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# Effect of Bio-Fertilizers on Tomato (*Solanum Lycopersicum*) Production and on Soil Physico-Chemical Properties In Sudan Area of Burkina Faso

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**Abstract**

In Burkina Faso, vegetable production is a very important asset for its socio-economic development. However, this production faces many constraints that negatively affect its potential. The use of organic fertilization appears to be an alternative to address these constraints and could also promote sustainable agricultural production. In such a context, this study was conducted on tomato using two bio-fertilizers based on local substrates (*Bokashi* compost and compost enriched with *Trichoderma harzianum*). The objective was to assess the efficiency of the two bio-fertilizers by determining their effects on tomato yield and soil physico-chemical properties. It was conducted from 2018 to 2020 in Soala using a randomized Fischer block design with six treatments in three replications. The treatments were T0 (control), T1 (NPK+urea), T2 (*Bokashi* compost), T3 (compost enriched with *Trichoderma harzianum*), T4 (T1+T2) and T5 (T1+T3). The results showed that the bio-fertilizers alone contributed to maintain the neutrality of soil pH and very significantly improved its C, N, P and K content. Moreover, in combination with or not with NPK+urea, they influenced significantly plant growth, yield components and yield of tomato compared to T0 plot. In these years of trials, compost enriched with *Trichoderma harzianum* in combination with or not with NPK+urea, was found to be the most improving tomato yield and the increase was more than 300%. This compost could be therefore recommended to farmers in agriculture in general and particularly for vegetable production.

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## Introduction

Tomato (*Solanum lycorpersicum*) is a major vegetable/fruit extensively grown worldwide for human consumption. It is Africa's most consumed fruit eaten by millions of people (Viskelis,[1] Tofunmi[2]) and considered as an important cash crop in sub-Saharan Africa (Venance and Deus,[3] Dube,[4] Malherebe and Marais,[5] Ochilo[6]). The fruit plays an important role in human nutrition, where it can be eaten as a fresh salad vegetable, processed, stewed, fried, baked and can also be used to produce soup or juice or ketchup (Dube).[4] According to these authors, tomato fruit may also be put into various dishes as the main ingredient.

In Burkina Faso especially, tomato is produced all over the country and is an important crop for increasing household resilience and nutrition. It is the second most important vegetable crop after onion (Son)[7] and one of the market garden crops grown throughout the country.According to these authors, its national production is evaluated to 289.572 tons on an area of 11.766.4 ha during the 2013–2014 vegetable season. From the northen to the southern parth of the country, tomato production varies and the largest production is found to the northen part with 39.639 tons, representing 25% of the total production of the country (Sawadogo).[8] According to these authors, the lowest production is recorded in the southern and central regions, with less than 1% of its total production nationally.

In recent years, several factors are constraining tomato production and its yields have declined from 11.3 t $ha^{-1}$ in 2010 to 9.7 $tha^{-1}$ in 2014 (FAOSTAT).[9] This yield decline is due to the increasing pest pressure, the intensified chemical treatments and the high postharvest losses (ranging from 20-60%) (Son[10&7]; Somé[11]). It is also due to soil fertility decline especially to the decrease in soil organic matter and phosphorus which arethe major constraints limiting crop production(Lompo).[12] The high pressure on agricultural land also reduces the availability of soil nutrients and causes a significant decrease in soil fertility and crop yields (Bado[13]; Boga[14]). Moreover, successive croppings with or without mineral fertilizers contribute to soil acidification and to organic matter depletion (Sawadogo).[15] One of the constraints is also the exclusive application of mineral fertilizers which is noted to be generally effective only during the first years of cropping. But few years latter, it leads to a degradation of soil physico-chemical properties and therefore a decrease of crop yields (Sikuzani).[16] Regarding this situation, as other crop, it is important to move towards integrated soil fertility management in tomato production. This management could be achieved through the use of organic/bio- fertilizers such as manure and compost. Nowadays, there are some industries specialized in producing improved bio-fertilizers in Burkina Faso. Among these bio-fertilizers, *Bokashi* compost and compost enriched with *Trichoderma harzianum* are subjected to experimentations to identify the best one able to increase vegetable crop yields. This study aims therefore to evaluate and compare the effect of the two bio-fertilizers on tomato production and on soil fertility.

## Materials and Methods

### Study Site

We conducted this study in 2017- 2018 and 2018-2019 in Soala (Figure 1), a village in the Centre-west of Burkina Faso, at around 90 km from Ouagadougou. It is located at 12°39'18'' N and 1°57'37''W (Sawadogo)[15] in the Sudan Sahel zone with annual rainfall between 600 and 1000 mm. According to Kaboréand Ouedraogo,[17] this rainfall is badly and irregularly distributed in this area, which is not favourable for cereal cropscultivation. Despite the existence of water resources advantageous to vegetable production, this vegetable production is still in its embryonic stage, but is gradually attracting the attention of producers. The main crops produced are tomato, onion, cabbage, squash, cucumber, eggplant, okra and pepper.

### Plant Material

We used the tomato variety F1 *Mongal* (65 days) as plant material. This variety is the most produced in the study site (Soala) and also in the country (Sawadogo).[15] Its fruits are flattened round, bright red as colour with a red pulpat maturity.

### Pesticides

For pests control, a fungicide was used. This fungicide was abio-stimulant based on *Trichoderma*, on organic nitrogen and humic acid. It was used during planting to control soil fungi. In addition, another biopesticide with natural extracts of pine, Mn, B, MaO and D-limonene was used to control some insects with soft-shelled and soft-bodied. Fruit pests were controlled using a biological pesticide

based on allium (*cepa* and *sativum*) *azadiractin*, and *capsicum annuum*. Then, a biological insecticide based on Neem, mustard, pepper, garlic and mint was used to control caterpillars.

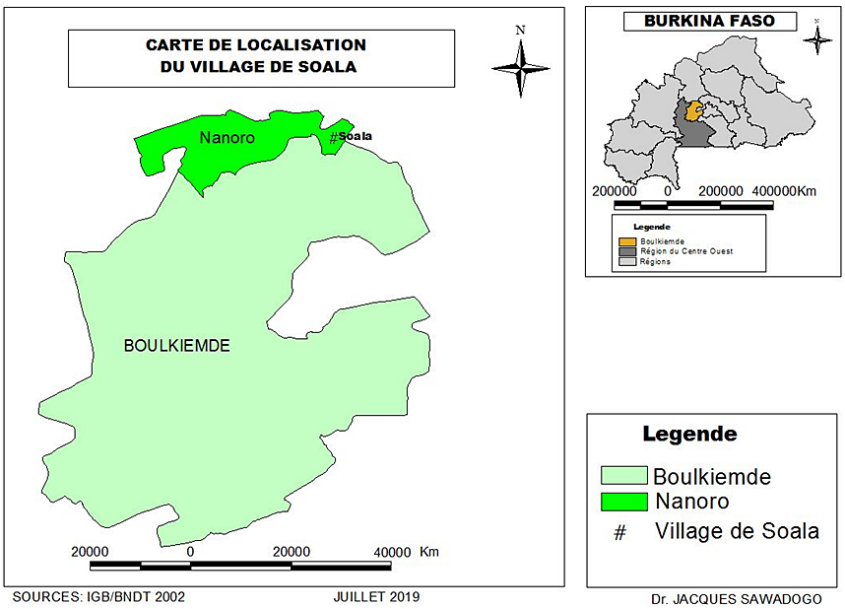


**Fig. 1: Location of the study site (Soala)**
Source. BNDT/BDOT 2002 PNGT-IGB

**Fertilizers Used**

Three types of fertilizers were used: two bio-fertilizers (*Bokashi* compost and compost enriched with *Trichoderma harzianum*) and an inorganic fertilizer (NPK + urea).

*Bokashi* compost is a fermented organic fertilizer produced from the aerobic or anaerobic degradation of plant or animal materials. It contains a large amount of nutrients and is comparable to NPK fertilizer. It is used to activate and increase the bacterial activity because of its high content in organic matter, in energy and in microorganisms.

The compost enriched with *Trichoderma harzianum* is a beneficial fungus that naturally colonizes the soil. It is very effective when it is allowed to establish itself before the pathogenic fungi arrive and therefore creates a protective sleeve around the roots to prevent the entry of pathogens. The amount of compost used was 30 t $ha^{-1}$, which is the recommended rate one in tomato production.

The inorganic fertilizer used in the study was NPK (14-23-14) + urea (46% N). These arefertilizers that act on the development of all kinds of plants but they do not affect soil fertility. Depending on their application, each of its chemical elements will have a direct impact on a part of the plants. Then, the N will promote the development of the aerial part of the plants, the P will affect rooting, fruit ripening and the overall resistance of the plant, and the K will influence the resistance to various diseases, stimulate the growth of flowers and fruits.The amount of NPK and urea used was 350 kg $ha^{-1}$ and 100 kg $ha^{-1}$ respectively and these are the recommended rates used in tomato production.

**Experiment Designand Treatments Applied**

This study used a randomized Fisher block design with six treatments in three replications: (1) T0 is the control treatment (without fertilizer), (2) T1: 350 kg $ha^{-1}$ of NPK + 100 kg $ha^{-1}$ of urea, (3) T2: *Bokashi* compost, (4) T3: compost enriched with *Trichoderma harzianum*, (5) T4: *Bokashi* compost + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea and (6) T5: compost enriched with *Trichoderma harzianum* + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea.

The plot side was 3 m x 2 m with the planting density of 80 cm between planting lines and 40 cm between plant hills. There were three (03) lines within each plots and seven (07) plant hills on each line with a total of twenty-one (21) plant hills within a plot.

**Husbandry Practices**

Before planting, tomato seeds were grown in some boxes in which we put a mixture of soil and 1 kg of simple compost. 15 g of tomato seeds were treated with 4 caps of bio-stimulant and sown in six (06) boxes which were covered with star-shaped bags and removed five (05) days after, when the seeds germinated. Then, some lighter bags were used to cover the boxes and removed few days after, when the first leaves appeared. To avoid some pest attacks, a mosquito net was used to protect the nursery which was watered twice a day until 24$^{th}$ day (planting day).

Six days before planting, basal application of bio-fertilizers were applied using *Bokashi* compost and compost enriched with *Trichoderma harzianum* in the plots prepared for the treatments. The plots were then dug and harrowed manually. Seven days after planting (336 tomato plants), the replanting was done in the plant hills where there was some mortality.

The experiment site was fertilized with an amount of 30 t ha$^{-1}$ of *Bokashi* compost and compost enriched with *Trichoderma harzianum* applied in single dose. The inorganic fertilizers NPK (at the rate of 300 kg ha$^{-1}$) and urea (46% of N) were used in single dose (for urea at 28 days after planting) and in two equal half dose at 14 and 28 days after planting (for NPK). For weed and pest management, all operations were done manually. Some bio-pesticides such as *SOLSAIN* was used to protect the seeds, and *LIMONSAIN*, *PIOL* and *BIOPODER* were used to control caterpillars, termites and other insects.

**Soil Sampling and Laboratory Analyses**

Two composite soil samples were taken before sowing at horizon 0-20 cm. After harvest, soil samples were again taken from all treatments and also at horizon 0-20 cm. The samples were air-dried and ground to pass a 2 mm and 0.5 mm sieve. The samples were analyzed at the INERA Kamboinsé Soil Water and Plant analysis laboratory for pH, soil organic carbon (C), total nitrogen (N), total and available phosphorus (P), and total potassium (K).

These analyses were done using standard analytical procedures. C was determined using the Walkley and Black method. The pH was measured with a pH-meter (*WTWInoLab, Weilheim*, Germany). After mineralization of soil samples, P and N were determined in the digest with a *SKALAR* automatic colorimeter (*Skalar SANplus* Segmented flow analyser, Model 4000-02, Breda, Holland), K was determined using a flame photometer, and available phosphorus was determined by the Bray$^{-1}$ method.

**Measurements and Data Collection**

The data collected for the experiment were plant height, plant diameter, the length and width of the fruit,and yield. For plant height and diameter, the measurement was done on 15 feet within each plot at 20, 35, 50 and 65 days after planting. The length and width of the fruit were randomly measured on five fruits within each plot on the harvest days. These fruits were measured longitudinally and transversely. The yield, converted in hectare, was estimated per treatment after each harvest. The formula used for the calculation was:

$$\text{Yield (kg ha}^{-1}) = \frac{\text{Yield (g/foot) x 31250}}{1000}$$

Where 31250 is the number of the feet/ha; and 1/1000 is the conversion factor in kg.

**Statistical Analysis**

Data collected were subjected to a simple descriptive analysis and a one-factor analysis of variance (ANOVA) (Sokal[18]; Matsoukis[19]; Matsoukis[20]) using Rstudio software version 1.1.423 coupled with R 3.4.3 software. When a significant difference was observed among treatments for a trait, ANOVA was supplemented by the Tukey test (Abdi[21]; Matsoukis[22]; Alevizos[23]). The X value of each sample was assigned a superscript letter (X(i) where i = a, b, c, ...). Then, the means were compared using the Newman-Keuls test, whose significance level chosen for the analyses was 5%. The degree of freedom was n-k where n and k represented the observation and group numbers. Prior to these analyses, data were tested for normality (Shapiro[24]; Shapiro[25]) and variance homogeneity (Brown).[26]

## Results

### Effect of *Bokashi* Compost and Compost Enriched with *Trichoderma Harzianum* on Soil Ph and Chemical Properties

The analysis of variance performed on the data shows the following results on the bio-fertiilizers (Table 1) and on soil pH and chemical properties (Table 2).

With regards to the bio-fertilizers, the analysis revealed a basic nature of *Bokashi* compost and compost enriched with *Trichoderma harzianum* (pH is around 8). The results also indicated that in maturity, the two bio-fertilizers had a temperature superior to 25°C and there was no significance difference in their N content (p>5%) (Table 1). The amount of organic carbon (C) noted was significantly higher (p=0.001) in *Bokashi* compost than in the compost enriched with *Trichoderma harzianum*. However, the C/N ratio showed that the capacity to mineralize this carbon was highly significant in the compost enriched with *Trichoderma harzianum* thanin *Bokashi* compost. In addition, regarding their P and K content, the Table 1 presented a high significance difference (p<0,0001) between the two bio-fertilizers. The compost enriched with *Trichoderma harzianum* was found to have the higher content in total N, P and K with a difference of 5.76 g $kg^{-1}$ and 3.57 mg $kg^{-1}$ respectively, compared to *Bokashi* compost.

**Table 1: Characteristics of the two bio-fertilizers**

| Bio-fertilizers | pH | C | N (g $kg^{-1}$) | P | K (mg $kg^{-1}$) | C/N | T (°C) |
|---|---|---|---|---|---|---|---|
| Bokashi | $8.2^{a}$ | $12.25^{a}$ | $0.81^{a}$ | $4.68^{b}$ | $7.85^{b}$ | $15^{a}$ | $26.5^{a}$ |
| Enriched with *Trichoderma harzianum* | $7.9^{a}$ | $11.56^{b}$ | $1.08^{a}$ | $10.44^{a}$ | $11.42^{a}$ | $11^{b}$ | $27.6^{a}$ |
| Ddl | | | | 02 | | | |
| P-Value | P> 5% | 0.001 | P> 5% | <0.0001 | 0.0001 | <0.0001 | P> 5% |
| Significance (5%) | * | ** | * | *** | ** | *** | * |

**Table 2: Soil pH and chemical properties as affected by the two bio-fertilizers**

| Years | Soil properties | Treatments | | | | | | | P-Value | Significance |
|---|---|---|---|---|---|---|---|---|---|---|
| | | T0' | T0 | T1 | T2 | T3 | T4 | T5 | | |
| 2017-2018 | pH | $7.2^{ab}$ | $5.7^{c}$ | $6.3^{b}$ | $6.9^{ab}$ | $7.5^{a}$ | | | 0.0001 | *** |
| | C (g $kg^{-1}$) | $3^{d}$ | $3.8^{e}$ | $4.08^{b}$ | $4.18^{b}$ | $4.57^{a}$ | | | | |
| | N (g $kg^{-1}$) | $0.28^{bc}$ | $0.26^{c}$ | $0.29^{bc}$ | $0.31^{b}$ | $0.36^{a}$ | | | | |
| | P (g $kg^{-1}$) | $135.33^{b}$ | $119.33^{d}$ | $130.55^{c}$ | $135.46^{b}$ | $153^{a}$ | | | | |
| | K (mg $kg^{-1}$) | $1.23^{a}$ | $1.44^{a}$ | $1.44^{a}$ | $1.24^{a}$ | $1.39^{a}$ | | | P> 5% | * |
| | C/N | $11^{d}$ | $15^{a}$ | 14b | $13^{c}$ | $13^{c}$ | | | 0.0001 | *** |
| | Ddl | 05 | | | | | | | | |
| 2018-2019 | pH | $7.22^{a}$ | $5.33^{f}$ | $5.94^{e}$ | $6.830^{c}$ | 6.95b | $6.33^{d}$ | $6.55^{a}$ | 0.0001 | *** |
| | C (g $kg^{-1}$) | $3.0^{d}$ | $3.8^{e}$ | $3.05^{d}$ | $3.47^{c}$ | 3.91b | $3.46^{c}$ | $4.57^{a}$ | | |
| | N (g $kg^{-1}$) | $0.22^{c}$ | $0.23^{c}$ | $0.18^{d}$ | $0.24^{b}$ | $0.29^{a}$ | $0.23^{c}$ | $0.3^{a}$ | | |
| | P (g $kg^{-1}$) | $125^{b}$ | $85^{d}$ | $119^{c}$ | $136^{a}$ | $136^{a}$ | $127^{c}$ | $144^{a}$ | | |
| | K (mg $kg^{-1}$) | $1.02^{d}$ | $1.13^{d}$ | $1.30^{c}$ | $1.41^{ab}$ | $1.47^{a}$ | $1,32^{c}$ | $1.52^{a}$ | | |
| | C/N | $14^{c}$ | $16^{ab}$ | $17^{a}$ | $14^{c}$ | $13^{d}$ | 15b$^{c}$ | $15^{bc}$ | | |
| | Ddl | 05 | | | | | | | | |

T0': initial soil sample; T0: control; T1: 300 kg $ha^{-1}$ of NPK + 100 kg $ha^{-1}$ of urea; T2: 30 t $ha^{-1}$of *Bokashi* compost; T3: 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum*; T4: 30 t $ha^{-1}$ of *Bokashi* compost + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea ; T5 : 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum*+ 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea ; *: no significance ; **: significance ; ***: high significance. Within rows, means followed by the same letter are not significantly different at p<5%.

Table 2 shows soil pH and chemical characteristics before and after the experimentation. Considering the results presented in this Table 2, we noted that the study was carried out on soil with low N and C content and with a neutral pH (pH = 7.2).

In the two years of cultivation, the two bio-fertilizers, in single and in combined use with NPK + urea, contributed to improve significantly (p>5%) soil fertility. Compared with the initial soil sample properties, *Bokashi* compost and the compost enriched with *Trichoderma harzianum* increased all soil properties (total C, N, P, K) measured in this study.

Concerning soil pH, the neutrality was maintained in the treatment using these bio-fertilizers *Bokashi* compost and the compost enriched with *Trichoderma* in single use (Table 2). But once combined with NPK + urea in the second year of cultivation, soil pH decreased slightly.

This Table 2 also indicated that the compost enriched with *Trichoderma harzianum* was the most improving soil properties content when used alone or combined with NPK + urea. Compared to the initial soil sample, it contributed to increase soil total C, N, P, K by 1.57 g $kg^{-1}$, 0.08 g $kg^{-1}$, 17.67 g $kg^{-1}$ and 0.16 mg $kg^{-1}$ respectively for the first year 2017-2018 and 0.91 g $kg^{-1}$, 0.07 g $kg^{-1}$, 0.11 g $kg^{-1}$ and 0.45 mg $kg^{-1}$ respectively for the second year 2018-2019.When combined with NPK + urea, the improvement waseven better for total P and K and the content was increased by 19 g $kg^{-1}$ and 0.50 mg $kg^{-1}$ respectively in the second year.

Compared to *Bokashi* compost, the compost enriched with *Trichoderma harzianum* increased soil total C, N, P, K contents by 0.39 g $kg^{-1}$, 0.05 g $kg^{-1}$, 17.54 g $kg^{-1}$ and 0.15 mg $kg^{-1}$ respectively for the first year 2017-2018 and 0.44 g $kg^{-1}$, 0.06 g $kg^{-1}$, 0 g $kg^{-1}$, 0.06 mg $kg^{-1}$ respectively for the second year 2018-2019. In combination with NPK + urea, similarly to the single use, the improvement was also even better and the content of total C, N, P, K was increased by 1.11 g $kg^{-1}$, 0.07 g kg-1, 17 g $kg^{-1}$ and 0.20 mg $kg^{-1}$ respectively in the second year 2018-2019.

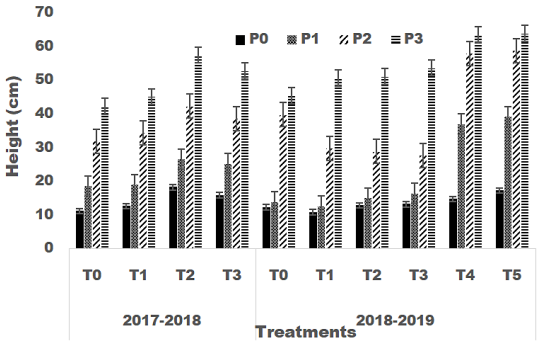


**Fig. 1: Tomato plant height measured at different growth periods**

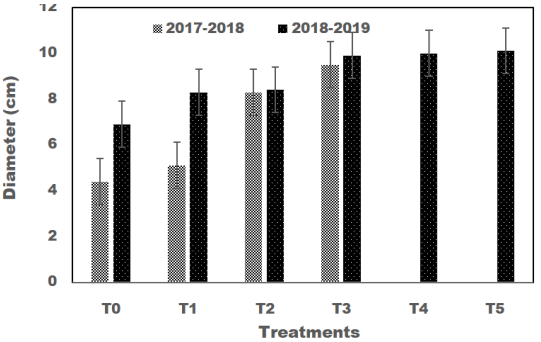


**Fig. 2: Tomato plant diameter measured at 80 DAP**

**Legend**

P0 : Measuement at 30 days after planting (DAP) ; P1 : Measuement at 45 DAP ; P2 : Measuement at 60 DAP ; P3 : Measuement at 80 DAP ; T0: control ; T1: 300 kg $ha^{-1}$ of NPK + 100 kg $ha^{-1}$ of urea ; T2 : 30 t $ha^{-1}$ of *Bokashi* compost ; T3 : 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum* ; T4 : 30 t $ha^{-1}$ of *Bokashi* compost + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea ; T5 : 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum* + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea; The bars represent the standard errors; The graphs with same letters are not significantly different.

**Effect of *Bokashi* Compost and Compost Enriched with *Trichoderma Harzianum* on Tomato Growth**

The effect of the two bio-fertilizers on tomato plant height (Fig. 1) and plant diameter (Fig. 2) was assessed.The analysis of variance indicated a significant influence (p<0,05) of *Bokashi* compost and the compost enriched with *Trichoderma harzianum* in single use and in combined use with NPK + urea on plant height and diameter compared

to the control and the NPK + urea treatments. In the two years of cultivation, no significant difference was noted between the influence of the two bio-fertilizers in single use on the two parameters (height and diameter) of tomato. However, in the second year 2018-2019, the addition of NPK + urea contributed to improve plant height (Fig. 1) but no significant influence was induced for plant diameter (Fig. 2).

**Effect of *Bokashi* Compost and Compost Enriched with *Trichoderma Harzianum* on the Yield Components of Tomato**

Assessing the effect of the two bio-fertilizers on tomato yield components, it was found that the *Bokashi* compost in combined use with NPK + urea and the compost enriched with *Trichoderma harzianum* in single use and in combined use with NPK + urea influenced significantly ($p<0,05$) the yield components (fruits height and width) of tomato (Fig. 3).

Regarding the weight of tomato fruit, only the two bio-fertilizers in combined use with NPK + ureapresented the highest weight (Fig. 4). Compared to the single use of the *Bokashi* compost and the compost enriched with *Trichoderma harzianum*, the combination effect contributed to increase their weight by 1312.6 g and 1137.1 g respectively in the second year 2018-2019. Compared to NPK + urea and the control treatments, the two bio-fertilizers contributed to increase the weight of tomato fruits by 180% and 300% respectively.

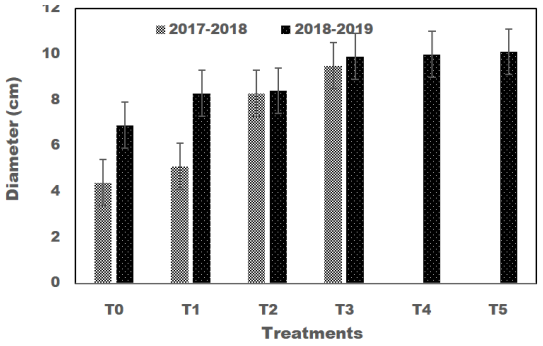


**Fig. 3: Tomato plant diameter measured at 80 DAP**

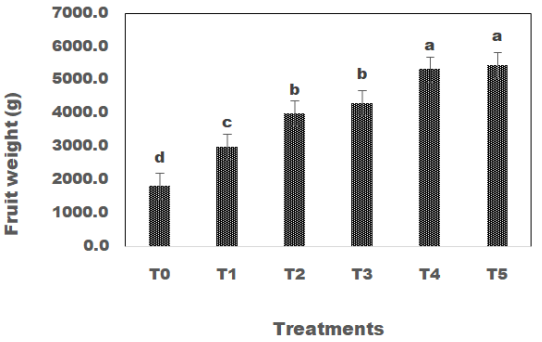


**Fig. 4: The weight of tomato fruits as affected by the treatments in 2018-2019**

**Legend**

Hfruit: Height of the fruits; Wfruit : the width of the fruits ; T0: control ; T1: 300 kg $ha^{-1}$ of NPK + 100 kg $ha^{-1}$ of urea ; T2 : 30 t $ha^{-1}$ of *Bokashi* compost ; T3 : 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum*; T4 : 30 t $ha^{-1}$ of *Bokashi* compost + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea ; T5 : 30 t $ha^{-1}$ of compost enriched with *Trichoderma harzianum* + 175 kg $ha^{-1}$ of NPK + 50 kg $ha^{-1}$ of urea; The bars represent the standard errors ; The graphs with same letters are not significantly different.

**Effect of *Bokashi* Compost and Compost Enriched with *Trichoderma Harzianum* on the Yield of Tomato**

Assessing the effect of the two bio-fertilizers on tomato yield, similarly to yield components, it was found that the *Bokashi* compost in combined use with NPK+urea (in 2018-2019) and the compost enriched with *Trichoderma harzianum* in single and in combined use with NPK + urea influenced significantly ($p<0,05$) the yield of tomato (Fig. 5).

With regards to the first year 2017-2018, the application of the compost enriched with *Trichoderma harzianum* in single use contributed to increase the yield of tomato by 3 t $ha^{-1}$ and 8 t $ha^{-1}$ compared to *Bokashi* compost and the NPK+urea treatment respectively. Compared to the control treatment, it contributed to increase tomato yield up to 19 t $ha^{-1}$ (300%).

In the second year 2018-2019, compared to the *Bokashi* compost, the application of the compost enriched with *Trichoderma harzianum* in combined use with NPK + urea increase tomato yield up to 10.2 t $ha^{-1}$. Regarding the yield obtained with NPK + urea and the control tratments, the increase in

yield of tomato induced by the compost enriched with *Trichoderma harzianum* in combined use with NPK+urea was 200% and 400% respecttively (Fig. 5).

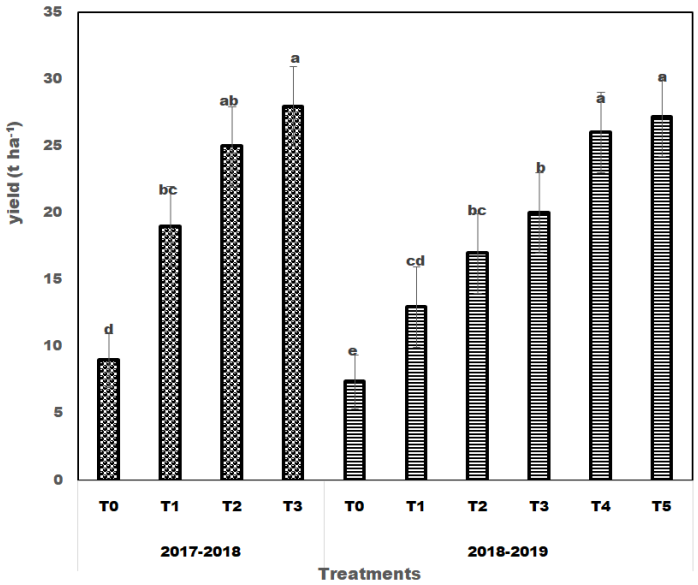


**Fig. 5: The yield of tomato fruits as affected by the treatments**

**Legend**

T0 : control ; T1: 300 kg ha$^{-1}$ of NPK + 100 kg ha$^{-1}$ of urea ; T2 : 30 t ha$^{-1}$ of *Bokashi* compost ; T3 : 30 t ha$^{-1}$ of compost enriched with *Trichoderma harzianum* ; T4 : 30 t ha$^{-1}$ of *Bokashi* compost + 175 kg ha$^{-1}$ of NPK + 50 kg ha$^{-1}$ of urea ; T5 : 30 t ha$^{-1}$ of compost enriched with *Trichoderma harzianum* + 175 kg ha$^{-1}$ of NPK + 50 kg ha$^{-1}$ of urea; The bars represent the standard errors ; The graphs with same letters are not significantly different.

## Discussion

### Effect of *Bokashi* Compost and Compost Enriched with *Trichoderma Harzianum* on Yield and Yield Components of Tomato

In the two years of cultivation, the application of the two bio-fertilizers (*Bokashi* compost and the compost enriched with *Trichoderma harzianum*) maintained soil pH neutrality and contributed to increase soil total C, N, P and K and the yield of tomato. The incorporation of these two bio-fetilizers in soil played major role in improving soil fertility, yield attributing characters and thereby final yield. Indeed, the bio-fertilizers are known to enhance the nutrient availability to crop plants and impart better health to plants and soil, hence enhancing crop yields (Suliasih and Widawati[27]; Kamlesh and Sarkar[28]) as they are modernized forms of organic fertilizers into which beneficial microorganisms have been incorporated. Kalbani[29] and Nacro[30] reported the best plant growth through the application of organic fertilizers which provide an additional source of nutrients and improve the efficiency of mineral fertilizers by making nutrients more available for plant growth.

The *Bokashi* compost and the compost enriched with *Trichoderma harzianum* are used for vegetables cultivation especially tomato and onion because of their quick decomposition in soil and efficient availability of their nitrogen to vegetables crop. The application of the two bio-fertilizers in single use in 2017-2018 and 2018-2019 brought an impressive increase especially in tomato yield by 300% and more than 200% respectively, compared with the control treatment. From this experiment, it can be said that the application of the two bio-fertilizers gave significant effect to almost all of soil parameters. According to Oviyanti,[31] this result can happen because of the symbiotic relationship between the fungi and a variety of plants that can produce

colonies on the outside part in a root system. This condition can make the uptake of water and nutrients by the plant roots increase.

The best improvement of the yield of tomato in the two years of cultivation was achieved through the application of the compost enriched with *Trichoderma harzianum* in single or in combined use with NPK + urea. In 2017-2018 and 2018-2019, the increase in tomato yield resulting from this bio-fertilizer was 300 and 400% respectively compared to the control treatment. This result could be linked to the nutrients content in this bio-fertilizer which was found to have the higher content in total N, P and K compared to *Bokashi* compost. In additin, eventhough the amount of organic carbon (C) noted was significantly higher in *Bokashi* compost than in the compost enriched with *Trichoderma harzianum*, the C/N ratio showed that the capacity to mineralize this carbon was highly significant in the compost enriched with *Trichoderma harzianum* than in *Bokashi* compost. Moreover, this result could be linked to the presence of *Trichoderma harzianum* in the compost. Indeed, it is a fungus that grows into the soil and can exert spatial and nutrient competition. This finding lend its support to that of Harman[32] who studied the influence of *Trichoderma harzianum* on plants. He successfully demonstrated that this fungus has the ability to release bioactive molecules and facilitate the supply of nutrients. Similarly, Sawadogo[15] tested the effect of compost enriched with *Trichoderma harzianum* on tomato plants and showed that the high content of total N, P and K in this bio-fertilizer could be due to *Trichoderma harzianum* that has the capacity to colonize the environment in which it is found and to promote the mineralization of organic matter. This capacity of *Trichoderma harzianum* to colonize and increase soil fertility was also reported by Mouria.[33]

## Conclusion

This study was conducted on tomato using two bio-fertilizers based on local substrates (*Bokashi* compost and compost enriched with *Trichoderma harzianum*) to assess their efficiency on tomato yield components and yield and on soil pH and chemical properties. The results showed that the two bio-fertilizers in single use, contributed to maintain the neutrality of soil pH and increase all its total C, N, P and K content and its yield components and yield. When combined with NPK+urea, it was found that the *Bokashi* compost and the compost enriched with *Trichoderma harzianum* in single and in combined use with NPK+urea influenced very significantly the yield of tomato. Moreover, this study revealed that the compost enriched with *Trichoderma harzianum* had the most improving soil properties content and tomato yield when used alone or combined with NPK+urea. Compared to the initial soil sample, it contributed to increase soil C, N, P, K by 1.57 g $kg^{-1}$, 0.08 g $kg^{-1}$, 17.67 g $kg^{-1}$ and 0.16 mg $kg^{-1}$ respectively for the first year 2017-2018 and 0.91 g kg-1, 0.07 g $kg^{-1}$, 0.11 g $kg^{-1}$ and 0.45 mg $kg^{-1}$ respectively for the second year 2018-2019. Compared to *Bokashi* compost, the NPK+urea and control plots, the compost enriched with *Trichoderma harzianum* in single use contributed to increase the yield of tomato by 3 t $ha^{-1}$, 8 t $ha^{-1}$ and 19 t $ha^{-1}$ (300%) respectively with regards to the first year 2017-2018. In the second year 2018-2019, compared to the *Bokashi* compost, the application of the compost enriched with *Trichoderma harzianum* in combined use with NPK+urea increased tomato yield up to 10.2 t $ha^{-1}$. This compost could therefore be an alternative for soil fertilization in vegetable production and in agriculture in general in Burkina Faso.

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**Conflict of Interest**

Authors declare no conflict of interest.

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