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Influence of the Leaf Biomass of *Piliostigma reticulatum* on Sorghum Production in North Sudanian Region of Burkina Faso

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Abstract

In northern Sudan zone of Burkina Faso, soils are increasingly vulnerable to degradation from erosion. Leaf biomass of *P. reticulatum*, is commonly used by farmers. This study aims (i) to quantify the impact of the leaf biomass of *P. reticulatum* on the growth and yield of sorghum, (ii) to determine an input composition for better performance and easy adoption by farmers. For three successive years, two different doses of foliar biomass (1.25 t/ha and 2.50 t/ha) were tested in combination and/or in comparison with NPK, Urea and Burkina phosphate. Soil moisture, vegetative growth and yield of sorghum were measured.

At stage 30 and 90 days after sowing, treatments showed no difference in growth. At the stage of 90 days after sowing, treatment.3 (T3) (100 kg NPK 50 kg Urea), T4 (200 kg of Burkina Phosphate), T5 (1.25 t/ha of leaf biomass of *P. reticulatum* + 100 kg NPK and 50 kg of urea) and T6 (2.50 t/ha of leaf biomass + 100 kg NPK + 50 kg Urea) did not show differences between the treatments. The contribution of the single organic matter gave a higher grain yield than that of the control. T6 gave the highest grain yield out of all treatments (2.40 t/ha). The addition of Burkina phosphate to various doses of dry matter did not influence the grain yield. T3, seems to have a better effect on soil protection and on improvement of grain yield.

Keywords: *Piliostigma reticulatum*, biomass, sorghum, growth, yield, inputs

1. Introduction

The traditional production system in the sahelian zone agroforestry (Yélémou, Bationo, Yaméogo, & Millogo-Rasolodimby, 2007; Diedhiou et al., 2009). This system is adopted by the majority of people, smallholder farmers who own small farming lands with limited resources. Low fertility soils experience very little organic matter inputs (Bationo & Buerkert, 2001; Yélémou, Dayamba, Bambara, Yaméogo, & Assimi, 2013). In farm lands, besides the main woody species spared (*Vitellaria paradoxa* Gaertn. f., *Parkia biglobosa* (Jacq.) Benth., *Balanites aegyptiaca* (L.) Del., *Lannea microcarpa* Engl. & K. Krause), shrubs are cut and burned every year as the sowing period draw near. According to Diedhiou et al. (2009) and Dossa et al. (2009), *Piliostigma reticulatum* (DC) Hochst. and *Guiera senegalensis* JF Gmel., are the shrubs generally found in Senegal. For Yélémou (2010), the agrarian system in Burkina Faso from North to South is characterised by a steady appearance of species like *Piliostigma*. For a few decades however, in Burkina Faso, because of on-going climate aridity, shrubs are cut and used for encrusted fields area mulching (Yélémou et al., 2007). In Central-western Burkina Faso, where population density is high, mulching is systematically used as a method of soil restoration. In this part of the country where we observe a wide presence of *Azadirachta indica* L. (neem), mulching, in farms near villages, is essentially made with neem leaves (Bationo , Yélémou, & Ouédraogo, 2004).

However, in wild fields, people principally use *Piliostigma reticulatum* leaves to cover affected areas (Yélémou et al., 2007).

The combined effect of anthropogenic pressure, irregular and insufficient rainfall, highly deteriorates the vegetation cover. Erosion is a phenomenon that significantly contributes to land and fertility loss in the Sudano-Sahelian area. For Mando (1997), land degradation is the main problem of West African soils. Mulching, the traditional process of soil fertility management, will not alone solve the problem of land productivity.

Given the low standard of living of rural dwellers who are mostly smallholder farmers, traditional production systems need to be better designed in order to address the problem of soil amendments, which is of great concern to farmers. Poverty of rural households also significantly reduces the potential for supply of mineral inputs. Improving the systems of production through lower costs and lower energy expenditures could encourage adhesion by peasant populations. *Piliostigma reticulatum*, a rustic specie available on fallow (Yélémou, 2010), presents real opportunities for soil fertilization by leaf biomass.

Most studies have focused more on tree-crops associations (Boffa, Taonda, Dickey, & Knudson, 2000; Bayala, Teklehaimanot, & Ouédraogo, 2002; Bayala, Mando, Ouédraogo, & Teklehaimanot, 2003) than on shrubs (Diedhiou et al., 2009; Dossa et al., 2012). Yet, shrubs with their abundance and their relatively rapid growth present a greater source of organic matter for traditional production systems. Studies on shrubs have mainly emphasized their role in carbon sequestration (Lufafa et al., 2008; Lufafa et al., 2009; Dossa et al., 2009). Few studies have focused on the impact of *Piliostigma reticulatum* leaf biomass on sorghum yield. Our study therefore aims to (i) determine the influence of *Piliostigma reticulatum* leaves biomass on growth, soil moisture and yield of sorghum, (ii) identify a formula for *Piliostigma reticulatum* leaves' biomass use, in association or not with low doses of inputs, and that could be easily embraced by rural populations.

2. Materials and Methods

2.1 Study Site

The study was carried out at INERA (Institut de l'Environnement et de Recherches Agricoles)'s research station in Saria (12°16'N; 2°09'W) located 80 km from Ouagadougou (Figure 1).

Climate is the northern Sudanese type characterized by two distinct seasons. The average annual rainfall is 800 mm, with high spatial and temporal variations. The average annual temperature is 28 °C with a maxima of 40 °C (March April). Saria is a densely populated area with 102 hab/km^2 (Taonda et al., 2003), where the main activity is agriculture. The main crops are sorghum and millet.

Soils are tropical ferruginous, washed or not, coming from granite rock. They are poor in phosphorus, in exchangeable bases and organic matters (Sedogo, 1981). From a vegetation perspective, Saria belongs to the north Sudanese sector (Fonts & Guinko, 1995), characterized by savannah annual grasses, trees and shrubs. The woody vegetation mainly comprises *Vitellaria paradoxa*, *Lannea microcarpa*, *Tamarindus indica* Linn., *Azadirachta indica* A.Juss. The Shrub layer is dominated by thickets scattered with Combretaceae as *Guiera senegalensis* J. F. Gamel., *Combretum nigricans* Lepr. ex Guill. et Perr. and *P. reticulatum*. The herbaceous layer consists mainly of *Loudetia togoensis* Hubb., *Dactyloctenium aegyptium* Beauv., *Cymbopogon giganteus* Chiev. and *Andropogon gayanus* Kunth.

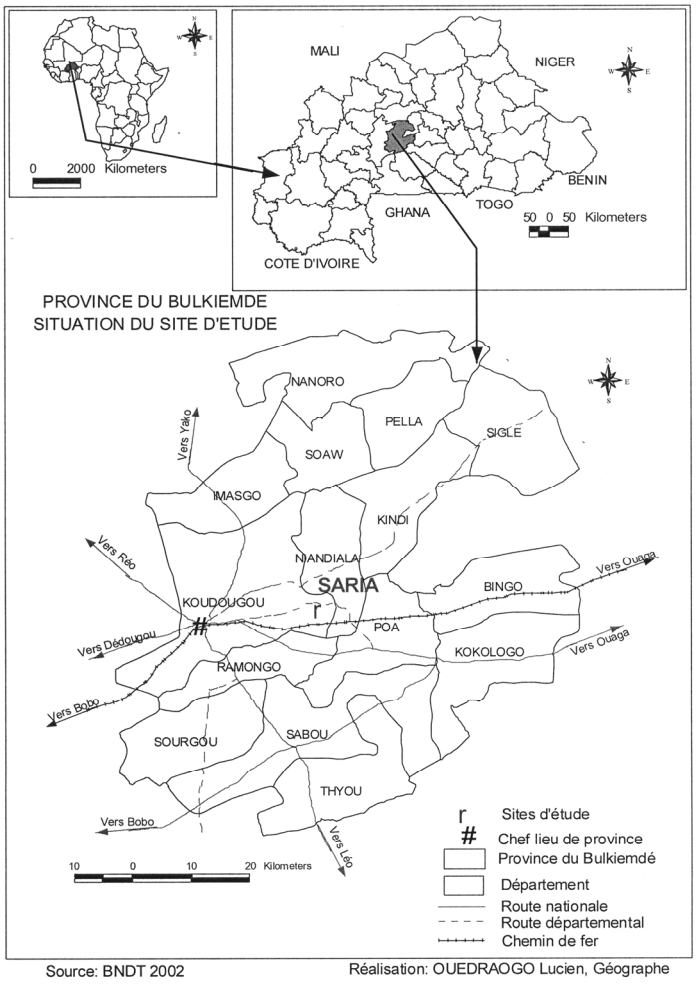


Figure 1. Location of study site

2.2 Methodological Approach

The study of the influence of *Piliostigma reticulatum*'s leaf biomass on sorghum productivity was conducted for three consecutive years, 2001, 2002 and 2003. The test design is a randomized complete block (Figure 2), with four (4) replications and nine (9) treatments. The unit plot is 9 m by 4 m, thus 36 m^2. The different treatments applied are as follows:

T_0= control

T_1= 1.25 $t.ha^{-1}$ Leaf biomass of *P. reticulatum*

T_2= 2.50 $t.ha^{-1}$ Leaf biomass of *P. reticulatum*

T_3= 100 kg NPK +50 kg Urea

T_4 = 200 kg Burkina Phosphate (200 BP)

T_5= 1.25 $t.ha^{-1}$ Leaf biomass of *P. reticulatum* + 100 kg NPK +50 kg Urea (T_1+T_3)

T_6= 2.50 $t.ha^{-1}$ Leaf biomass of *P. reticulatum* + 100 kg NPK + 50 kg Urea (T_2+T_3)

T_7= 1.25 $t.ha^{-1}$ Leaf biomass of *P. reticulatum* + 200 kg BP (T_1+T_4)

T_8 = 2.50 $t.ha^{-1}$ Leaf biomass of *P. reticulatum* + 200 kg BP (T_2+T_4)

T_8	T_5	T_0	T_2	T_3	T_7	T_1	T_6	T_4	R I
T_4	T_1	T_6	T_0	T_8	T_5	T_3	T_2	T_7	R II
T_7	T_3	T_2	T_1	T_6	T_4	T_0	T_8	T_5	R III
T_2	T_6	T_7	T_3	T_5	T_8	T_1	T_4	T_0	R IV

Figure 2. Experimental design R= repetition

The amount of *Piliostigma reticulatum*'s leaf biomass applied is inspired from current methods used by peasants in Burkina Faso (Yélémou et al., 2007) to recover field encrusted areas through mulching. The used cereal is an early variety of white sorghum developed at Saria by INERA and called "Sariasso 14". Burkina phosphate consists of 25% non-soluble P_2O_5 (tricalcium phosphate). The various inputs (biomass, manure) were brought to the soil at each agricultural campaign.

Before plowing, dried *Piliostigma reticultum*'s foliar biomass, and Burkina Phosphate, are spread in unit plots, based on treatments.

The following parameters were annually monitored during the three- year period of the study:

*Moisture rate in two periods of the plant's vegetative cycle: during plant growth, and during the heading-flowering stage. This was done by sampling the horizon 0-20 cm and subdividing it in two classes: (0-10 cm) and (10-20 cm). 3 soil samples were made, based on treatment, repetition and Horizon. The samples were weighed in their raw state then dried in an oven and eventually weighed again. The moisture was estimated according to the weight of soil removed.

* Vegetative growth: in order to monitor growth, areas were prepared based on treatment. Monitoring was done every 30 days after the sowing. Sorghum height was measured with a graduated pole. For each treatment and repetition, 15 sorghum plants were monitored.

* Yield: Ears or panicles weight, dry straw weight and grain weight were determined. To determine sorghum yields, three rows at the center of the plot were harvested. A total of 60 pockets per treatment and repetition were collected.

* In addition, the color of sorghum leaves and the evolution of the mineralization of *Piliostigma reticultum*'s leaf biomass were regularly monitored. Three colors were considered: dark green, light green and yellow. The evolution of leaves mineralization is estimated by observing their physical appearance.

2.3 Chemical Analyses

In the first year of the trial, samples were taken from the control plots in order to determine the initial state of the soil. In each control plot, a composite sample was made. The sampling layers considered were 0-20 cm and 20-50 cm. In total, four composite samples were analyzed. The following chemical analyses were performed: total carbon, organic matter, total nitrogen, total phosphorus and water pH.

- The organic carbon was determined by the method of Walkey and Black;

- The total nitrogen by Kjeldahl's method;

- The total phosphorus was measured with the automatic self analyzer;

- The water pH was measured using an electronic electrode directly incorporated into a suspension of soil diluted in distilled water (1/2, 5).

Piliostigma reticulatum's leaves biomass contains a significant amount of minerals. The Chemical analyses conducted by Iyamuremye et al. (2000), provide the following chemical characteristics:

Table 1. Chemical characteristics Piliostigma reticulatum's leaves

chemical parameters	Ntotal	Ctotal	Ptotal	C/N	Lignin	cellulose	hemicellulose
Quantity (g/kg)	12.4	345	0.74	27	62	392	333

Source: Iyamuremye et al. (2000).

2.4 Statistical Analysis

Data were subjected to the analysis of variance (ANOVA) and the least squares test of Fisher (LSD) was used to compare the means of the different parameters studied (growth, yield and moisture), at a 5% level of significance. Statistical analyses were performed using the statistical software Xlstat.

3.Results

3.1 Initial State of the Soil

The chemical analyzes performed in the first year of study give the characteristics of the initial state of the soil (Table 2). The trial soils were acidic (pH = 5.49 ± 0.09 in top soil and 5.86 ± 0.16 in 20-50 cm depth) and relatively poor in total N and total P. These soils also contain little organic matter at the top and in deep soil (respectively 0.53 ± 0.13 and 0.50 ± 0.12).

Table 2. Soils' chemical characteristics (Mean ± SDE, n= 5)

	Ctota (%)	MO (%)	Ntotal (%)	Ptotal (%)	PH_2O
0-20 cm	0.30 ± 0.07	0.53 ± 0.13	0.015 ± 0.006	0.011 ± 0.002	5.49 ± 0.09
20- 50 cm	0.30 ± 0.04	0.50 ± 0.12	0.013 ± 0.005	0.010 ± 0.002	5.86 ± 0.16

3.2 Influence of Piliostigma's Leaf Biomass

3.2.1 Growth of Sorghum

After sowing, the growth of the seedling did not appear to be influenced by the treatments. All treatments have a good growth rate (mean of 98%). From the rise of sorghum plants to 30 days after the seeding, treatments show no statistical difference ($P \geq 0.05$) (Table 3). In addition, the standard deviation, between the values of growth, shows slight variations. 60 days after sowing, the various treatments showed no difference in the growth of sorghum plants ($P > 0.05$). However, 90 days after sowing, ANOVA showed a difference between treatments ($P < 0.05$).

Table 3. Data Analysis (ANOVA) of growth for the three years period

		Sum of squares	ddl	Mean of squares	F	Level of Significance
Height after 30 days (Cm)	Inter-groups	554.0515	8.0000	69.2564	1.0491	0.4050
	Intra-groups	6535.2216	99.0000	66.0123		
	Total	7089.2731	107.0000			
Height after 60 days (Cm)	Inter-groups	8586.1177	8.0000	1073.2647	0.7651	0.6342
	Intra-groups	13 8874.2661	99.0000	1402.7704		
	Total	147 460.3838	107.0000			
Height after 90 days (Cm)	Inter-groups	12 807.9702	8.0000	1600.9963	3.0679	0.0040
	Intra-groups	51 663.7242	99.0000	521.8558		
	Total	64 471.6944	107.0000			

Ninety (90) days after rise, two homogenous treatment groups differ. Treatments T0, T1, T2, T7 and T8

displayed low growth rate of sorghum plants. There was no statistical difference between these treatments ($P > 0.05$). However, treatments T3, T4, T5 and T6 were statistically equivalent and provided the greatest changes in sorghum growth compared to previous treatments.

At the beginning of the sorghum growth, treatments show a linear curve with low standard deviations (Figure 3). At 60 and 90 days sorghum growths have significant standard deviations.

3.2.2. Soil moisture

Moisture in the sampled layers was higher in the top soil (0-10 cm) than it was in the sub soil (10-20 cm) at the start of the agricultural campaign (Figure 3). For each sample layer considered, humidity has changed in a saw tooth way. Yet, there is no statistical difference ($P > 0.05$) between treatments concerning the evolution of humidity and between treatments and the sampling level (Table 4).

Table 4. ANOVA analysis of data on humidity

Source	ddl	Sum of squares	Mean square	Fisher F	Pr > F
Level	1	62.546	62.546	12.473	0.001
Row	8	43.498	5.437	1.084	0.376
Level*Row	8	6.501	0.813	0.162	0.995

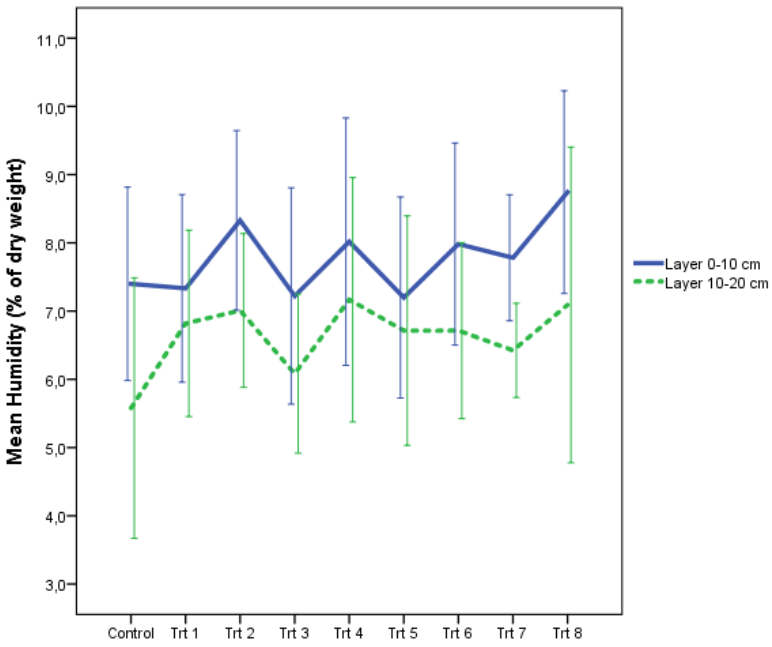


Figure 3. Trend of humidity at the beginning of the rainy season for 3 years in the two layers

At the end of the rainy season (in September), the humidity factor showed no difference from one layer to the other. Moreover, whatever the sampled layer, treatment showed no statistical difference. The humidity evolution curves from the different sample layers are very close to each other (Figure 4). For treatment 4, considering the 10-20 cm layer, we observe a higher trend in the humidity rate. The humidity evolution curve for the 10-20 cm level lied above that of the upper level. Soil moisture is relatively important at the beginning of the rainy season. It is around 7.5 to 8% for the upper soil (0-10 cm) and 6 to 6.5% for the sub layer (10-20 cm). At the end of the rainy season, the moisture rate in the top soil was 3 to 3.5% and that in the sub layer, 3.5 to 4%.

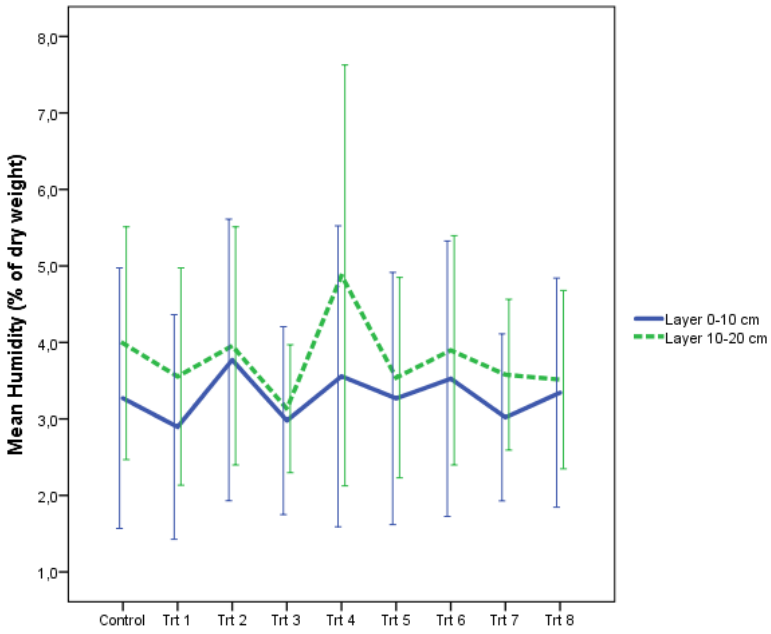


Figure 4. Trend of humidity at the beginning of the dry season

3.2.3 Yields (Panicle, Straw, Grain)

Yield parameters considered (panicle with grain weight, dry straw, grains) varied depending on treatments. Analysis of variance revealed significant differences ($P < 0.05$) in each yield parameter depending on treatments (Table 5). The panicle yield for sorghum varied depending on treatments. The panicle yield in the control plot, and that of the plot which received high doses of dry matter associated with Burkina phosphate (T7) were the lowest (Table 6). Both treatments (T0 and T7) are statistically different ($P < 0.05$) from T6 (high dose of leaf biomass + 100NPK-50Urea). T6 gives the best panicle grain yield with 2.99 ± 0.8 t/ha. Although the treatments T1, T2, T3, T4, T5 and T8 were slightly higher than T0 and T7, they were statistically equivalent ($P > 0.05$).

Table 5. Analysis of variance of yield factors

		Sum of squares	ddl	Mean of squares	F	Level of Significance
weight panicules (Kg)	Inter-groups	14 346 101.7717	8.0000	1 793 262.7215	2.6213	0.0120
	Intra-groups	67 726 328.5318	99.0000	684 104.3286		
	Total	82 072 430.3034	107.0000			
dried straw (Kg)	Inter-groups	32 328 201.5407	8.0000	4 041 025.1926	2.3996	0.0207
	Intra-groups	166 722 724.2203	99.0000	1 684 067.9214		
	Total	199 050 925.7609	107.0000			
grains (Kg)	Inter-groups	10 869 083.7890	8.0000	1 358 635.4736	2.5742	0.0135
	Intra-groups	52 251 983.7121	99.0000	527 797.8153		
	Total	63 121 067.5011	107.0000			

The straw yield obtained on the control plot (T0) was the lowest. High doses of dry matter (T2) associated with popularized dose of NPK-Urea (T3) or T6 gave the best straw yield (4.88 ± 1.64 t/ha). T6 was statistically different ($P < 0.05$) from T0. Burkina phosphate (BP) associated with various doses of dry matter did not show a statistically different yield ($P > 0.05$) from the control.

An input of dry matter alone, at low or high doses (T1 or T2), gives a slightly higher grain yield than that of the

control. Doses of dry matter (T1 and T2) gave statistically identical yields ($P > 0.05$). From an agronomic point of view, T6 gave the most interesting grain yield (2.40 ± 0.73 t/ha). The addition of urea in various doses of dry matter had no influence on grain yield.

Table 6. Trends in sorghum yield depending on treatment

Treatment	Weight of panicule grains (t/ha)	Straw weight (t/ha)	Grains weight (t/ha)
T0	1.89 ±0.69b	3.18± 0.96b	1.33 ± 0.61b
T1	1.93 ± 0.64ab	3.47 ± 0.99ab	1.52 ± 0.54ab
T2	2.15 ± 0.86ab	3.78 ± 1.12ab	1.71 ± 0.73ab
T3	2.42 ±0.92ab	4.41 ± 1.00ab	1.79 ± 0.79ab
T4	2.57 ±1.06ab	4.26 ± 1.64 ab	2.02 ± 0.96ab
T5	2.65 ± 0.78ab	4.40 ± 1.11ab	2.08 ± 0.72ab
T6	2.99 ± 0.82a	4.88 ± 1.64 a	2.40 ± 0.73a
T7	1.88 ± 0.71b	3.37 ± 1.09ab	1.50 ± 0.60ab
T8	2.42 ± 0.88 ab	4.33 ± 1.78ab	1.94 ± 0.77ab

In each column, values carrying different letters are statistically different.

4. Discussion

The soils of the station belong to the class of leached tropical ferruginous soils (Sedogo, 1981). The poverty of these soils in organic matter and total phosphorus, as shown by our results, was also highlighted by Sedogo, (1981) and Bonzi, (1989). For Sedogo, (1981), croplands in Burkina Faso have reached a high level of acidification. According to Hien, (2004), soils in the Central Plateau of Burkina are experiencing a critical degradation of their organic matter and carbon stocks. A combination of several factors, including overexploitation and a decreasing rainfall, could explain this situation (Hien, 2004). Indeed, the accumulation of organic matter in the soil depends on the amount and quality of the litter but also on the speed with which it is decomposed by microorganisms (Sagar et al., 1999). The Central Plateau in Burkina Faso, with the highest population density (Ministère de l'Economie et du Développement/ Direction Générale de la Planification et des Etudes [MEDEV / DGPE], 2005) is experiencing strong anthropogenic pressure resulting in natural resources degradation. In order to tackle the problem of land degradation and poor soils, rural population practice mulching (Yélémou et al., 2007) rather than cutting and burning biomass as before. For rural populations, this ancient practice revives soils, in other words it allows plant regeneration in the encrusted areas of the field.

However, due to the degradation of climatic factors and poverty of rural dwellers, mulching is more commonly practiced in different areas of the field depending on the availability of biomass.

In terms of growth, treatments did not show any difference in the evolution or trends 30 days after planting, therefore explaining the shape of the curve and the low standard errors observed. The effect of treatment was observable 60 days after sowing, which is illustrated by the variations in mean values and the wide standard errors noted. This slight expression of treatments can be related to the beginning of mineralization found in leaf biomass. According to Dossa et al. (2009), soil amendment with *Piliostigma reticulatum* leaves causes the immobilization of nitrogen during the first 62 days. For Diack et al. (2000), the rate of degradation of *Piliostigma reticulatum* leaf biomass is high.

Up to 60 days after sowing, "sariasso 14" is elongating. Observations made on the field showed that a significant part of the widespread biomass is still intact. This also applies to treatments involving Burkina phosphate, which is a substantive amendment aiming at gradually correcting soil deficiencies. However, treatments with Urea-NPK inputs (T3, T5, T6) generate sorghum plants which are darker in color and larger in size. This phenomenon will increase with time. Regular rainfall or satisfactory moisture during the elongation period allows a regular vegetative growth of cereals.

90 days after sowing, sorghum plants reach the end of flowering and beginning of maturity. During this period the mineralization of leaf biomass is very advanced, releasing carbon and nitrogen. In treatment T6, the amount of mineral elements is important, due to the importance of the leaf biomass associated. The application of NPK Urea's popularized dose is more expressive on the growth of grain when the dose of leaf biomass is high.

Moisture is an important factor in the rise, growth and maturation of grains. When the agricultural campaign starts, soil moisture in the top layer (0-10 cm) is higher than in the lower layer (10-20 cm). At the beginning of the rainy season, rainwater infiltration into sub soils is low due to the high absorption capacity of the upper layer. However, as rainfall continues, the second follow-up period to monitor humidity shows no difference between levels. When the rainy season draws near, rains become more frequent and more important (Some, 1989). Rainwater filters through the soil and accumulate in deeper layers, especially when soils are fairly deep like Saria's ferruginous tropical soil (Hien, 2004). Therefore there is no longer a difference in moisture between layers. Regular rainfall during the rainy season could also explain the little difference observed in the trend of moisture between treatments.

Apart from treatment T7 (low dose of leaf biomass of *P. reticulatum* + Burkina Phosphate), all treatments applied are better than the control considering the different yield factors (panicle grain weight, straw weight, grain weight). *Piliostigma reticulatum* leaf biomass input, slightly improves the yield. *Piliostigma reticulatum* leaf biomass, is rich in carbon and nitrogen (Dossa et al., 2009; Yélémou et al., 2013). For Dosa et al. (2009), *Piliostigma reticulatum* leaf biomass' content in total nitrogen is closed to that of peanut foliage, which is a vegetable specie. For Yélémou et al. (2013), the level of carbon is increased under *Piliostigma reticulatum* to 105% and nitrogen content for 27-66%. According to Iyamuremye et al. (2000), soil amendment with *Piliostigma reticulatum* leaf biomass increases the content of soluble PO4 into the soil. Practicing mulching is a way for farmers to improve the long-term mineral status of soil. Indeed, according to Bationo et al. (2006), most soils in agro-ecosystems in West Africa are poor in organic carbon. For these authors, the low carbon content is in part due to the lack of leaf and underground biomass, and to the insufficient levels of clay in the soils.

Treatment T3 (100 kg + 50 kg urea NPK) comprises nitrogen and phosphorus that can be directly used by crops. It gives a yield that does not differ from that obtained with high doses of *Piliostigma reticulatum* leaf biomass (T2) alone or Burkina phosphate alone (T4). The same applies to treatments T5 (low dose of NPK + biomass-Urea) and T8 (high dose biomass + Burkina Phosphate). These results could be explained by the soil needs in phosphorus and nitrogen that have to be satisfied. Indeed soils in our study area are very poor in nitrogen and phosphorus (Bonzi, 1989; Buerkert et al., 2001; Bationo et al., 2006). Burkina Phosphate is a PO4 in its raw state. Time is required for it to be dissolved. Therefore, when applied alone, it has little effect on crops yield. When Burkina phosphate is associated with a low dose of *Piliostigma reticulatum* leaf biomass, it has a regressive effect on crop yields. Degradation of leaf biomass occurs after 60 days following seeding, around 90 days after planting, when the plant reaches the final stage of flowering and starts the maturity phase. Moreover, the higher the dose of leaf biomass applied, the more sensitive the phenomenon of degradation. Application of biomass does not meet the short-term needs of crops in N and P, thus explaining the yields recorded. For Dossa et al. (2009), *Piliostigma reticulatum* leaf biomass input into the soil, causes an immobilization of soil nitrogen during the first 62 days. For these authors, residues of *Piliostigma reticulatum* input to the soil cannot meet the short-term needs of crops in nitrogen. According to Iyamuremye et al. (2000), crop residues cannot provide a source of nitrogen to the crops in the short term. It is therefore necessary to satisfy crop needs while gradually raising the soil deficiencies in nutrients. That is why, of all formulas studied, treatment T6 (high dose of *Piliostigma reticulatum* leaf biomass + NPK-Urea), gives the best yield, both in grain and straw. The high yield obtained is explained by the presence of nitrogen and leaf biomass which literally doubles. T8 and control have the same level of performance due to the lack in nitrogen supply. Nitrogen plays an important role in the mineralization of organic substances in raw state (biomass). *Piliostigma reticulatum* leaf biomass contains high levels of carbon and nitrogen.

However, the productivity of soil with leaf biomass amendment requires input of mineral fertilizers. For Bationo et al. (2006), in order to sustain food production, considering the rapid population growth in West Africa, it is necessary for smallholder farmers to include mineral fertilizers and soil organic substances in their crops. For sustainable management of soil productivity, associating NPK-Urea and organic residues is recommended by many authors (Bationo & Buerkert, 2001; Buerkert et al., 2001; Bationo et al., 2006).

5. Conclusion

It appears that for rural smallholder farmers, the formula combining popularized dose of NPK-Urea and strong dose of *Piliostigma reticulatum* leaf biomass is the most profitable. In the short term it allows a good productivity of crops and maintains soil fertility. However, because smallholder farmers have low purchasing power and do not respect the prescribed doses of fertilizers to apply in order to sow a larger area, treatment T2 could be an alternative. The application of a high dose of leaf biomass before seeding protects soils against erosion, maintains moisture (Zoumboudré et al., 2005) and in the long-term, maintains soil fertility. This option would prevent people from burning crop debris or shrubs before seeding, from exporting any biomass after

harvest and promote natural regeneration of woody plants. Studies on the rate at which biomass contributes to soil fertility and the different effects in the long-term would provide a useful guide to populations.

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