and Tilemsi Natural Phosphate on the soil

- **Effect of the input of park yard manure and Tilemsi Natural Phosphate (PNT) on the N, P2O5 and K2O levels of the soil in the commune of Koporo pen.**

The results of chemical analyzes of the soil after the first year of cultivation showed that the rate of increase of soil nitrogen relative to T0 was 66.6%, respectively for: T1, T3, and T5 (Table 1). This rate of increase was 44.4% with T2 and T4. In the second year, the rate of nitrogen increase was 9.52% with T1, 14.29% for T2, and 23.81% for T3. T4 generated a nitrogen deficit of 4.76% compared to T0. Finally, the nitrogen level in the soil did not increase with T5. The results of chemical analyzes of the soil showed in the third year a rate of improvement of nitrogen in the soil of 20% with T5. T1 yielded a nitrogen increase rate of 15% over T0, as did T3 and T4. Finally, Q2 allowed us to obtain an increase rate of 5%.

The level of P2O5 in the soil in the first year, increased with the T1, of 126.70% (52.2ppm). The improvement rate was 18.20% (7.5ppm) for both T2 and T4. The level of P2O5 in the soil was 37.86% (15.6ppm) with T3 and T5. In the second year, the level of P2O5 in the soil showed an improvement rate of 7.12% (2.6ppm) with both T1, T2 and T4. The regain rate was 48% (16.9ppm), with T3 and T5. The improvement rate of P2O5 in the soil was 7.79% (4.30ppm) with T3 and T5. The level of P2O5 in the soil also increased by 7.61% (4.20ppm), with T1 and T4. T2, however, showed no improvement in soil P2O5.

The progression of the K2O level in the soil compared to T0 was 107.2% (303.7ppm) with T1 and T4 in the first year. For T5, the K2O regain in the soil was 89.16% (252.6ppm). This rate was 80.16% (227.1ppm) with T3. Finally, for T2, the rate of increase over T0 was 53.16% (150.6ppm). However in the second year, the improvement of the K2O rate in the soil compared to T0 was 40.26% (93ppm) with T1, 27.2% (63ppm) for T2, and 70.13% (162ppm) with the T3. T4 resulted in an increase rate of K2O in soil of 48.92% (113ppm). The rate of progression of K2O in the soil was 52.8% (122ppm) for T5. In third, the K2O level in the soil experienced a deficit compared to T0 of 18.75% (62ppm) with T1, 20.84% (68.9ppm) for T2, 4.17% (13.8ppm) with T3 and 10.41% (34.4ppm) for T4. But with T5, the rate of progression of soil K2O over that of T0 was 8.35% (27.6ppm).

Table 1: Variation in the rate of nitrogen and the amounts of phosphorus and potassium in the soil according to technical itineraries in the rural commune of Koporo pen

Itineraries Techniques / Fertilizers	Years	Mil (Témoin) T_0	Mil and 300kg PNT T_1	Mil+2t/ha/an Cattle Manure and 300kgPNT T_2	Mil+5t/ha/3ans Cattle Manure and 300kgPNT T_3	Mil+2t/ha/an Small manure Ruminants and 300kgPNT T_4	Mil+5t/ha/3ans Small manure Ruminants and 300kgPNT T_5
		0 - 40	0 - 40	0 - 40	0 - 40	0 - 40	0 - 40
N total %	2005	0,009	0,015	0,013	0,015	0,013	0,015
	2006	0,021	0,023	0,024	0,026	0,020	0,021
	2007	0,020	0,023	0,021	0,023	0,023	0,024
P_2O_5 total ppm	2005	41,2	93,4	48,7	56,8	48,7	48,7
	2006	39,3	42,1	42,1	56,2	42,1	56,3
	2007	55,2	59,4	55,2	50,9	59,4	50,9
K_2O total ppm	2005	283,3	587,0	433,9	510,4	510,4	535,9
	2006	231	324	294	393	344	353
	2007	330,6	268,6	261,7	316,8	296,2	358,2

- **Effect of the input of parkland manure and Tilemsi Natural Phosphate (PNT) on total soil carbon in the rural commune of Koporo pen.**

The results of chemical analyzes of the soil after the second year of cultivation showed an increase in the carbon content in the soil compared to T0 of 19.8% for T1, 28.5% for T2, 39.6 % for T3, 7.4% for T4, and 23.9% for T5 (Figure 1). After the third year of cultivation, a decrease in the total carbon content is observed in all treatments compared to the second year. The carbon rate in the soil has increased by 26.29% with T1, 26.6% with T2, 23.47% with T3, 26.29% with T4, and 44, 13% with the T5. The C / N ratio was 14 for T1 and 12 for T2. A C / N of 13 were obtained for T3.

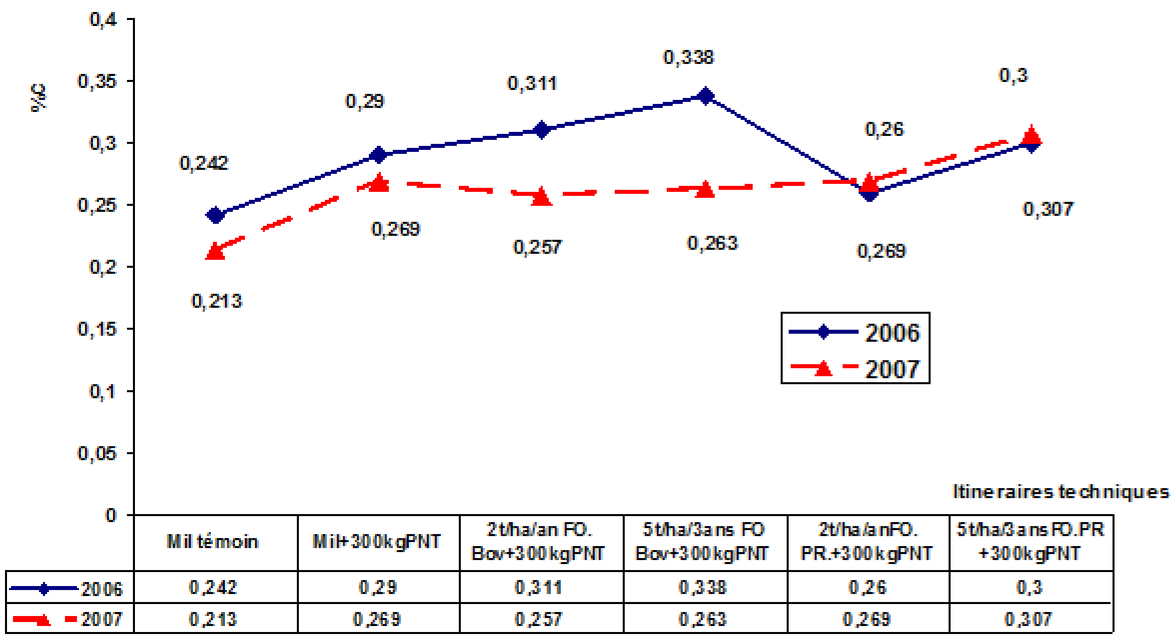

Figure 1: Variation of the soil carbon rate according to technical routes in the rural commune of Koporo pen

- **Effect of the input of parkland manure and Tilemsi Natural Phosphate (PNT) on soil pH in the rural commune of Koporo pen**

The results of the chemical analyzes of the soil after the second year showed that the pH of the soil has values between 5.0 and 6.5 therefore remains acidic, but the variations of the values of the pH towards 6 were observed in all the treatments who have received PNT. The pH values close to 5 are found in the treatments, which each year receive manure. (Figure 2). By the third year, soil pH values decreased in all treatments. The pH fell in the treatments, which received cattle manure.

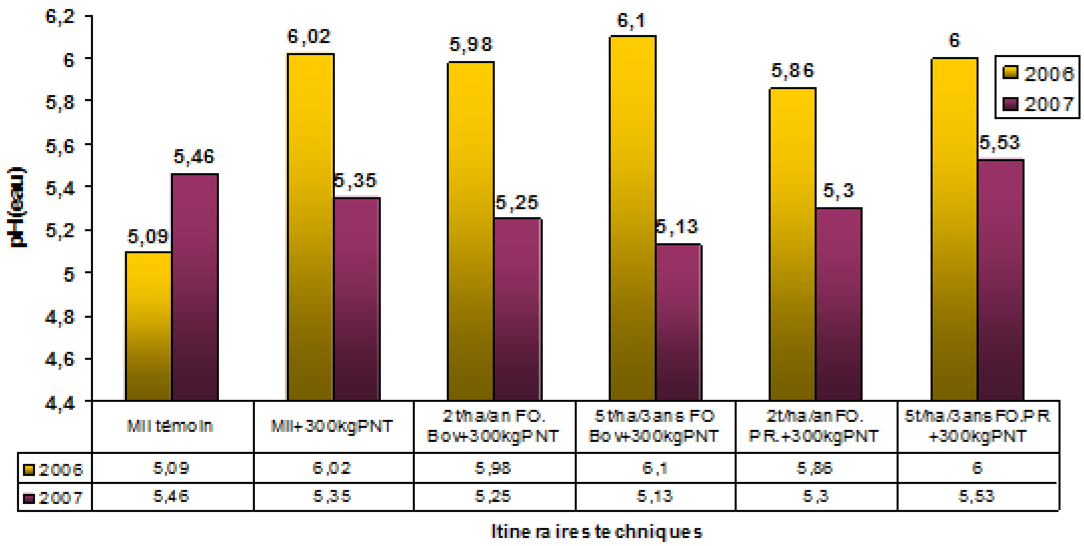

Figure 2: Variation in soil pH according to technical routes in the rural commune of Koporo pen.

Effect of the input of park manure and Tilemsi Natural Phosphate (PNT) on millet yield in the rural communes studied.

Tests in a peasant environment have shown that the application of manure from cattle and small ruminants at different doses and $300kg.ha^{-1}$ $3ans^{-1}$ of PNT in the fertilization of millet in three years makes it possible to obtain yields (grains and straw) higher than those of the continuous cultivation of millet. Thus, the application of $2t.ha^{-1}$.year-1 of cattle manure and $300kg.ha^{-1}$ $3ans^{-1}$ of PNT makes it possible to increase the production per hectare of millet grain compared to the control by 57.59%, and 52.8% with the application of $5t.ha^{-1}.3ans^{-1}$ of cattle manure and $300kg.ha^{-1}$ $3ans^{-1}$ of PNT. The contribution of $2t.ha^{-1}$.year-1 of small ruminant manure and $300kg.ha^{-1}$ $3ans^{-1}$ of PNT allows to obtain a grain yield increase rate of 60.11% and 63.8% with $5t.ha^{-1\cdot}$3ans-1 of small ruminant manure and $300kg.ha^{-1}$ $3ans^{-1}$ of PNT compared to the control. Finally, the application of $300kg.ha^{-1}$ $3ans^{-1}$ of PNT makes it possible to obtain an increase in grain yield of 16%.

Table 2: Production indicators of stockyard manure and Tilemsi rock phosphate (PNT) in the rural municipalities studied

Municipalities	Indicators/Technical route	Years	Mil Témoin T_0		Mil + 300Kg PNT T_1		Mil+2T/ha/an Cattle Manure + 300 Kg PNT T_2		Mil+5T/ha/3ans Cattle Manure + 300Kg PNT T_3		Mil+2T/ha/an Manure PR + 300Kg PNT T_4		Mil+5T/ha/3ans Manure PR + 300 Kg PNT T_5	
			Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Koporo pen	Yield Way (kg/ha)	2005	485	4350	595 (ns)	4200 (ns)	630 (ns)	4600 (ns)	780 (ns)	5850 (ns)	675 (ns)	5500 (ns)	1 055 (ns)	7400 (ns)
		2006	1440	4310	1255 (ns)	3550*	1600 (ns)	5850*	1730 (ns)	5700*	1385 (ns)	4600*	1840 (ns)	6300*
		2007	506	2512	621**	2722 (ns)	1 280**	3768 (ns)	956**	3200 (ns)	1240**	4608 (ns)	1200**	3904 (ns)
	Total cost of production	2005	24 075	-	70 505	-	116 985	-	189 635	-	133 555	-	235 095	-
		2006	36 005	-	35 240	-	92 965	-	42 855	-	106 110	-	44 045	-
		2007	23 863	-	26 985	-	88 805	-	32 793	-	104 225	-	35 725	-
	Benefits /Losses	2005	43 825	-	12 795	-	-28 785	-	-80 435	-	-39 055	-	-87 395	-
		2006	151 195	-	127 910	-	115 035	-	182 045	-	73 940	-	195 155	-
		2007	41 917		53 615	-	77 595	-	91 487	-	56 975	-	120 275	-
Madiama	Yield way (kg/ha)	2005	645	4680	850*	6300*	1 175*	6050*	1 030*	8795*	1 075*	8150*	1 000*	8200*
		2006	1560	14500	1810**	12400**	2450**	18100**	2300**	16300**	2250**	16800**	2850**	20800**
		2007	778	3385	1133**	4933**	1538**	6693**	1238**	5388**	1625**	7067**	1330**	5795**
	Total cost of production (Fcfa)	2005	26 315	-	70 575	-	124 615	-	193 135	-	139 155	-	234 325	-
		2006	39 125	-	44 265	-	106 465	-	52 565	-	119 605	-	60 025	-
		2007	28 170	-	34 780	-	93 690	-	37 690	-	110 855	-	38 745	-
	Benefits /Losses	2005	63 985	-	48 425	-	39 885	-	-48 935	-	11 345	-	-94 325	-
		2006	179 275	-	209 135	-	236 535	-	269 435	-	195 895	-	338 975	-
		2007	80 680	-	123 770	-	121 560	-	135 560	-	116 785	-	147 455	-
Doucombo	Yield medium (kg/ha)	2005	870	5525	770 (ns)	6025 (ns)	600 (ns)	5466 (ns)	690 (ns)	6825 (ns)	500 (ns)	4225 (ns)	540 (ns)	5600 (ns)
		2006	960	3050	1 180**	3375**	1 333**	4200**	1 620**	4375**	1 430**	3925**	1 550**	4275**
		2007	865	2300	1 311**	3710*	1 493**	4127*	1 308**	4515*	1 533**	3700*	1 385**	4125*
	Total cost of production	2005	33 465	-	76 955	-	120 765	-	192 375	-	135 105	-	231 885	-
		2006	30 725	-	35 445	-	90 832	-	43 045	-	108 125	-	41 825	-
		2007	29 395	-	37 283	-	93 072	-	38 670	-	109 560	-	39 515	-
	Benefits /Losses	2005	88 335	-	30 845	-	-36 765	-	-95 775	-	-65 105	-	-156 285	-
		2006	103 675	-	129 755	-	95 835	-	183 755	-	92 075	-	175 175	-
		2007	91 705	-	146 293	-	115 995	-	144 380	-	104 990	-	154 385	-

*: Significant; **: very significant; ns: not significant (PR = Small Ruminant) (Source: tests en milieu paysan)

Assessment of techniques

For the evaluation of the different techniques, working time, price (FCFA), quantity (kg / ha) of inputs and agricultural products were calculated. Thus, Table 10 shows the number of men who work per day (man / day) for the different jobs. It was estimated from the number of workers involved in setting up the test in a farmer. The values obtained were reduced to the hectare. Thus, numerous investigations were carried out in the field with technicians and farmers to arrive at data that were supposed to be reasonable man / days per task. As for the work concerning the harvest, it was evaluated at 10% of the value of the production.

Table 3: Number of men per day and per hectare

Activities	**Mil**	**Cowpea**
Plowing (every year)	2	2
Sowing (every year)	1	1
Weeding 1 (every year)	3,75	4
Weeding 2 (every year)	2,25	1
2T spreading of organic manure (every year)	2	-
5T spreading of organic manure (1st year)	3	-
Spreading 300kg of PNT (1st year)	1,5	1,5
Spreading 600kg of PNT (1st year)	-	2

(Source: enquête exploitations 2005)

The selling prices of millet, cowpea to the producer vary from year to year towards the start of the following crop year. The ad in the same year prices vary from one period to another. They are lowest, just after the harvest, and gradually rise to reach a maximum investigations on the markets of the different sites made it possible to retain the average selling price of millet at 140FCFA.kg^{-1} in the Central Niger Delta over the three years and in the Séno in the first year, the average price of 130FCFA.kg^{-1} on the Dogon Plateau during the three years and the last two years for Séno. The average selling price of cowpea grains used in our evaluations was 300FCFA and that of tops 125FCFA for all the sites. Fertilizer prices, recommended amounts and manure value are shown in Tables 3, 4 and 5.

Table 4: Price (FCFA) of millet, cowpea, inputs and quantity (Kg / ha) of inputs

Products and inputs	**Unit**	**Price in FCFA**	**Quantity of inputs per hectare**
Millet (seed)	kg	225	5kg.ha^{-1}
Cattle manure	kg	22,32	2 et 5 t.ha^{-1}
Small ruminant manure	kg	30,69	2 et 5 t.ha^{-1}
Recommended manure	kg	26,50	10 à 15t.ha^{-1}
PNT	kg	120	300-600 kg.ha^{-1}
Labour	½ ha	4000	
Manure transport	kg	250	
Other workforce	h/jour	750	

(Source: enquête exploitations 2005)

Table 5: Value (FCFA) of manure, calculated from its rate in elements, the coefficient (Kg fertilizer / Kg element), the rate of fertilizer in the manure and the fertilizer price (FCFA.kg-1)

Fertilizer	% of element in manure	Coefficient (Kg fertilizer / Kg element)	% fertilizer in manure	Fertilizer price ($FCFA.kg^{-1}$)	Manure value ($FCFA.kg^{-1}$)
Cattle manure					
Kg. N	0,980	2,18	0,021	310	6,51
Kg. P_2O_5	0,580	2,27	0,013	310	4,03
Kg. K_2O	1,680	2,27	0,038	310	11,78
					22,32
Small ruminant manure					
Kg. N	1,250	2,18	0,027	310	8,37
Kg. P_2O_5	0,830	2,27	0,018	310	5,58
Kg. K_2O	2,400	2,27	0,054	310	16,74
					30,69

Discussions

In this context, and faced with the irregularities of the rains and the multiple risks associated with the application of fertilizers, it is necessary to determine the doses, methods of application of organic and mineral manures in order to meet the needs of the crops. Indeed, the application of manure from cattle, and small ruminants at different doses and 300kg.ha^{-1} 3ans^{-1} of PNT in the fertilization of millet makes it possible to obtain yields (grains and straw) higher than those of continuous culture of mil. It also improves nitrogen and phosphorus levels in grains and straw. Thus, the application of 2t.ha^{-1} yr-1 of cattle manure and 300kg.ha^{-1} 3yrs-1 of PNT increases the production per hectare of millet grain compared to the control by 57.59%, and 52.8% with the application of 5t.ha^{-1} 3ans^{-1} of cattle manure and 300kg.ha^{-1} 3ans^{-1} of PNT. The contribution of 2t.ha^{-1} yr-1 of small ruminant manure and 300kg.ha^{-1} 3yrs-1 of PNT makes it possible to obtain a grain yield increase rate of 60.11% and 63.8% with the 5t.ha^{-1} 3ans^{-1} of small ruminant manure and 300kg.ha^{-1} 3ans^{-1} of PNT, compared to T0. Finally, the application of 300kg.ha^{-1} 3ans^{-1} of PNT makes it possible to obtain an increase in grain yield of 0 to 16%. This improvement in production has been demonstrated from studies carried out in Cinzana, on improving the quality of parkland manures, evaluating the source and method of spreading organic manure. The addition of a mineral supplement based on ammonia phosphate, cereal complex or Natural Tilemsi Phosphate (PNT) can significantly improve cereal production (Traore et al., 2000). Despite the surpluses observed with the application of manure and PNT at different doses, the years of poor rainfall were marked by production deficits, with burning of the plants (in the plots that received large quantities of manure) and loss in added value compared to the witness. The application of 300kg.ha^{-1} 3ans^{-1} of PNT gave mixed yields, little different from that of the control.

The results of chemical analyzes of the soil in all the treatments showed in the second year, an increase in the pH value of the soil, and in its organic matter concentration. This increase in the pH value would be due to the improving properties of PNT allowing to recover degraded soils, to increase the buffering capacity of acidic soils, in certain cases to ensure the role of liming thanks to its high concentration of calcium (Doumbia, 1993). In the third year, a drop in the pH value is observed accompanied by a decrease in the soil's organic matter concentration for all treatments. The K2O balance was positive for the routes used, on the other hand it was in deficit for N and P205. But the deficit is lower with the contribution of 5t.ha-13ans^{-1} of small ruminant manure and 300kg.ha-13ans^{-1} of PNT, and that of 5t.ha-13ans^{-1} of cattle manure and 300kg. ha^{-1} 3ans^{-1} from PNT. This leads to a conclusion similar to that of Traore et al., 2000 according to which the level of soil nutrient reserves decreases as a result of the effects of exporting crops.

Conclusion

In Mali, cereals cover 80 to 90% of the food needs of the population. In this Sahelian zone, the poor management of agricultural land and the mismatch between the price of inputs and that of food crops are important elements in the continued degradation of the soil. Reducing or even abandoning fallow that was the traditional method of restoring soil fertility has led to rapid soil nutrient depletion and reduced crop productivity. In the Mopti region, millet is one of the most important crops and accounts for 53% of agricultural production. Over the past three decades, yields have declined as a result of soil degradation and the adverse effects of the climate on plant cover and water resources. As a result, the region experiences permanent food insecurity.

Thus, a better understanding of the management practice of organic amendments based on the transport of manure to the fields, improved with Tilemsi Phosphate: Tests in farmers' environment have shown that the application of manure from cattle, and small ruminants to different doses and 300kg.ha^{-1} 3ans^{-1} of PNT in the fertilization of millet in three years makes it possible to obtain yields (grains and straw) higher than those of the continuous culture of millet. Thus, the application of 2t.ha^{-1}.year-1 of cattle manure and 300kg.ha^{-1} 3ans^{-1} of PNT makes it possible to increase the production per hectare of millet grain compared to the control by 57.59%, and 52.8% with the application of 5t.ha^{-1}.3ans^{-1} of cattle manure and 300kg.ha^{-1} 3ans^{-1} of PNT. The contribution of 2t.ha^{-1}.year-1 of small ruminant manure and 300kg.ha-13ans^{-1} of PNT allows to obtain a grain yield increase rate of 60.11% and 63.8% with 5t.ha^{-1}.3ans^{-1} of small ruminant manure and 300kg.ha^{-1} 3ans^{-1} of PNT compared to the control. Finally, the application of 300kg.ha^{-1} 3ans^{-1} of PNT makes it possible to obtain an increase in grain yield of 16%. The results of chemical analyzes of the soil in all treatments showed in the second year an increase in the pH value (which always remains) of the soil and an increase in the soil's organic matter concentration. In the third year, a drop in the pH value is observed accompanied by a decrease in the soil's organic matter concentration for all treatments. The development of sustainable agriculture in the Mopti region requires the use of local resources (rock phosphate, organic manure) combined with good cultivation techniques as an alternative to the use of imported mineral fertilizers. Adequate fertilization for sustainable production is possible by using organo-mineral fertilizer.

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