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Effects of biological fertilizers on the yields of onion (*Allium Cepa* L.) and on soil physico-chemical, microbiological properties in the Centre-weste of Burkina Faso

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ABSTRACT: In Burkina Faso, vegetable production is a very important asset for the socio-economic development. However, many constraints negatively affect its potential. The use of biological fertilization has been proved to be a satisfactory alternative to these issues. Therefore, this experiment uses some composts based on local substrates (*Bokashi* compost and compost enriched with *Trichoderma harzianum*) to study their agro-economic benefit on onion and their effects on soil chemical properties. The study was carried out in the Central-West region of Burkina Faso, using a completely randomized Fisher block design with six treatments in three replications. The applied treatments were: T0 (control); T1 (*Trichoderma harzianum* enriched compost + 175 kg ha^{-1} of NPK (14-23-14) + 50 kg ha^{-1} of urea (46%)); T2 (compost enriched with *Trichoderma harzianum*); T3 (350 kg ha^{-1} of NPK (14-23-14) + 100 kg ha^{-1} of urea (46%)); T4 (*Bokashi* compost + 175 kg ha^{-1} NPK (14-23-14) + 50 kg ha^{-1} urea (46%)); T5 (*Bokashi* compost). The results showed that the use of biological fertilizers enhanced onion yield compared to that of the control plot. In addition, the combination of compost enriched with T*richoderma harzianum* and mineral fertilizer led to better yield increase of more than 200% compared to the control plot. Moreover, these biological fertilizers were able to stabilize soil pH neutrality and significantly increased soil organic matter content and its mineral properties (N, P, K, Mg, Ca). Then, for a sustainable and efficient agriculture, it would be necessary to disseminate these two composts in particular that enriched with *Trichoderma harzianum* having better agro-economic benefit and increasing soil fertility.

KEYWORDS: Burkina Faso, *Bokashi* compost, compost enriched with *Trichoderma harzianum*, economic benefit, onion yield, soil fertility.

1 INTRODUCTION

Onion (*Allium cepa*) is the most widely cultivated species of the genus Allium [1]. It is recognized worldwide as one of the most important vegetable crops. It has high nutritional value and many highly beneficial properties for human health, such as polyphenols, flavonoids and antioxidants [2], as well as carbohydrates and sugar [3], protein and vitamin C [4]. Also, it was reported by Adriouch (2017) [5] that onions may decrease the risk of heart disease and certain cancers. This vegetable crop is produced on a total of 2.7 million hectares in the world with a total production of 742.51 million tons (FAO, 2012) [6]. The largest producers include China (205.08 million tons), India (133.72 million tons) and the United States of America (33.21 million tons) (FAO, 2012). In West Africa, the average annual production of onions is about 1.1 million tons, accounting for less than

2% of world production [7]. According to these authors, Nigeria is the region's largest producer and importer with a total annual production of 618,000 tons. It is followed by Niger with a production of 447,000 tons. In Burkina Faso, onion accounts for about a third, or 32.4% of the market-garden production and mobilizes more than 160,000 producers It ranks 4th in Africa with an average annual production of 242,258 tons [8] and a turnover of 4.38 billion CFA Francs in 2005 to 24.87 billion in 2008 [9]. This sector also contributes to the reduction of unemployment, especially in the dry season. Producers can find on-site cash income to improve their socio-economic conditions, which can make an important contribution to improving the living conditions of populations. Onion production can also be a partial alternative to reducing the exodus of young people to urban centers. Therefore, this sector is a source of hope for producing countrie's economies. However, nowadays, crop vegetable production is facing more and more difficulties link to climate, to land issues, and mainly to arable soil fertility decrease. In Burkina Faso, land degradation problem affects agricultural production. Crop yields are decreasing with a huge impact on food security. Therefore, to increase food security and environmental sustainability in agricultural systems, there is a need to adopt an integrated soil fertility management approach which could maximize crop production and minimize nutrients depletion and soil physical and chemical properties contents. Then, this study uses biological inputs to improve onion production and soils physico-chemical properties.

2 Materials And Methods

2.1 Study Site

The study was conducted in the village of Soala (Figure 1) located in the department of Nanoro, Province of Boulkiemdé, in the Central West Region of Burkina Faso. The study site was situated between 12°39' and 12°18' N and between 1°57' and 1°37 W and was at 62.8 km from Ouagadougou along the Ouagadougou-Yako axis.

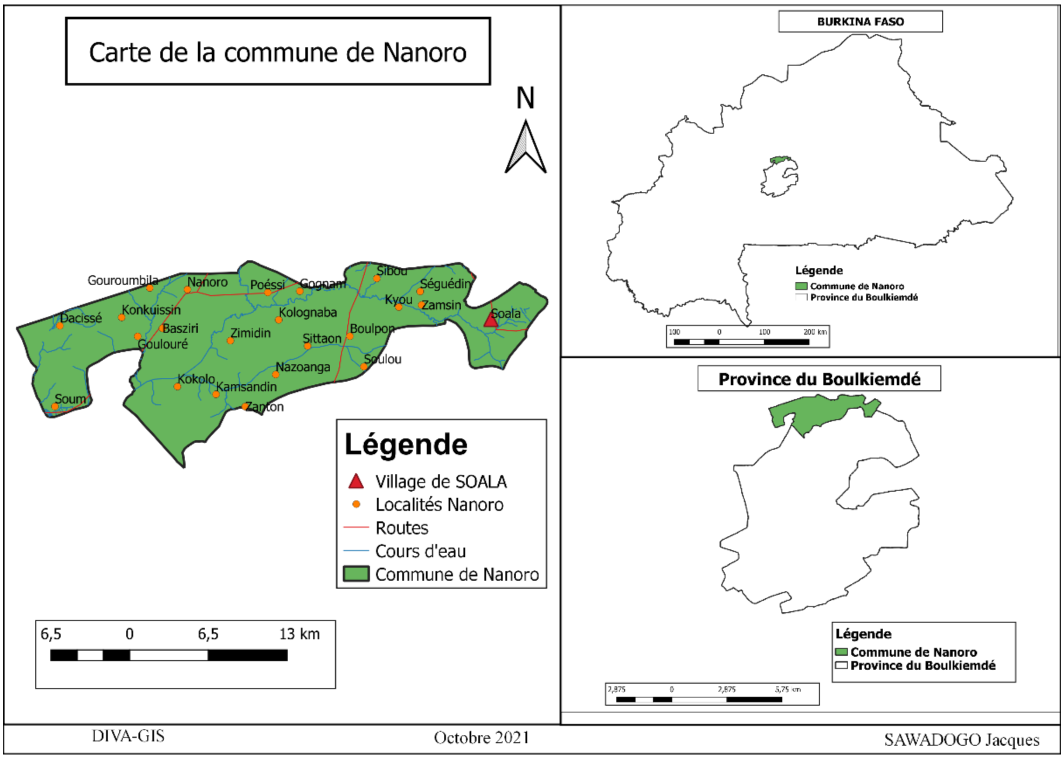

Fig. 1. Location of the study site

2.2 Plant Material

Karibou variety of onion (*Allium cepa* L.) was used in this experiment. It has a maturity cycle of 120 days with a potential yield between 40 and 45 t/ha [10].

2.3 BIOLOGICAL AND MINERAL FERTILIZERS

The biological fertilizers used were *Bokashi* compost and compost enriched with *Trichoderma harzianum*. These fertilizers were applied according to their recommended rate (30 t. ha^{-1} or 3 kg/m²). Mineral fertilizers such as NPK (14-23-14) were brought in two fractions, on the 14th and 28th day after transplanting (JAR) at a dose of 350 kg ha^{-1} and urea (46%) was brought in a single dose of 50 kg ha^{-1} at the 28th day after transplanting. The biological pesticide Solsain was used at a rate of 2 mL/ha to improve soil health, Piol at emergence to control onion leaf pests, and BioPoder at 2 mL/ha to control all underground pests.

2.4 EXPERIMENTAL DEVICE AND CULTURAL PRACTICE

A completely randomized Fisher block design was used. Two factors were considered in this design: the fertilization factors (compost enriched with *Trichoderma harzianum*; *Bokashi* compost and mineral fertilizer) and water supply for onion speculation. The combination of these factors led to six (06) treatments in three replications, with a total of eighteen (18) elementary squares randomly distributed on the site plots. The applied treatments were: T0 (control); T1 (compost enriched with *Trichoderma harzianum* + 175 kg ha^{-1} of NPK (14-23-14) + 50 kg ha^{-1} of urea (46%)); T2 (compost enriched with *Trichoderma harzianum*); T3 (350 kg ha^{-1} of NPK (14-23-14) + 100 kg ha^{-1} of urea (46%)); T4 (*Bokashi* compost + 175 kg ha^{-1} NPK (14-23-14) + 50 kg ha^{-1} urea (46%)); T5 (*Bokashi* compost). The *Karibou* variety was transplanted with a density of 48 plants per plot of 2 m^2 of area, after 45 days in a nursery. Three manual weeding were performed at 3, 6 and 8 weeks after transplanting. Water was supplied twice a day at the beginning of transplanting, and one per day from 30 days after to the end of the experiment.

2.5 ONION BULB YIELD

Yield was assessed at harvest on each plot. Extrapolation to the hectare has been possible by the formula:

$$\text{Yield (t. ha}^{-1}\text{)} = \text{Yield (g/foot)} \times 500\,000 \qquad \text{equation 1}$$

With 500,000 as the average number of feet per hectare.

2.6 YIELD GAIN

The yield gain is the additional yield gain due to a fertilizer over the absolute control. It was determined as follows:

$$\text{Efficiency gain} = \frac{X_2 - X_1}{X_1} \times 100 \qquad \text{equation 2}$$

With X_2: Processing yield; X_1: control yield

2.7 VALUE COST RATIO (VCR) AND RETURN ON INVESTMENT (ROI)

A cost-to-value (RVC) ratio has been calculated to identify the best treatment that can be readily adopted by producers. It is the ratio of the net monetary gain to the total variable costs of fertilizers calculated according to the following formula:

$$\text{VCR} = \frac{X - Y}{Z} \qquad \text{equation 3}$$

Where X: Net Treatment Benefit (CFA Francs/ha); Y: Net Control Benefit (CFA Francs/ha) and Z= Total Variable Costs. A technology can only be readily adopted if the VCR value is equal to or greater than 2. Adoption is reluctant if this value is between 1.5 and 2 and below 1.5 there is rejection [11], [12].

The return on investment (ROI) makes it possible to see whether the profits obtained after the sale of the tomato have made it possible to offset the expenses made during the production.

$$\text{ROI} = \frac{X - Z}{Z} \times 100 \qquad \text{equation 4}$$

Where X is the treatment net benefit (CFA Francs) and Z is the total variable costs (CFA Francs).

To assess the benefits of growing onions, the following costs were taken into account: the costs related to biological fertilizers and pesticides, the seeds, harvesting of onion bulbs, transport and incorporation into the soil. The cost of *Bokashi* compost and compost enriched with *Trichoderma harzianum* is 5000 CFA Francs/50 kg and 6000 CFA Francs/50 kg respectively. The average price per kg of onion in the market of Burkina Faso is about 700 CFA Francs. The net profit was obtained with a margin of 15% loss.

2.8 Collection And Preparation Of Soil Samples

Soil samples were collected using the diagonal method before and after the experiment at 0 – 20 cm depth. For each plot, a composite sample was obtained by mixing 4 elementary samples. The soil samples collected were then dried at 40°C for four days in a SHIMADZU and STAC S-50M oven, and ground using a TM-25S mechanical device and sieved to 2 mm and bagged for analysis.

2.9 Measurements Of Soil Chemical And Biological Parameters

Soil samples analyses were done using the analytical methods developed by Blume [12], [13]. These analyses involved the determination of pH (water and KCl), total nitrogen, organic carbon, and available phosphorus [14], [15], [16]. Soil respiration was measured by respirometry method. This expresses the potential soil biological activity depending on the the presence of the biodegradable organic matter. The respirometry (CO_2) test measured the amount of CO_2 released from soil samples incubated. For its measurement, fifty grams (50 g) of each soil sample sieved to 2 mm and moistened to 2/3 of their maximum holding capacity were placed in a glass jar. Tightly sealed jars are incubated at room temperature. Each sample is in three (03) replications. Measurements of CO_2 release were made every twenty-four (24) hours for one week and then every 48 hours until the 14th day of incubation [17]. All these measurements were done in the Soil-water-plant Laboratory of the Environmental, Agricultural Research and Training Centre of Kamboinsé (CREAF) in Burkina Faso.

2.10 Data Analysis

To assess the differences and identify the correlations among parameters, data was subjected to one factor analysis of variance (ANOVA) [18], [19]. The means comparison was performed using the Student Newman-Keuls (SNK) test at the 5% threshold using GenStat Release 12.1 software. The histograms were built with the 2016 Excel spreadsheet. Also, changes in soil characteristics between the beginning and the end of the experiment were calculated using the formula:

$$Y\,(\%) = \frac{Y_2 - Y_1}{Y_1} \times 100 \qquad \text{equation 5}$$

with Y_2: value of the parameter considered at the end of the experiment and Y_1: value of the parameter considered at the beginning of the test [20], [21], [22],. Indeed, according to the formula, negative values suggest losses in soil properties, whereas positive values suggest an improvement in soil fertility.

3 Results

3.1 Effects Of Biological Fertilizers On Yield And Yield Gain Of The Onion Crop

Figures 2 and 3 showed the effect of the applied treatments on onion bulb yield. At the end of the study, High significant differences were observed in yield and yield gain ($p < 0.001$ and $p = 0.002$ respectively). The highest yields were obtained within plots under compost enriched with Trichoderma harzianum (T2 = 50.32 t. ha-1), followed by *Bokashi* compost combined or not with recommended mineral fertilizer (T4 = 44.77 t. ha-1 and T5 = 43.27 t. ha-1). The lowest yield was noted in the control plot (T0 = 30.37 t. ha-1).

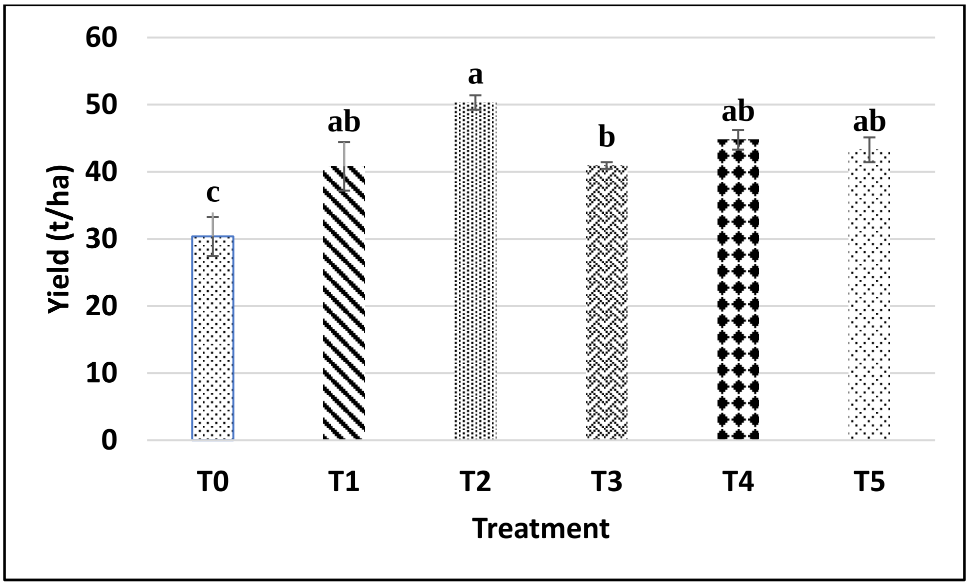

Fig. 2. Effects of Fertilizer on Onion Yield

Legend: T0: control; T1: compost enriched with T. harzianum + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T2: compost Enriched compost with T. harzianum; T3: 350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea; T4: Bokashi compost + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T5: Bokashi compost

Similarly, to onion yield, the results indicated that the highest yield gain (Figure 2) was reported within plots amended with compost enriched with *Trichoderma harzianum* (T2= 1995%), followed by *Bokashi* compost combined or not with the recommended mineral fertilizer (T4 = 1441% and T5 = 1291% respectively). Here too, the lowest yield gain was assessed in the control plots and in the plots amended with 350 kg ha-1 of NPK + 100 kg ha-1 of urea (T3= 1057%) and with compost enriched with *Trichoderma harzianum* combined with the recommended mineral fertilizer (T1 = 1045%). At the end of the study, treatments are classified according to their positive influence on yield and yield gain: T2>T4>T5>T3>T1>T0.

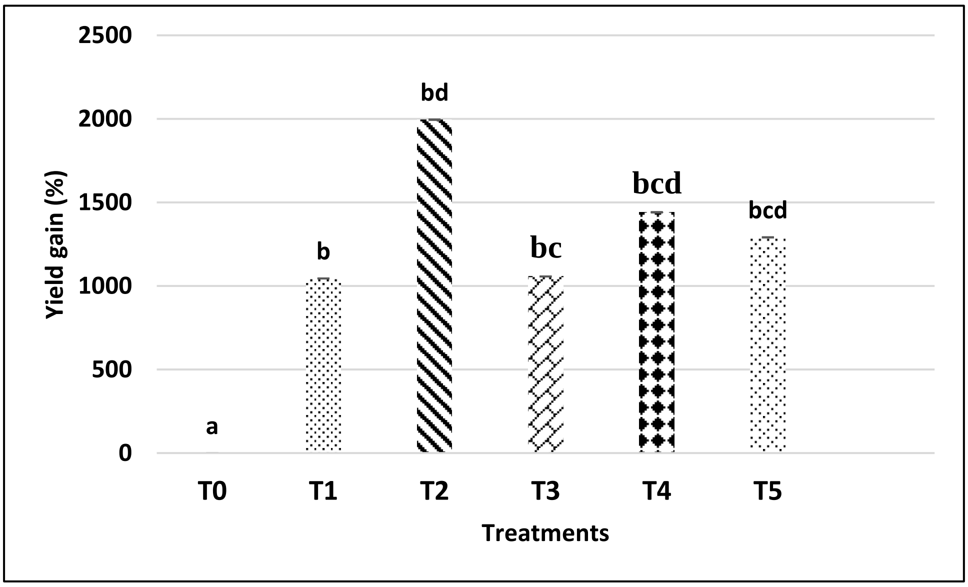

Fig. 3. Effects of Fertilizer on Yield Gain of Onion Crop

Legend: T0: control; T1: compost enriched with T. harzianum + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T2: compost enriched with T. harzianum; T3: 350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea; T4: Bokashi compost + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T5: Bokashi compost

3.2 Economic Results

Data collected and analyzed on economic profitability showed in that total variable costs, gross profit, net profit, and financial profitability on one hectare of onion were greater in the treatment T2 and T4 where compost enriched with *T. harzianum* and *Bokashi* compost combined with mineral fertilizer were applied. These two treatments (T2 and T4) profit margins were 27,159,159 and 24,058,965 CFA Francs respectively. The lowest profit margin with an amount of 16, 287, 503 CFA Francs resulted from the control. Then, using the biological fertilizer (compost enriched with *Trichoderma harzianum*) alone proved to be the most advantageous treatment compared to *Bokashi* compost combined with mineral fertilizer. The whole treatments applied impacted positely the economic profitability of onion through the values of the VCR and ROI. Therefore, all treatments can be suggested to vegetable growers with more chance of adoption. However, because of the purchasing power of most growers in the study area or even in the country, the treatment based on compost enriched with *Trichoderma harzianum* (T2) could be recommended.

Table 1. Economic analysis of 1 ha of onion according to fertilizer treatments

Treatment	Total variable costs (FCFA/ha)	Yield (kg/ha)	Gross income (FCFA/ha)	Gross profit (FCFA/ha)	Net profit (FCFA/ha)	VCR	ROI
T0	897 802	30 367	21 257 180	20 591 628	16 287 503	-	17.14
T1	1 224 253	40 818	28 572 880	27 619 877	21 878 902	4.57	16.87
T2	1 276 172	50 322	35 225 120	34 220 198	27 159 158	8.52	20.28
T3	1 244 697	40 942	28 659 120	27 685 673	21 931 538	4.53	16.62
T4	1 268 654	44 775	31 342 360	30 344 957	24 058 965	6.13	17.96
T5	1 169 268	43 274	30 291 800	29 393 783	23 298 026	6.00	18.93

Legend: T0: control; T1: compost enriched with T. harzianum + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T2: compost enriched with T. harzianum; T3: 350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea; T4: Bokashi + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T5: Bokashi; VCR: cost ratio; ROI: return on investment

3.3 Effect Of Treatments On Soil Physico-Chemical Parameters

Soil samples were collected and analyzed in the laboratory at the beginning and at the end of the experiment to characterize its physico-chemical properties. The results of the analysis of variance shows some variations in C, N, P, K and exchangeable bases contents among treatments in and their changing rate in Significant differences were noted among these treatments at 5% of probability. Compost enriched with *Trichoderma harzianum* combined to mineral fertilizer (T1) was found to have great influence on soil chemical properties (C, N, P, K, Ca^{2+} and Mg^{2+}). This study also reported that the exclusive application of mineral fertilizer led to soil acidification (pH<6). However, treatments with biological fertilizer (Compost enriched with *Trichoderma harzianum* and *Bokashi* compost) contributed to increase soil pH (pH>6), result of reduction of soil acidity. Comparing the basic sample and those collected at the end of the experiment, it was sought that all chemical elements increased excepted the total P that decreased in all treatments. At this level too, compost enriched with T. *harzianum* combined to mineral fertilizer (T1) was the most contributing to high percentages of change in total carbon (98.7%), total nitrogen (32.05%), total potassium (49.18%), and organic matter (7.82%). Moreover, the smallest decreases in total phosphorus were observed in this (T1) treatment and also in T2 one (compost enriched with T. *harzianum*). Nevertheless, the results showed improvements in C/N ration, in organic carbon, N and K contents induced by biological amendment.

3.4 Effect Of Fertilization On The Biological Properties Of Soils At The End Of The Season

At the end of the experiment, soil samples were collected to measure CO_2 release. The results presented on showed the highest values of CO_2 released within plots amended with *Bokashi* compost combined with a ½ dose of mineral fertilizer (T4 = 8.35 mg.100g^{-1}) and compost enriched with *Trichoderma harzianum* (T2 = 7. 25 mg.100g^{-1}). The other CO_2 emissions from *Bokashi* compost (T5 = 4.463 mg.100g^{-1}), mineral fertilizer (T3 = 3.66 mg.100g^{-1}) and compost enriched with *Trichoderma harzianum* combined to a ½ dose of mineral fertilizer (T1 = 3.44 mg.100g^{-1}) were found medium-high. The lowest CO_2 release was noted in the control plot with a released CO_2 value of 2.41 mg.100g^{-1} soil.

Table 2. Soil properties (0-20 cm) before and at the end of the study

Treatment	pH	pH	C	N	P	K	Ca	Mg	MO	C/N
	H_2O	KCl	%	$g.kg^{-1}$	$g.kg^{-1}$	$mg.kg^{-1}$	$g.kg^{-1}$	$g.kg^{-1}$	%	
T0': Pre-test	7.17	7.45	2.3	2.26	125	1.02	40.4	0.85	3.94	13
T0: Control	5.33[a]	5.717[a]	2.383[a]	1.233[a]	85[a]	1.133[a]	71.67[bd]	1.0[a]	4.080[a]	17[cd]
T1: enriched compost + ½ FMV	7.2[f]	6.547[a]	4.57[e]	2.953[e]	124[c]	1.517[d]	139.33[e]	1.05[a]	7.824[e]	15[bc]
T2: enriched compost	6.95[e]	6.467[a]	3.907[d]	2.984[e]	116[b]	1.47[cd]	25.87[abc]	0.98[a]	6.688[d]	13[a]
T3: FMV	5.94[b]	5.893[a]	3.050[b]	1.811[b]	119[bc]	1.3[b]	40.33[abcd]	0.977[a]	5.222[b]	17[d]
T4: *Bokashi* compost + ½ FMV	6.33[c]	6.183[a]	3.46[c]	2.320[c]	124[c]	1.32[b]	14.63[a]	1.063[a]	5.924[c]	14[ab]
T5: *Bokashi* compost	6.83[d]	6.433[a]	3.47[c]	2.424[d]	136[d]	1.41[c]	24.33[ab]	0.97[a]	5.941[c]	15[b]
Cv (%)	0.7	8.8	1.1	1.8	2.5	3.2	37.5	14.5	1.1	4.6
Probability	<0.001	0.389	<0.001	<0.001	<0.001	<0.001	<0.001	0.944	<0.001	<0.001
Meaning	THS	NS	THS	THS	THS	THS	THS	NS	THS	THS

Legend: FMV: Mineral Manure (350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea); THS: Very Highly Significant; NS: Non-Significant; Cv: Coefficient of variation

Table 3. Percentage change in physical-chemical properties of soils

Treatment	pH_{H2O}	pH (KCl)	C	N	P	K	Ca	Mg	MO
	%								
T0: Control	-25.7[a]	-23.3[a]	3.62[a]	-45.44[a]	-32[a]	11.48[a]	77.39[bd]	17.65[a]	3.62[a]
T1: enriched compost + ½ FMV	0.37[f]	-12.16[a]	98.7[e]	32.05[e]	-0.8[c]	49.18[d]	244.88[e]	23.53[a]	98.7[e]
T2: enriched compost	-3.11[e]	-13.24[a]	69.86[d]	30.66[e]	-7.2[b]	44.59[cd]	-35.97[abc]	15.29[a]	69.86[d]
T3: FMV	-17.19[b]	-20.93[a]	32.61[b]	-19.87[b]	-4.8[bc]	27.87[b]	-0.17[abcd]	14.9[a]	32.61[b]
T4: *Bokashi* compost + ½ FMV	-4.79[d]	-17.04[a]	50.43[c]	2.64[c]	-0.8[c]	29.84[b]	-63.78[a]	25.1[a]	50.43[c]
T5: *Bokashi* compost	-11.76[c]	-13.69[a]	50.87[c]	7.26[d]	8.8[d]	38.69[c]	-39.77[ab]	14.12[a]	50.87[c]
Cv (%)	6.3	43.9	3.3	152.7	37.7	12.6	160.5	93.3	3.3
Probability	<0.001	0.389	<0.001	<0.001	<0.001	<0.001	<0.001	0.944	<0.001
Meaning	THS	NS	THS	THS	THS	THS	THS	NS	THS

Legend: FMV: Mineral Manure (350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea); THS: Very Highly Significant; NS: Non-Significant; Cv: Coefficient of variation

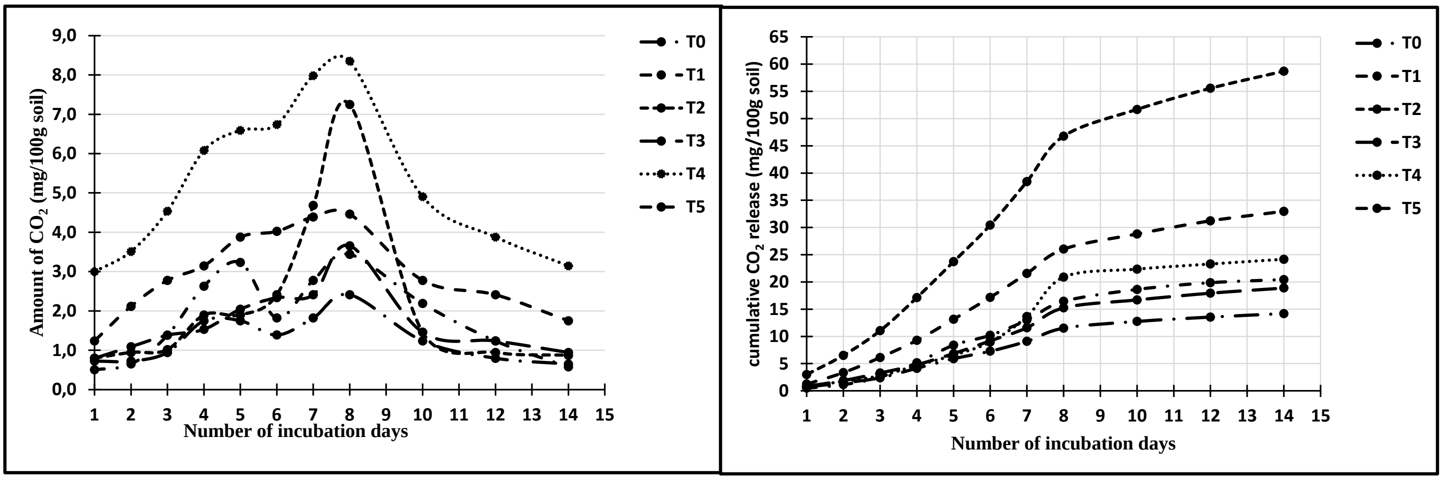

Fig. 4. Effect of treatments on soil respiration under onion culture

Legend: T0: control; T1: compost enriched with T. harzianum + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T2: compost enriched with T. harzianum; T3: 350 kg ha^{-1} of NPK + 100 kg ha^{-1} of urea; T4: Bokashi + 175 kg ha^{-1} of NPK + 50 kg ha^{-1} of urea; T5: Bokashi

4 Discussion

4.1 Effects Of Treatments On Onion Yield

The results showed that the biological composts combined with chemical fertilizer contributed to enhance onion yield. In addition, soil fertility was improved under these treatments [23]. This finding resulted from soil microorganism's activities where the recommended mineral fertilizer was used to accelerate the mineralization of the organic manure. Lot of research findings asserted this result. According to them, the combination of biological and chemical fertilizers led to better production conditions that improves the physico-chemical and biological properties of the soil [24]. And, mineral fertilizers provide plants with the nutrients for increasing agronomic efficiency [25]. With 500 kg. ha-1 of biological fertilizer, the average yield gain of onion bulb is 1995% (T2) and 1291% (T4) against 1045% (T5) and 1441% (T3). These results proved that onions can be produced using only biological or biological fertilizers. For that reason, regular application of biological fertilizer would be necessary to restore soil fertility and increase crops yields. This experiment highlighted also the nature of the biological fertilizers applied in this study. The mineralization of compost enriched with *Trichoderma harzianum* incorporated into the soil was faster than that of the *Bokashi* compost. The C/N ratio asserted these results. Indeed, the ratio was 14 in *Bokashi* and 13 in compost enriched with *Trichoderma harzianum*. The high ratio of *Bokashi* indicates low mineralization and nutrient release from this compost. The low C/N ratio of compost enriched with *Trichoderma harzianum* indicating a best mineralization could explain the best growth, yield and yield gain and soil chemical properties noted within treatments with *Trichoderma harzianum*.

4.2 Effects Of Treatments On Economic Profitability

This study showed that the best profitability was achieved with compost enriched with *Trichoderma harzianum* (T2=8.52) followed by T4 (6.13) (*Bokashi* compost + Mineral fertilizer) and T5 (6) (Bokashi compost alone). Although all treatments were cost-effective, the profitability was significantly improved with the use of compost enriched with *Trichoderma harzianum* alone (T2 = 8.52) compared to *Bokashi* compost (T5 = 6). The additional contribution of the mineral fertilizer resulted in a decrease in the profit margin of the different composts (T2 and T5). These results were linked to the additional costs of purchasing mineral fertilizers for each treatment. These findings were similar to that of lots of authors [22], [26], [27] who reported that the high profitability of treatments resulted from their low cost of production The value/cost ratio was greater than 2 in all treatments, indicating that the production of this onion variety was profitable [11].

4.3 Effects Of Treatments On Soil Physico-Chemical And Biological Parameters

The low pH noted in the mineral fertilizer treatments asserted the results of previous works. According to these works, the excess use of chemical fertilizers led to tropical ferruginous soils acidification in Burkina Faso [25], [28], [29]. The improvement in soil pH within plots amended with biological composts was due to the high content of cation in these biological fertilizers. The basic cations bind to the argilo-humic complex and reduce the concentration of the Al^{3+} and H^+ ions in the soil solution. Basic cations are essential to neutralizing soil acidity [30], [31, 32]. The findings reported on soil chemical properties in this study resulted from the use of biological fertilizers combined or not with chemical fertilizer agreed with lots of previous results found by several authors. Biological fertilizers and composts increase organic carbon, biological activity, soil moisture and also soil nitrogen, phosphorus, potassium, magnesium and calcium [33], [34], [35]. The high content of these soil chemical properties and improvement in pH noted in the plots amended with compost enriched with *Trichoderma harzianum* alone asserted the ability of compost enriched with *Trichoderma harzianum* to restore soil fertility. This is due to soil microbial activity favored by some fungi contained in this compost. Many authors in the Democratic Republic of the Congo such as [34], [36], [37], [38], highlighted this ability of *Trichoderma harzianum* to restore the acidic soils. Moreover, Sawadogo et al. (2020) [10] showed that compost enriched with *Trichoderma harzianum* and *Bokashi* maintained soil pH neutrality and improved soil organic carbon, nitrogen, phosphorus and potassium contents. Biological production of CO_2 is a function of the microbial population, mainly the decomposers, their diversity and the metabolic enzymes secreted [39], [40]. The CO_2 emission curves as a function of incubation time show that the different stages of mineralization are similar to those described by Zombre (2006) [32]; the small CO_2 emissions observed at less than 24 hours (1 day) show low biological activity in the soil, meaning that, soil microorganisms would still be dormant and would have little activity. High releases during the first six (06) days of incubation would be consistent with the removal of dormancy that initiates soil biological activity and degradation of readily biodegradable products. Microbial species emerging from their dormancy after water supply, have found sources of energy under favourable pH conditions [41]. This growth stage would correspond to the biodegradation of dead microorganisms during the desiccation stage and labile compounds such as sugars and protein compounds [25]. This phenomenon results in a peak of CO_2 release culminating from the 6th day. These results show that biological fertilizers combined with a half dose of mineral fertilizer (T1, T4), compost enriched with *Trichoderma harzianum* (T2) and *Bokashi* compost (T5) promote the release of CO_2 compared to the control, but this release is more important under the *Bokashi* compost than in that enriched with *Trichoderma harzianum*. The chemical composition of these two (02) fertilizers, particularly nitrogen (N) and phosphorus (P), could explain the larger amounts of CO_2 release as reported by several authors [41], [42]. This release of CO_2 into the soil results in the biological response to a change in the environment. The application of compost enriched with T. harzianum would further increase the mineralization of organic matter caused by better water conditions and favourable pH. This would explain the importance of CO_2 release in the treatments amended with compost enriched with *Trichoderma harzianum* and that of *Bokashi*. These results are consistent with those of Karimou et *al*. (2004) [43] who concluded that polyter stimulated mineralization of organic manure. Also, the appearance of peak mineralization would be explained by the mineralization of water-soluble compounds, celluloses and lignin, the diversity of soil microorganisms, nutrient content and physical properties of the soil [24]. The downward stage observed from the 7th day of incubation would reflect the decrease in biological activity justified by the decrease in the level of readily biodegradable substances in all treatments. This decrease in CO_2 release may also be due to the presence of recalcitrant compounds that may inhibit microbial growth [32].

5 CONCLUSION

The study showed that all treatments applied increased the agronomic potential of onion variety. The application of biofertilizers has greatly contributed to the improvement of yield, physico-chemical and biological parameters. However, among these treatments, compost enriched with Trichoderma harzianum proved to be the most effective in onion production because of the presence of a fungus in this compost. Studying the economic profitability, the production of one hectare of onion was profitable at all levels of the applied treatments. However, the T2 treatment (compost enriched with Trichoderma harzianum) resulted in the best financial return (VCR = 8.52 and ROI = 20.28) while the T3 treatment had the lowest cost of production. For these results, the amendment based on compost enriched with *Trichoderma harzianum* could be an interesting alternative to the use of chemical fertilizers in onion production. Using this local and natural resources at low cost of production and ecologically sustainable, could help improving onion producer income, maintain soil fertility and the health of the environment, and guaranteeing the quality of onion produced.

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