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The Role of *Cajanus cajan* in Enhancing Soil Fertility and Macrofauna Populations in Intensively Cultivated Systems in Korhogo (Northern Côte d'ivoire)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the Korhogo department, it is almost impossible to practice fallowing. The aim of this study is to determine how the Cajanus fallow impact the soil the biological and physical soil fertility. Macrofauna and soil samples were taken in different cropping systems (Cajan + maize, Cajanus + groundnut, Cajanus + maize + groundnut, Cajanus) and compared with the control (soil that did not contain any legume). The population density and abundance of the different macrofauna sampled were calculated and compared by analysis of variance ANOVA at the threshold of 0.05. The results show that the cropping system based on *Cajanus cajan* favoured the repopulation of the soil with Termicidae, Lumbricidae and Formicidae to the control. These values varied from 90 to 340 individuals/m^2 for Lumbricidae in the system based on Cajanus. compared to the control values lower than 5 individuals/m^2. The comparison of the population density according to the type of tillage also shows that flat plowing systems stimulate increase Lumbricidae populations more than ridged soils (325; 275; 125 individuals/m2 on plowing. against 230; 100 individuals /m^2 on ridge) respectively on Cajanus+ groundnut, Cajanus + groundnut+ maize and pure Cajanus. On the other hand, the intercropping which increased the number of Lumbricidae, Termicidae and Formicidae, whatever the type of tillage, are, respectively, Cajanus + groundnut, Cajanus + groundnut + maize, Cajanus + maize and pure Cajanus.The introduction of Cajanus into intercropping systems leads to an improvement in the physical and biological fertility of the soil.

Keywords: Cajanus; density; intercropping systems; macrofauna; tillage.

1. INTRODUCTION

Population growth increases demand for food, while land pressure increases the need for arable land (Moussa, 2014). With a population of 440,926 inhabitants, Korhogo is the third city in Côte d'Ivoire with a high population density (General Population and Housing Census (RGPH), 2021). As a result, fallowing as means of soil restoration became difficult in this region. However, in the past, fallowing was the only real means used by farmers to naturally restore their soil fertility (Koulibaly et al., 2010, N'Guessan et al., 2019). Today, farmers claim that the soils are became poor and use mineral fertilizers to face to soil fertility declining (Kouakou et al., 2021). Fallowing was possible because the farmers were practicing itinerant agriculture which allowed the soil to replenish itself through biological processes. Indeed, in the 1960s, Ivory Coast had sufficient arable land fallows could last for decades before being cultivated (Kouakou et al., 2021). Today, the cultivable lands are insufficient compared to demand. This strong pressure on the soil has led to a profound modification of the farming system which has changed from itinerant agriculture to fixed agriculture, particularly in the dense area of Korhogo (Bigot et al., 1982). Furthermore, the sedentarization of agriculture requires the adoption of cropping systems adapted to climatic conditions which activate the biological processes of restoring soil fertility. Several research studies indicate the benefits of using leguminous. In particular, the improvement of soil fertility by the symbiotic fixation of nitrogen from the air (Barro et al., 2016, Coulibalyet al., 2017, Gbakatchetcheet al., 2010, Kouassiet al., 2016, Myriamet al., 2017), to produce quality fodder for animals and improve the financial income of farmers (Bambara et al., 2018, Bloukounon et al., 2015, Ido et al., 2016). But, with the strong land and demographic pressures observed in recent years in the northern part of Côte d'Ivoire, the use of soil restoration techniques with leguminous becomes problematic. This study was initiated to study the effect of intercropping systems based on *Cajanus cajan* (shrub legume) on the density of Termicidae, Lumbricidae and Formicidae population and its effect on the soil structure.

2. MATERIAL AND METHODS

2.1 Study Site

The study site was an agricultural farm with 7 ha of surface area approximately, located at Korhogo (northern Côte d'Ivoire) (09º55'28.2" N and 5º34'38 W). the most representative soil of the site are Cambisols at the top of the slope and at the mid-slope and, Gleysols in the lower slopes (WRB, USS Working Group et al., 2014). Within this study area, a permanent plot of 1 ha was created whose soils have a high load of coarse elements, with a sandy or sandy-clay texture in the superficial horizons (0-20 cm). The climate of the Korhogo region is Sudano-Sahelian of transitional tropical type with a rainy season (April-October) and a dry season (November-March), with annual precipitation is 1350 mm (Kouakou, 2021).

2.2 Methods

2.2.1 Sampling of macrofauna in different cultural practices

Macrofauna samples were taken in the different cropping systems (Cajan associated with different maize and groundnut harvest residues) and compared to a control. Also, to assess the effect of the Cajanus population on the structure of the soil, different clods of earth were taken from different types of fallow and compared.

The non-specific method of Anderson an Ingram (Anderson and Ingram, 1993) was used to determine the abundance of soil macrofauna. Sampling was done following the TSBF (Tropical Soil Biology and Fertility) method. The targeted community was Termicidae, Lumbricidae and Formicidae. This method consists of isolating a monolith measuring 25 x 25 x 30 cm. The fauna was harvested manually after dividing the monolith into 3 strata depending on the depths (0 - 10 cm, 10 - 20 cm, 20 - 30 cm). This stratification according to these depths is linked to the fact that these macrofaunas colonize more of these horizons. In fact, by following a 7 meter-long transect, five monoliths or TSBF points were positioned per plot. Thus, 280 TSBF points were positioned along 56 transects. The fauna sampled was in 90% alcohol and identified by Indval method (Dufrene and Legendre, 1997). Thus, TSBF points measuring 25 cm x 25 cm side were positioned. Then using a spade manually graduated, and after the contours have been demarcated with a chisel (Fig. 1a), the spade is sunk to a depth of 10 cm and a soil sample with a volume of 6250 cm^3 is taken and placed on a support to serve as excavations (Figs. 1b, 1c and 1d). This same process was repeated three times in order to reach thirty (30) cm depth (Fig. 1i). The different individuals observed after excavation were sampled and counted by stratum (Figs. 1f, 1g, and 1h).

2.2.2 Sampling of clods of earth and soil structure

The clods of earth are taken from the different legume associations at the level of the first twenty (20) centimeters of the soil. This horizon level is chosen because soil transformations are more easily carried out on the surface. The shape of the particles and their mode of arrangement makes it possible to determine the structure of the soil.

Fig. 1. Steps for sampling soil macrofauna

a: 2 years fallow; b: soil under continuous cultivation; c: 11 months improved fallow of Cajanus cajan; d: soil structure of 2 years natural fallow, e: soil structure in continuous cultivation; f: soil structure from improved fallow Cajanus cajan; g: Termicidae colony; h: Formicidae colony; i: TSBF point of depth 30 cm

3. RESULTS

3.1 Effect of the Association of Legumes on the Population Density of Soil Macrofauna

Figs. 2, 3 and 4 present, respectively, Termicidae, Lumbricidae and Formicidae population density taken in the different cultural practices. The analysis of variance reveals a highly significant difference between the populations of Lombricidae, Termicidae, and Formicidae), resulting from the different cultural associations compared to the Control ($P<0.05$). However, the test of the smallest significant difference LSD, at the threshold of 0.05, did not show any difference between the populations of macroinvertebrates from the groundnut + maize associations, pure groundnut culture and the control. Furthermore, differences were observed between the invertebrate populations from Cajanus-based systems (pure Cajanus; Cajanus + groundnut; Cajanus + maize and Cajanus + groundnut + maize) and the control. The greatest numbers of macroinvertebrates were obtained in cultural associations based on Cajanus. These values varied from 90 to 340 individuals/m^2 for Lumbricidae at the level of Cajanus-based systems compared to values lower than 5 individuals/m^2 for the control.

The number of individuals obtained on the plowing system were 325; 275; 125 individuals/m^2 against 230; 145; 100 individuals /m^2 on billon respectively in Cajanus + groundnut, Cajanus + groundnut + maize and pure Cajanus associations. It was observed that the cultural associations which increased Lumbricidae, Termicidae and Formicidae population, whatever the type of tillage, were, respectively, the associations Cajanus + groundnut, Cajanus + groundnut + maize, Cajanus + maize then pure Cajanus. Termicidae were the most abundant macroinvertebrate species in all associations based Cajanus with an average oscillating between 60 and 70%, followed by Lumbricidae.

3.2 Effect of Different Fallows on Soil Structure

The textures observed in the different cropping systems are presented as follows. The particle structure under continuous cultivation (Fig. 6 b), the polyhedral structure in the 2 years old improved fallows (Fig. 6 d) and the lumpy structure in the improved fallow of 11 months old Cajanus (Fig. 6c).

4. DISCUSSION

The supply of exogenous organic matter, represented in this study by combinations of leguminous – maize and different mulches, stimulated the growth of populations of Termicidae, Lumbricidae and Formicidae compared to controls (without leguminous and without mulch). These results are similar to those observed in many previous works (Mboukou-Kimbatsa, 1997, Traoré et al., 2012). The presence of Termicidae in the soil modifies the environment by the rise of particles from the subsoil to the surface (Traoré et al., 2012, Zaremski, 2019). Thus, a soil with a particle structure on the surface and rich in clay in the depth horizons can have its texture modified on the surface, under the action of Termicidae, like the soils of Termicidae mounds which have a higher clay content than the rest of the soil. surrounding ground. The agricultural practices implemented had a positive impact on the enrichment of clay soils in the context of this study, which would be linked, in part, to the action of termites through their ability to bring clay up from the depths to the surface.

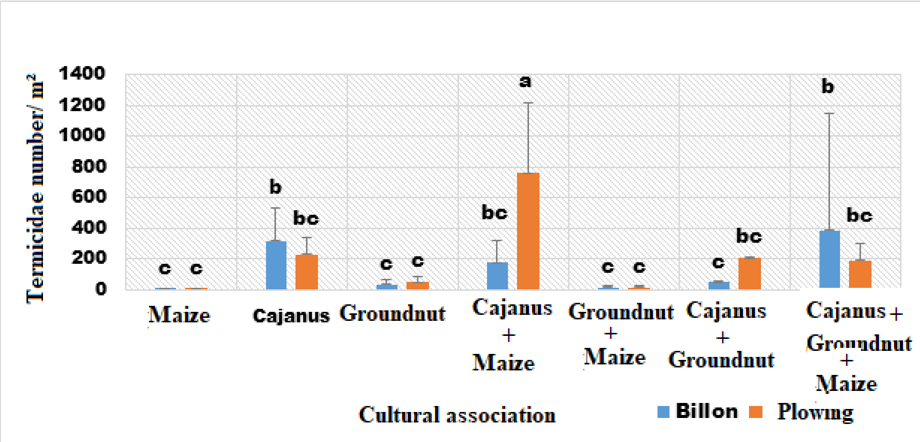

Fig. 2. Termicidae population density according to cultural associations

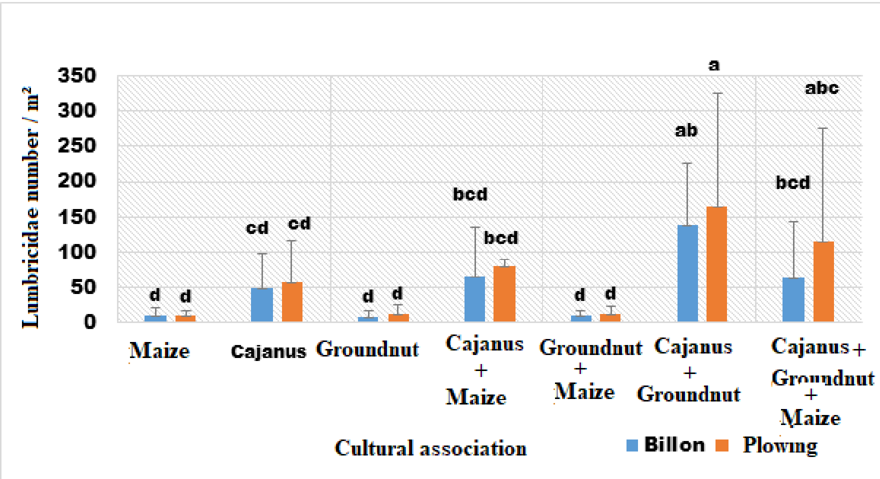

Fig. 3. Lumbricidae population density according to the plowing type and cultural association

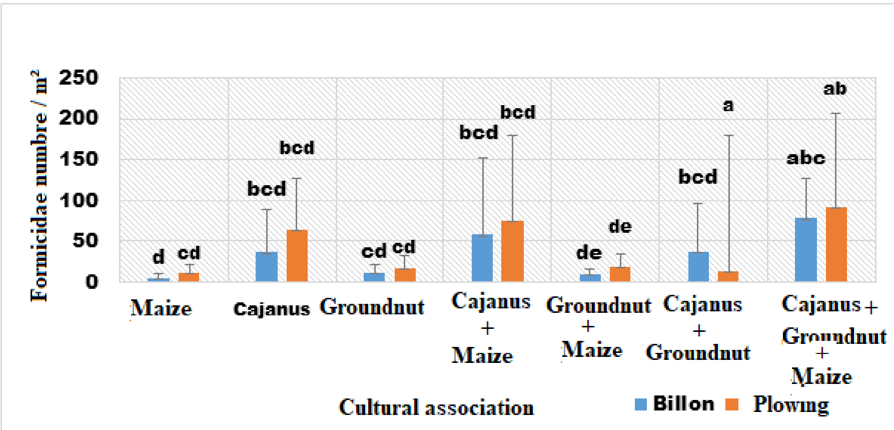

Fig. 4. Formicidae population density according to cultural association

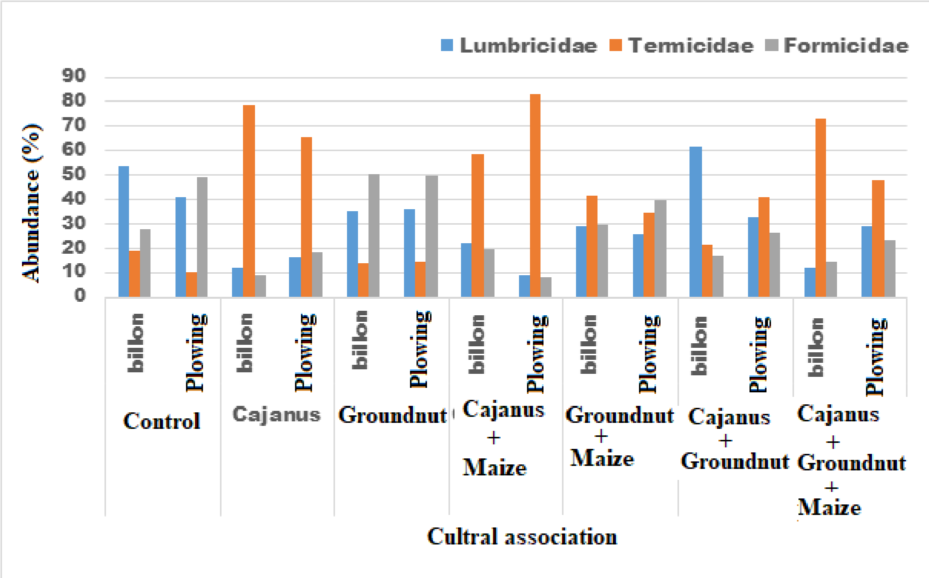

Fig. 5. Aboundance of macrofauna population according cultural association

Fig. 6. Types of fallows and associated soil structures

a: fallow for 2 years; b: soil under continuous cultivation; c: Improved fallow of Cajanus cajan aged 11 months; d: soil structure of natural fallow for 2 years, e: soil structure in continuous cultivation; f: soil structure from improved fallow Cajanus cajan)

Indeed, the ground cover with straw constitutes a food source for Termicidae which attracts them to the surface of the soil. By consuming the straw, the Termicidae will begin the process of decomposition of organic matter. Which would place them at the forefront in the decomposition of organic matter even before the action of soil microorganisms. The richness of the cellulose straw from cultural associations would attract Termicidae. In fact, the cellulose content of the straw amounts to 46% compared to 8% for manure (Hien, 2004). This high density of the Termicidae population could therefore be explained by the abundance of food (cellulose) contained in the straw. they occupy an important place in tropical ecosystems; They participate in numerous ecosystem services such as the decomposition of organic matter and the evolution of soil structure (Rakotomanga et al., 2016, Verma et al., 2004).

As for the population of Lumbricidae, the systems stimulated more their to the controls. This enrichment of soils with Lumbricidae would partly result from the humidity producted by cultural practices, and their permanent enrichment with organic matter through the constant deposition of dead leaves. Indeed, the study revealed an enrichment of soils with organic matter under the agricultural practices implemented. Furthermore, the evolution of the quantity of organic matter under different cultural systems would more attract Lumbricidae (Traoré et al., 2012). Lumbricidae, thanks to their bioturbative activity, ingest organic matter to form more stable aggregates with the clay fraction, under different populations of *Cajanus cajan* (Ratsiatosika et al., 2018, Frouz et al., 2008, Lavelle et al., 2021). The evolution of soil structure under different cultivation practices is an illustration of this. The presence of these organisms in an environment accelerates the restoration of the soil and the establishment of a functional ecosystem. In fact, they constitute a source of food for many predators, or even the recycling of organic waste; likewise, they improve primary production and provide numerous ecosystem services such as improving soil fertility at surface horizon level (Boyer et al., 2010, Villeneuve, 2023).

5. CONCLUSION

The study showed the highlight changes induced by *Cajanus Cajan* on the repopulation of Termicidae, Formicidae and Lumbricidae in the soils of Kafigué. The greatest numbers of macrofauna were observed in plowed soil. As for the structure of the soil, the Cajanus favoured the structuring of the soil. It appears from this study that leguminous associations accelerated soil repopulation by Termicidae, Lumbricidae and Formincidae.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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