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Combined Effects of Compost, Supraxone and Lambda-Super on Soil Microbial Activity under Pluvial Cultivation of Sesame (*Sesamum indicum* L.) in Burkina Faso

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Abstract

Sesame cultivation is strategic for the economy of Burkina Faso. Indeed, after cotton, sesame is the second most important agricultural product for exportation. However, its production is limited by plant diseases and pest attacks. Facing this situation, large amounts of pesticides are used to boost productivity. But, these chemicals have a negative impact on soil fertility. In this instance, the effects of Supraxone and Lambda-super in the presence of compost on soil microbial activity under rainfed sesame cultivation in a peasant environment were studied. The experiment design was a block of Fisher (BCR) comparing the non-treated parcel (TNT) to the parcel amended only with compost (C) and to the parcel amended with compost and treated with the pesticides (C + P), respectively. Soil samples were taken at depths of 0 - 20 cm before sowing at 41st and 81st days after sowing. Respiratory activity and soil microbial biomass were monitored respectively by respirometric tests and by the fumigation-incubation method. The results show that the addition of compost into the soil with or without supraxone treatment and Lambda-super resulted in an increase in microbial biomass and soil respiratory quotient. These results show that the provision of compost in sufficient quantity corrects the inhibitory effect of soil biological activity by pesticides.

Keywords

Supraxone, Lambda-Super, *Sesamum indicum* L., Burkina Faso, Respiratory Quotient, Microbial Biomass

1. Introduction

The fast growth to the population in Africa involved an increase in food consumption needs leading to higher agricultural productivity. In Burkina Faso, the sesame production is a major component of the agricultural sector. It is cultivated on more than 800 hectare and yields more than 8 billion CFA francs in the country (Son et al., 2011). However, sesame production is highly negatively impacted by plant diseases and pest attack which causes the decrease of yield. Thus, to overcome the limits of production in terms of yield and nutritional quality of food, we are witnessing an intensification of agricultural production through the mechanization of increasingly advanced agricultural techniques, plant and animal selection, and especially the use of phytosanitary products (Joly, 2014). In Burkina Faso studies have shown the use of several pesticide formulations at widely varying doses (Gomgnimbou et al. 2009). Although effective in controlling crop pests, pesticide use causes damage that leads to reduced soil fertility (Schreinemachers & Tipraqsa 2012; Naré et al. 2017). After pesticide application, a significant portion is concentrated in the soil as a result of runoff, infiltration, adsorption and desorption processes. This can be harmful to living soil organisms (Savadogo et al. 2009). Several studies have highlighted the impact of pesticides on soil microbial activity. Some of their studies indicate that the impacts of pesticides on soil microbial activities depend on such large factors as pH, soil organic matter, clay content, temperature and type of pesticide, and applied dose (Kim et al. 2002). The study conducted by Mäder et al. (2002) showed that pesticides such as Dinoseb and Glufosinate induce a reduction of soil microbial biomass in the order of 20% to 50%, three (3) weeks after their application. Some research showed that the use of Chlorpyriphos-ethyl leads to a decrease in dehydrogenase activity (Tejada, Gomez, & DelToro, 2011). In addition, Naré et al. (2014) showed a decrease in the dehydrogenase activity after application of pesticides such as Endosulfan, Deltamethrin and Profenofos. According to the same authors, this decrease in the dehydrogenase activity is accompanied by the decrease of the microbial biomass and soil respiratory activity. Soil amendment by organic matter especially compost is practiced by most producers in Burkina Faso. This practice not only brings mineral elements to the soil but also stimulates the activity of soil microorganisms (Ros, Hernandez, & Garcia, 2003). They also play an important role in the future of pesticides (Savadogo et al., 2008; Kumar & Singh, 2013). These organic amendments have a positive effect regarding the maintenance of soil biological fertility (Ouédraogo, Mando, & Brussaard, 2004). However, data on the impact of pesticides on soil microorganisms in the presence of compost need to be confirmed and completed. The objective of this study was to evaluate the combined effect of herbicide, insecticide and compost on soil microbiological activity including soil respiration and soil microbial biomass.

2. Materials and Methods

2.1. Study Area

The study area located in the commune of Bagre, central-eastern region of

Burkina Faso, between 11˚32'51" north latitude and 0˚28'09" west longitude. The climate is tropical Sudanese type with a rainy season from May to October. The average rainfall is 700 to 1000 mm/year. The minimum and maximum temperatures are respectively 16.8˚C and 39.6˚C. There are lithosols and leached tropical ferruginous soils. An analysis of these soils at depths of 0 - 20 cm and 20 - 40 cm of soil gives the characteristics indicated in Table 1.

2.2. Pesticides Used

In this study, two pesticides were used. Supraxone witch is a herbicide of the chemical family Bipyridylium with the active ingredient Paraquat (200 g/l) and Lambda super 2.5 EC, an insecticide belonging to the chemical family Pyrethrinoids with active ingredient Lambdacyhalothrin 25 g/l.

2.3. Compost Used

The compost used was produced by farmers using stem residues of *Andropogon gayanus*, *Pennisetum pedicellatum* and *Loudetia togoensis* at a rate of 5 tonnes/ha. The characteristics of the compost are recorded in Table 2.

2.4. Plant Material

Sesame (*Sesamum indicum* L.) is an annual plant of the family *Pedaliaceae* grown in warm and moderately humid areas. The plant has a development of 0.70 to 2.30 meters according to the varieties (Rongead, 2013). Sesame seeds are housed in 2, 3 or 4-lobed capsules. Variety S-42 was used in this study. This variety has a vegetative cycle of 80 to 90 days and its agronomic potential is from 1000 to 1500 kg/ha of sesame seeds. The capsules are dehiscent at maturity. The average weight of 100 seeds is between 3 and 5 grams. The seed germination rate is above 90% to 95% in the first year and around 70% to 75% in the third year

Table 1. Selected chemical and physical parameters and soil microbial biomass.

Soil depth (cm)	Granulometry (%)					OM total	C total	N total	C/N	P_{ass} (g/kg)	K_{disp} (g/kg)	pH H_2O	pH_{KCL}
	Clay	Gross silt	Soft silt	Gross sand	Soft sand								
0 - 20	31.3	12.37	10.2	19.86	26.3	1.31	0.76	0.05	15.12	1.29	132.00	6.31	5.56
20 - 40	21.0	13.12	12.25	22.48	31.15	1.04	0.60	0.05	12.81	0.94	64.00	6.26	5.38

NB: OM total: total organic matter; C total: total carbon; N total: total nitrogen; Pass: assimilable phosphorus; Kdisp: potassium available.

Table 2. Characteristic of the compost used.

Parameters	pH eau	M O (%)	C total (%)	N total (%)	C/N	P total (g/kg)	P ass (mg/kg)	K total (g/kg)	K disp (mg/kg)
Values	7.46	66.5	38.57	2.4	16.07	0.65	103.67	3.51	153.06

NB: MO total: total organic matter; C total: total carbon; N total: total nitrogen; Ptotal: phosphorus total; Pass: assimilable phosphorus; Kdisp: potassium available; Ktotal: potassium total.

(Rongead, 2013). The first flowers appear after the 3rd week and the capsules are formed from the 4th or 5th week.

2.5. Experimental Design

The experimental set-up was a completely randomized block with three treatments and three replicates and was located on low slope terrain. With a total area of 868 m^2 (35 m × 24.8 m), it comprised 3 blocks of 179.2 m^2 (32 m × 5.6 m). Each block consisted of 3 elementary plots of 56 m^2 (10 m × 5.6 m). The driveway between two blocks was 2 m and the elementary plots were separated from each other by paths of 1 m. The treatments studied were as follows:

TNT: control plot not treated neither with pesticide nor compost;

C: plot amended with compost only;

C + P: composted plot treated with the herbicide Supraxone (Paraquat) and sowed with the insecticide Lambda Super (Lambda Cyhalothrin) on 31st and 56th days after sowing of sesame.

Seeding was carried out on flat plowed soil with a spacing of 20 cm between the pockets and 60 cm between the rows.

2.6. Soil Sampling

Soil sampling was carried out prior to trial placement at day 41 and day 81 after sowing sesame. The soil samples were taken at depths of 0 - 20 cm using an auger and at 3 points along the diagonal of each elementary parcel. These soil fractions were mixed to form a composite sample. They were dried in the shade, sieved to 2 mm and stored at room temperature.

2.7. Microbiological Analyzes

2.7.1. Respiratory Test

One hundred grams (100 g) of soil sieved at 2 mm and humidified to 2/3 of its retention capacity are introduced into a one liter glass jar. A beaker containing 20 ml of 0.1N sodium hydroxide (NaOH) and a container containing distilled water is also placed therein. The jar is hermetically sealed and incubated at 29˚C. The CO_2 released is trapped with sodium hydroxide and assayed by titration with 0.1 N HCl in the presence of phenolphthalein, after preliminary precipitation of the sodium bicarbonate with 2 ml of 3% Barium Chloride ($BaCl_2$). The incubation experiment lasted 21 days. The release of CO_2 was measured daily the first week, then every other day, from the 2nd and 3rd week of incubation. The quantity (Q) of CO_2 released, and hence of the mineralized carbon, is given by the following formula:

$$Q = (V_1 - V_2) \times 2.2$$

where Q: amount of CO_2 released in mg/100g of soil; V_1 = average volume of 0.1 N HCl used for the control and V_2 = average volume 0.1 N HCl used for the treatments.

2.7.2. Measurement of Soil Microbial Biomass

Determination of microbial biomass was made by fumigating the soil samples with chloroform vapor for 24 hours. Then, the incubation and the determination of the released CO_2 are carried out according to the method described by Dommergues (1960). The microbial biomass (MB) was determined by using the follows formula (Jenkinson, 1966).

$$\text{MB}(\text{mg}/100\text{ g of soil}) = \frac{\text{F0-7} - \text{F8-14}}{\text{Kc}}$$

where F0-7 = CO_2 released between 0 and 7 days by the fumigated samples; F8-14 = CO_2 released between 8 and 14 days by fumigated samples; Kc = 0.41 is the coefficient of proportionality representing the mineralizable fraction in CO_2 of the carbon.

2.7.3. Determination of the Respiratory Quotient of the Soil

Respiratory Quotient (qCO_2) is the daily amount of mineralized carbon per gram of microbial biomass. It was determined using the following formula (Ramade, 1992).

$$qCO_2 = \frac{\text{Cm}(14)}{1 \times \text{MB}}$$

Cm (14) is the mineralized carbon for 14 days of incubation; C-BM is microbial biomass; 14 is the number of days of incubation.

2.8. Statistical Treatment of Data

The Xlstat 2015 software version 17.1.01 was used for descriptive analysis and variance analysis (ANOVA). The separation of the means was performed by the Student-Newman-Keuls test at the 5% threshold. The modeling of the graphics was done using the Microsoft Excel 2016 software.

3. Results

3.1. Combined Effect of Compost, Supraxone and Lambda-Super on Cumulative CO_2 Production

The evolution of the cumulative amount of CO_2 during the 21 days of incubation is shown in **Figure 1**. In general, we note an increase in the release of CO_2 in all treatments during incubation. We also observe that for a given date, the total CO_2 production of the treatments does not differ statistically. Nevertheless, a comparison of the arithmetic mean values shows a higher CO_2 production at soil level amended to compost and treated with pesticides followed by soil compost alone and finally the control soil for samples from the 41st and 81st days after sowing (**Table 3**).

3.2. Combined Effect of Compost, Supraxone and Lambda-Super on Soil Microbial Biomass

The results of the impact of pesticide and compost treatments are shown in **Figure 2**. They also show that at each soil sampling date, the biomass of the

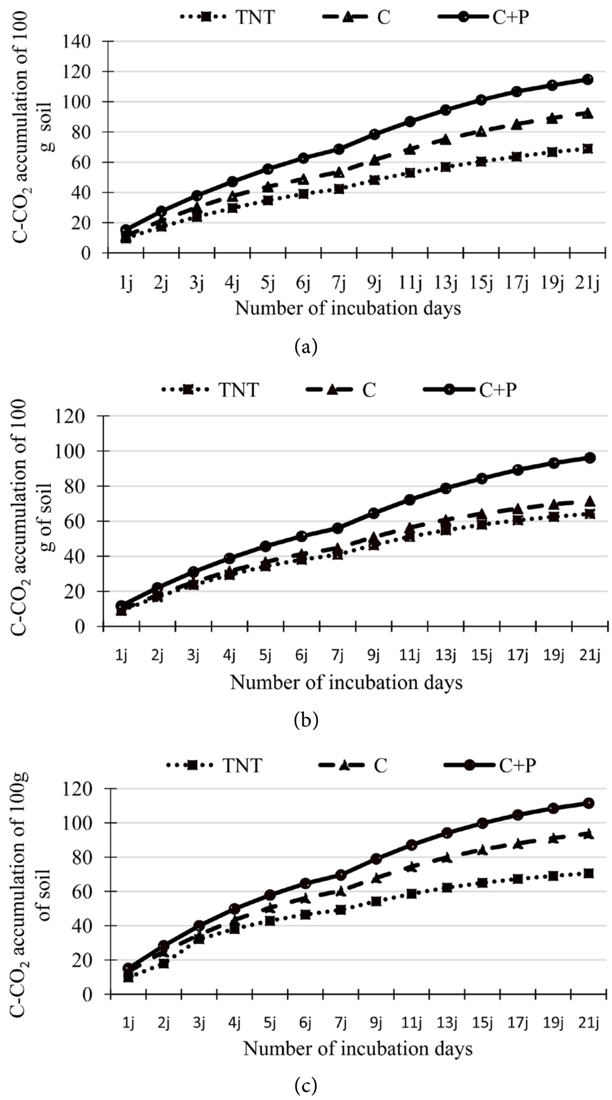

Figure 1. Evolution of cumulative CO_2 of the soil taken (a) before the establishment of the crop; (b) 41st and (c) at the 81st day after sowing sesame. NB: each value is the average of 3 measures.

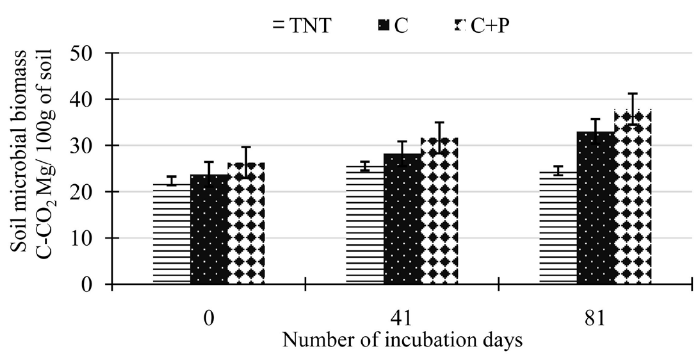

Figure 2. Evolution of the microbial biomass of soils collected at 0, 41, and 81st Days after sowing. TNT = control without pesticide and without compost; C = amended parcel with compost; C + P = plot amended with compost and treated with pesticides; NS = Not significant, values are averages of 3 repetitions.

Table 3. Cumulative CO_2 production after 21 days of incubation.

Sampling date (days)	Cumulative CO_2 production (mg/100g soil)		
	TNT	C	C+P
0	73.48 ± 08.58	71.04 ± 11.32	109.12 ± 13.43
41	64.19 ± 09.93	77.01 ± 10.18	82.44 ± 12.94
81	70.56 ± 10.59	93.78 ± 13.39	111.47 ± 14.19
Meaning	NS	NS	NS

TNT = control without pesticide and without compost; C = amended parcel with compost; C + P = plot amended with compost and treated with pesticides; NS = Not significant, values are averages of 3 repetitions.

composted and pesticide-treated parcel is always greater than that of the soil. of the plot amended with compost alone followed by the control. Statistical analyzes reveal no significant difference between treatments throughout the experiment (Figure 2). However, compared to the control, we note an increase in soil microbial biomass from 10.47% to 34.61% respectively at 41st and 81st days after sowing in the composted plots alone. In the presence of pesticides, we also observe an increase in soil microbial biomass from 23.85% to 54.31% respectively at 41st and 81st days after sowing.

3.3. Combined Effect of Compost, Supraxone and Lambda-Super on the Respiratory Quotient (qCO_2) of Soil

The results of the impact of pesticide treatments on the soil respiratory quotient are shown in Table 4. These results show that this quotient increases over time for all treatments, even if it drops to 81 days after sowing with soil amended and treated with Supraxone and Lambdasuper and with composted soil only. They indicate that the highest value of qCO_2 was obtained on the 41st days after sowing in the composted and pesticide-treated plot. However, these results do not reveal a significant difference between treatments. A comparison of the value of the averages makes it possible to classify the respiratory quotients of the treatments as follows: C + P < C < TNT for the soils taken at 41 days after sowing and TNT < C + P < C for soils collected at 81 days after sowing.

4. Discussion

4.1. Combined Effect of Compost, Supraxone and Lambda-Super on Cumulative CO_2 Production

The increasing evolution of cumulative CO_2 in all treatments shows an intensification of the soil's respiratory activity throughout the experiment. The higher CO_2 production at compost treatments compared to the control would be due to the effects of the amendment. Indeed, compost provides the sugars and nitrogenous materials necessary for these microorganisms for their own development and thus constitutes an energy source for soil organisms (Soltner, 2003). Similar results were obtained by many authors who observed a higher respiratory

Table 4. Evolution of the respiratory quotient of soils collected at 0, 41 and 81 days after sowing.

Sampling date (days)	qCO_2		
	TNT	C	C + P
0	$0.184^a \pm 0.01$	$0.183^a \pm 0.01$	$0.185^a \pm 0.01$
41	$0.184^a \pm 0.01$	$0.192^a \pm 0.02$	$0.201^a \pm 0.03$
81	$0.188^a \pm 0.03$	$0.178^a \pm 0.01$	$0.186^a \pm 0.02$
Meaning	NS	NS	NS

TNT = control without pesticide and without compost; C = amended parcel with compost; C + P = plot amended with compost and treated with pesticides; NS = Not significant, values are averages of 3 repetitions.

activity of soils richer in organic matter (Chaussod et al., 1992; Traoré et al., 2007; Ouattara et al., 2010). However, the intensity of respiration is greater in soils composted and treated with Supraxone and Lambdasuper than composted soils only. This seems to be related to the combined effect of pesticides and compost used. Indeed a study showed that endosulfan stimulated soil respiratory activity at a concentration of 6 ppm (Savadogo et al., 2009). Also, another study revealed that Diuron (800 g/kg), Endosulfan (500 g/l) and Lambdacyhalothrin (12 g/l), Profenofos (200 g/l) and Cypermethrin (72 g/l) couples, Acetamipride (16/l) stimulated the soil's respiratory activity after 30 days of application (Ouattara et al., 2010).

4.2. Combined Effect of Compost, Supraxone and Lambda-Super on Soil Microbial Biomass

Evolution of total microbial biomass for all treatments indicates an increase in the microbial population. But this is higher for compost treatments associated with pesticides compared to compost treatments alone. The stimulatory effect of compost on microbial biomass has been shown by an author for which the organic matter brings an additional biomass to the soils (algae, bacteria), acts as a soil buffer and promotes the catabolic activity of the microflora (Savadogo et al., 2008). This organic matter is also a source of nutrients for soil microorganisms (Soltner, 2003). Activation of microbial biomass following the associated intake of compost, Supraxone and Lambdasuper is consistent that microbial communities could be stimulated by pesticides if they were used as a source of complementary nutrients (carbon, nitrogen, phosphorus …) for this microbial population (Joly, 2014). This result is also similar to many studies which reveal that the organic amendment causes an increase in soil microbial biomass (Perucci et al., 2000; Chowdhury et al. 2008; Naré et al. 2010).

4.3. Combined Effect of Compost, Supraxone and Lambda-Super on the Respiratory Quotient (qCO_2) of Soil

The decrease in soil respiratory quotient observed in plots amended with compost and treated with Supraxone and Lambdasuper at the 81st days after sowing would reflect a good efficiency of the use of organic matter by the microorganisms present (Traoré et al., 2007). Our results corroborate those studies which showed that the combination compost and pesticides such as Diuron (800 g/kg), Endosulfan (500 g/l), Lambdacyhalothrin couples (12 g/l), Profenofos (200 g/l) and Cypermethrin (72 g/l), Acetamipride causes a decrease in the soil respiratory quotient of 41.9% 119 days after sowing (Ouattara et al., 2010). This result is similar to other study which showed that Endosulfan, used at a dose of 3 ppm did not affect soils cultivable aerobic microflora [6]. We can therefore conclude that doses of pesticides applied in the present study are insufficient quantities to produce a negative impact on soil respiration.

5. Conclusion

The effects of pesticides and compost on soil biological activity were studied during this work. The contribution of compost has led to an increase in the respiratory activity and soil microbial biomass both in the presence and absence of pesticide residues. Thus, the contribution of compost makes it possible to reduce the inhibitory effects of pesticides on the biological activity of the soil under cultivation. Our results show that the use of compost makes it possible to maintain the biological activity and consequently the fertility of the soil under cultivation. To better appreciate the effect of pesticides on soil microbiological activities, it would be interesting to study the impact of pesticides on soil biodiversity and some specific enzymatic activities of soil under sesame cultivation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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