Effect of supplemental irrigation and organic fertilization rates on soil fertility and contamination.

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ABSTRACT

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| **Objective**: To evaluate the combined effect of compost and different irrigation regimes on soil chemical properties and pesticide sequestration, in a rain-fed tomato farming context.  **Experimental set-up**: The experimental set-up adopted was a split-plot design with four replications and nine treatments.  **Location and duration**: The experiment took place at the IPD-AOS site in Wayalgin, Ouagadougou (Sudano-Sahelian zone), during two consecutive wet seasons.  **Methodology**: The primary factor corresponded to three irrigation levels (100%, 75% and 50% of tomato water requirements), equivalent respectively to 36, 24 and 12 liters of water per furrow (3, 2 and 1 watering cans). The secondary factor involved three doses of compost: 0, 5 and 10 t/ha, i.e. 0, 2 and 4 kg per sub-plot. Each block comprised three main plots (for irrigation doses), subdivided into three sub-plots according to compost doses, making a total of 36 sub-plots.  **Results**: Results showed that composting at 10 t/ha significantly increased carbon and organic matter contents at all irrigation levels (D50%, D75%, D100%), with respective increases of 43%, 79% and 23%. Similarly, doses of 5 and 10 t/ha increased nitrogen content by 50%, 125% and 62%, depending on the irrigation level. Potassium content also increased, albeit unevenly. On the other hand, the sum of exchangeable bases increased by around 40% and cation exchange capacity by 32%, regardless of treatment. Finally, pesticide residues were detected only in the amended soils, suggesting a scavenging effect of the compost.  **Conclusion**: These treatments durably improved soil fertility while reducing the risk of groundwater contamination. |

*Keywords: supplementary irrigation, compost, chemical pesticid, soil fertilization, pollution, tomato,*

1. INTRODUCTION

Agriculture in sub-Saharan Africa faces many challenges, exacerbated by climate change. These include prolonged droughts and floods, which disrupt agricultural production and compromise food security [1], [2], [3]. These climatic disturbances have a particularly marked impact in Sahelian zones, where farmers are among the most vulnerable populations. They have to cope with particularly restrictive soil and climate conditions, characterized by high rainfall variability and soil poverty, limiting their capacity to adapt [4], [5]. This is due to their low organic matter content, a key element in soil fertility and structure [6]. In addition, these soils have a reduced capacity to filter and retain contaminants, thus favoring water pollution by pesticides [7]. This dual constraint, both agronomic and environmental, represents a major challenge for the sustainability of Sahelian farming systems. Faced with this situation, several strategies have been put in place to restore soil fertility. These include water and soil defense and conservation techniques, as well as approaches to improve fertilization, such as zaï, half-moons, stone cordons, grass strips and organo-mineral fertilization [8], [9], [10]. However, despite their proven effectiveness, these practices have not been widely adopted by farmers due to socio-economic, technical and cultural constraints, limiting their widespread use [11], [12]. As a result, soil fertility continues to deteriorate, enduringly compromising agricultural productivity. This situation particularly affects vegetable crops, such as tomatoes, which are increasingly grown in the rainy season, but whose yield remains severely limited by biotic and pedoclimatic constraints.

In this context, it is crucial to explore alternative fertilization strategies adapted to water scarcity, while also ensuring the efficient management of water resources for crop irrigation [13]. Several studies have shown the effectiveness of reducing supplementary irrigation depth in improving irrigation water productivity [14], [15]. In addition, compost represents a promising solution, as it enhances soil water retention while gradually releasing nutrients essential for plant growth. However, the effectiveness of reducing irrigation depth and using compost in terms of soil fertilization and contamination remains insufficiently documented.

The aim of this study is therefore to evaluate the effect of compost under different irrigation regimes on the chemical properties and sequestration of pesticides in the soil, as well as on the presence of pesticides in the soil in a rain-fed farming context. More specifically, this research focuses on the impact of compost, combined with different doses of supplementary irrigation, on soil chemical parameters in tomato cultivation. To this end, a split-plot experimental set-up combining several levels of irrigation and compost was set up to assess their short- and medium-term effects on soil fertility.

2. material and methods

2.1 Experimental site

The experiment was conducted at the IPD-AOS experimental site, located in the Wayalgin district of Ouagadougou, along Route Nationale N°4 linking the capital to Fada N'Gourma. The site's geographical coordinates lie between 12°23' and 12°32' north latitude, and between 1°28' and 1°04' west longitude. It lies in the Sudano-Sahelian agroclimatic zone, characterized by two distinct seasons: a dry season and a rainy season. Average annual rainfall is estimated at around 800 mm. Minimum temperatures, which can drop as low as 11°C, are generally recorded between December and January, while maximum temperatures, which can reach 41°C, are mainly observed in April. The soil at the site is sandy loam, with a field capacity of 18% and a permanent wilting point of 1.4%. Experimentation took place over two consecutive cropping seasons, exclusively during the rainy season of each year.

2.2 **Experimental set-up**

The experimental set-up adopted was a split-plot design with four replications and nine treatments. The main factor studied was irrigation level, while the secondary factor was organic matter dosage.

Each experimental block comprised three main plots, corresponding to the three irrigation levels. Each main plot was subdivided into three subplots corresponding to the compost doses, i.e. nine subplots per block, 36 in all.

Each sub-plot measured 2 m × 2 m, i.e. an area of 4 m², and contained five ridges. On each ridge, six tomato bunches were planted, for a total of 30 bunches per sub-plot. The blocks were spaced 1 m apart, while the sub-plots were separated by 0.5 m. The total experimental area covered 264 m².

**2.3 Treatment application**

The treatments consisted of a combination of three levels of irrigation and three doses of compost :

* C0 + 100%: 100% irrigation and no compost ;
* C5 + 100%: 100% irrigation and 5 t/ha compost;
* C10 + 100%: 100% irrigation and 10 t/ha of compost;
* C0 + 75%: Irrigation at 75% and no compost;
* C5 + 75%: Irrigation at 75% and 5 t/ha compost;
* C10 + 75%: Irrigation at 75% and 10 t/ha of compost;
* C0 + 50%: Irrigation at 50% and no compost;
* C5 + 50%: Irrigation at 50% and 5 t/ha compost;
* C10 + 50%: Irrigation at 50% and 10 t/ha compost.

The compost applied is characterized by a C/N ratio of 19, which, according to the AFNOR standard, would indicate a well-stabilized compost capable of slowly releasing nutrients. It was applied at rates of 0, 5 and 10 t/ha, corresponding respectively to 0, 2 and 4 kg of compost per sub-plot. Irrigation water was administered at three levels corresponding to 100%, 75% and 50% of tomato water requirements, equivalent to 3, 2 and 1 watering cans per ridge respectively, i.e. 36, 24 and 12 liters of water per ridge. These quantities of water were applied every other day, except in the event of rain, when irrigation was postponed.

During the first year of experimentation, the pesticides BOMEC, PACHA and DEAN were applied respectively at 17th, 47th and 60th days after transplanting. The active substances in these formulations included:

* Abamectin, a member of the avermectin family,
* Lambda-cyhalothrin, a synthetic pyrethroid,
* Acetamiprid, a neonicotinoid,
* Imidacloprid, also a neonicotinoid.

In the second year, the pesticide Cypercal, whose active ingredient is cypermethrin, was used. This compound belongs to the synthetic pyrethroid family. BOMEC was also used in the second year of experimentation.

These pesticides are mainly neurotoxic insecticides targeting various pests, notably aphids, whiteflies, beetles and termites, by disrupting their central nervous system. The pesticides were applied at a rate of 0.5 l/ha.

**2.4. Soil sampling and analysis of soil physico-chemical parameters**

Before treatments were applied, soil samples were taken with a soil auger at a depth of 0-20 cm, using the diagonal and median methods. The samples were pooled to form a representative composite sample for analysis of the soil's initial physical, chemical and biological properties.

Légende

* : Sampling point

: Operating perimeter

Figure 1: Sampling method at the experimental site

At the end of each campaign, new composite samples were taken from each sub-plot, at the same depth, to assess the effect of treatments combining different doses of irrigation and compost.

Legend

* : Sampling point

 : Sub plot





Figure 2: Subplot sampling method

Table 1 shows the physico-chemical parameters analyzed and the methods used.

Table 1. Summary of chemical parameters analyzed and methods used for analysis

|  |  |
| --- | --- |
| **Physico chemical parameter** | **Analysis method** |
| Granulometry five fractions |  |
| pHeau | Potentiometric (AFNOR, 1981). |
| Organic matter (OM) | Walkley et Black (1934). |
| Cation exchange capacity (CEC) | (METSON A.J ; 1956) |
| Exchangeable bases | METSON A.J ; 1956 |
| Total nitrogen | Hillebrand *et al*., 1953 |
| Total phosphore | Hillebrand *et al*., 1953 |
| Total potassium | Hillebrand *et al*., 1953 |
| Assimilable phosphorus | Bray et Kurtz, 1945 |
| Potassium available | Walinga *et al*., 1989 |
| Cation exchange capacity | METSON A.J ; 1956 |
| Saturation rate |  |
| Soil breathing | Dommergue 1960 |
| Pesticide extraction and detection | QuEChERS NF 15662  GC-µECD |

**3. RESULTS AND DISCUSSION**

**3.1 Results**

**3.1.1 Climate data**

Figure 3 shows the monthly evolution of effective rainfall and evapotranspiration between May and October for the years 2023 (a) and 2024 (b). Analysis of the curves shows that in 2024, monthly evapotranspiration was 4% lower than effective rainfall, while in 2023, effective rain was 48% lower than evapotranspiration. These results indicate that the period from May to October 2024 was characterized by higher humidity and relatively more moderate temperatures, compared to 2023.

(a)

(b)

Figure 3. Effective rainfall and monthly evapotranspiration in 2023 (a) and 2024 (b)

**3.1.2. Effect of treatments on carbon and organic matter content**

Table 2 below shows the effects of the various treatments on carbon and OM content. The results show that the treatments only had a significant effect on carbon and OM levels in the second year. Furthermore, at each irrigation level D50%, D75%, D100%, the addition of compost at 10T/ha resulted in a significant increase in carbon and organic matter content of 43.79% and 23% respectively. Moreover, an increase in carbon content was observed from one year to the next, even in plots treated without compost. These results suggest that the variability of carbon and OM levels depends on the time elapsed since compost application. Moreover, after two years of experimentation, the application of compost at 5 and 10 T/ha resulted in an increase in carbon and OM levels, irrespective of the irrigation rate applied. This increase was statistically greater in the plots amended at 10 T/ha.

Table 2. Effect of treatments on carbon and organic matter content (%)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | C-2023 | C-2024 | MO-2023 | MO-2024 |
| Witness | 0.68±0.05 | 0.68±0.05b | 1.16±0.08 | 1.16±0.08b |
| C10+D100 | 0.7±0.06 | 1.09±0.12ab | 1.2±0.1 | 1.88±0.21ab |
| C5+D100 | 0.63±0.07 | 1.59±0.2a | 1.08±0.11 | 2.74±0.35a |
| C0+D100 | 0.55±0.05 | 0.88±0.04ab | 0.95±0.09 | 1.52±0.06ab |
| C10+D75 | 0.76±0.11 | 1.45±0.15ab | 1.31±0.19 | 2.51±0.27ab |
| C5+D75 | 0.59±0.09 | 1.29±0.26ab | 1.02±0.15 | 2.23±0.45ab |
| C0+D75 | 0.55±0.07 | 0.81±0.23ab | 0.94±0.11 | 1.4±0.4ab |
| C10+D50 | 0.82±0.06 | 1.22±0.11ab | 1.41±0.11 | 2.1±0.19ab |
| C5+D50 | 0.67±0.06 | 1.39±0.14ab | 1.16±0.11 | 2.4±0.24ab |
| C0+D50 | 0.57±0.07 | 0.85±0.18ab | 0.98±0.12 | 1.46±0.32ab |
| P | 0.151 | 0.014 | 0.15 | 0.014 |
| Significance | ns | \* | ns | Ns |

ns: non significative

\*: significative with p˂0.05

**3.1.3. Effect of treatments on total nitrogen, total phosphorus and available potassium**

The effect of the different treatments on nitrogen (N), phosphorus (P) and potassium (K) levels is shown in the table below. Statistical analysis reveals that in year 1, the different treatments did not significantly influence soil nitrogen, phosphorus and potassium levels. However, in the second year, a significant effect was observed on available nitrogen and potassium levels. In the second year of the experiment, for irrigation rates D50%, D75% and D100%, compost application at 5 and 10T/ha respectively resulted in an average increase in nitrogen of 50, 125 and 62% compared with the unamended plots. In the case of potassium, although a significant effect was noted, the resulting increase was not systematic. In addition, nitrogen, phosphorus and potassium levels decreased from one year to the next. The results therefore suggest that the variability of NPK levels is a function of compost application time. The results also show that, for the same compost rate, the irrigation rate would also affect the amount of nitrogen available in the soil.

Table 3. Effect of treatments on total nitrogen, total phosphorus and available potassium

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | N%-2023 | N%-2024 | P%-2023 | P%-2024 | K%-2023 | K%-2024 |
| Witness | 0.06±0.01 | 0.06±0.01a | 4.59±1.14 | 4.59±1.14 | 95.18±10.25 | 95.18±10.25a |
| C10+D100 | 0.18±0.03 | 0.11±0.01abc | 15.39±8.77 | 9.53±3.18 | 139.57±9.08 | 147.49±10.37abc |
| C5+D100 | 0.18±0.01 | 0.15±0.02d | 8.61±3.22 | 8.89±1.73 | 158.32±46.24 | 106.24±12.33c |
| C0+D100 | 0.23±0.03 | 0.08±0ab | 24.46±8.14 | 9.73±3.64 | 136.45±26.7 | 117.49±20.87ab |
| C10+D75 | 0.15±0.01 | 0.13±0.02cd | 17.09±4.1 | 8.29±1 | 119.79±8.05 | 102.49±3.88bc |
| C5+D75 | 0.15±0.04 | 0.14±0.02cd | 11.63±2.1 | 8.33±1.35 | 133.32±20.05 | 136.66±11.49bc |
| C0+D75 | 0.18±0.02 | 0.06±0a | 12.34±2.19 | 6.68±2.21 | 134.37±14.87 | 137.91±4.43a |
| C10+D50 | 0.17±0.03 | 0.12±0.01cd | 12.6±6.14 | 10.6±0.66 | 123.95±15.9 | 121.66±10.95abc |
| C5+D50 | 0.16±0.02 | 0.12±0.01cd | 14.18±3.01 | 7.36±0.27 | 88.54±2.62 | 111.66±11.44abc |
| C0+D50 | 0.17±0.02 | 0.08±0.01ab | 12.47±4.92 | 5.43±0.29 | 140.62±32.91 | 86.25±4.48ab |
| P | 0.057 | 0 | 0.0575 | 0.603 | 0.0674 | 0.013 |
| Significance | ns | \*\*\* | ns | ns | ns | \* |

ns : non significative

\*\*\*: significative with p˂0,001

\*: significative with p˂0,05

**3.1.4. Effect of treatments on exchangeable bases**

Table 4 shows the effects of the various treatments on exchangeable bases. Statistical analysis reveals that treatments only significantly impacted calcium and magnesium minerals and the sum of exchangeable bases during the second year of experimentation. Moreover, Duncan's test shows that at each irrigation level D50%; D75% and D100%, the addition of organic matter at 5 and 10 t/ha resulted in an average increase of 102%, 92% and 93% respectively for calcium, and 80%, 68% and 41% for magnesium. The sum of exchangeable bases increased significantly by around 40% compared with the unamended controls, for each irrigation level. However, this increase was not systematic for potassium and sodium minerals. On the other hand, there was a relative decrease in all the minerals studied from one year to the next. The results therefore suggest that mineral availability in supplemental irrigation depends on the compost application period. Compost application also guarantees a significant increase in calcium and magnesium minerals, whatever the irrigation dose applied.

Table 4. Effect of treatments on exchangeable bases

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | ca2+-2023 | Ca2+-2024 | Mg2+-2023 | Mg2+-2024 | K+-2023 | K+-2024 | Na+-2023 | Na+ -2024 | SB-2023 | SB-2024 |
| Witness | 2.16±0.35 | 2.16±0.35b | 1.35±0.03 | 1.35±0.03b | 0.08±0.02a | 0.08±0.02b | 0.06±0.01a | 0.06±0.01a | 3.64±0.29a | 3.64±0.29ab |
| C10+D100 | 2.65±0.18 | 2.14±0.1b | 1.1±0.19 | 1.23±0.13ab | 1.09±0.05b | 0.94±0.12a | 0.41±0.02b | 0.25±0.05b | 5.25±0.25b | 4.56±0.13c |
| C5+D100 | 2.42±0.22 | 2.25±0.15b | 1.03±0.07 | 1.15±0.35ab | 1.33±0.23b | 0.74±0.12a | 0.4±0.05b | 0.2±0.01b | 5.17±0.14b | 4.33±0.41c |
| C0+D100 | 2.27±0.22 | 1.14±0.08a | 0.88±0.09 | 0.84±0.04a | 1.08±0.05b | 0.99±0.06a | 0.46±0.01b | 0.22±0.02b | 4.68±0.21ab | 3.19±0.16ab |
| C10+D75 | 2.5±0.07 | 2.05±0.09b | 0.89±0.11 | 1.25±0.08ab | 1.08±0.05b | 0.93±0.06a | 0.36±0.04b | 0.24±0.06b | 4.82±0.04b | 4.46±0.2c |
| C5+D75 | 2.47±0.22 | 2.01±0.15b | 1.26±0.19 | 1.52±0.12b | 1.04±0.04b | 0.82±0.13a | 0.45±0.03b | 0.18±0.02b | 5.22±0.4b | 4.53±0.03c |
| C0+D75 | 2.55±0.25 | 1.05±0.06a | 1.22±0.09 | 0.82±0.04a | 0.91±0.1b | 0.95±0.03a | 0.37±0.04b | 0.21±0.02b | 5.05±0.21ab | 3.03±0.03ab |
| C10+D50 | 2.36±0.09 | 1.99±0.07b | 1.1±0.2 | 1.4±0.13b | 1.1±0.06b | 0.77±0.03a | 0.42±0.06b | 0.18±0.02b | 4.97±0.34b | 4.33±0.18c |
| C5+D50 | 2.32±0.13 | 2.06±0.17b | 1.15±0.27 | 1.38±0.13b | 1.05±0.03b | 0.72±0.08a | 0.33±0.04b | 0.17±0.02b | 4.85±0.21b | 4.32±0.26c |
| C0+D50 | 2.57±0.08 | 1±0.07a | 1.29±0.25 | 0.77±0.05a | 0.99±0.13b | 0.91±0.08a | 0.4±0.07b | 0.24±0.04b | 5.25±0.27ab | 2.92±0.14a |
| P | 0.77 | 0 | 0.66 | 0.007 | 0 | 0 | 0.002 | 0.049 | 0.048 | 0 |
| Significance | ns | \*\*\* | ns | \*\* | \*\*\* | \*\*\* | \*\* | \* | \* | \*\*\* |

ns : non significative

\*\*\*: significative with p˂0,001

\*\*: significative with p˂0,01 \*: significative with p˂0,05

**3.1.5. Effect of treatments on Cation Exchange Capacity (CEC)**

The effect of treatments on cation exchange capacity is shown in Table 5. Statistical analysis reveals that treatments had a significant impact on CEC only in the second year. Furthermore, at each irrigation level (D50%, D75% and D100%), compost application at 5 and 10T/ha significantly increased CEC by an average of 31%, 38% and 28% (respectively) compared to the no-application controls. The results therefore indicate that in supplemental irrigation, the soil's cation exchange capacity depends on the compost application period. In addition, compost applied at 5 and 10T/ha would guarantee a significant increase in soil cation exchange capacity, regardless of the irrigation rate applied.

Table 5. Effect of treatments on cation exchange capacity in meq/100g

Significance ns \*\*\*

ns : non significative

\*\*\*: significatif with p˂0,001

**3.1.6. Effect of treatments on soil biological activity**

The effect of the different treatments on soil respiration is shown in Table 6. Statistical analysis reveals that the various treatments had no significant impact on soil respiration during the two years of experimentation, despite the 5 and 10T/ha compost inputs. However, there was a 57% drop in soil respiration compared with the control sample during the first year of experimentation. On the other hand, in the second year of experimentation, an average increase of 143% was observed. In addition, the D50% irrigation level induced the greatest rate of respiration compared with the other irrigation doses. These results suggest that, with supplemental irrigation, the effect of compost on soil biological activity is only perceptible in the medium to long term. Furthermore, this effect would depend on the soil's moisture content.

Table .6. Effect of treatments on soil respiration in mg CO2.g-1 dry soil.h-1

|  |  |  |
| --- | --- | --- |
| Treatments | Respirometrics -2023 | Respirometrics-2024 |
| Witness 1 | 6,86 | 6,86 |
| Witness 2 | 8,23 | 8,23 |
| C10+D100% | 3,07±0,5 | 18,41±3,85 |
| C5+D100% | 3,14±0,34 | 16,06±1,48 |
| C0+D100% | 3,45±0,59 | 22±5,19 |
| C10+D75% | 3,52±0,47 | 15,27±2,55 |
| C5+D75% | 2,83±0,35 | 15,7±2,8 |
| C0+D75% | 3,25±0,49 | 20,48±3,54 |
| C10+D50% | 3,79±0,34 | 22,88±2,96 |
| C5+D50% | 3,08±0,5 | 17,17±3,05 |
| C0+D50% | 2,72±0,35 | 17,57±1,48 |
| P | 0,78 | 0,63 |
| Significance | ns | Ns |

ns : non significative

3.1.7. Effect of treatments on soil pesticide content

Table 7 shows the effect of irrigation rates and compost on the presence of pesticides applied to crops in the soil. The results show that pesticide residues were detected in soils amended with 5 and 10 t/ha of compost, irrespective of the irrigation rate. In contrast, no residues were found in unamended plots, irrespective of irrigation. Furthermore, the amount of pesticide present in the soil did not seem to be influenced by the dose of compost applied. These observations suggest that the application of compost affects the behaviour of pesticides in the soil. However, the application of compost at 5 and 10 t/ha would not affect the variability of their concentration.

Table 7. Effect of different treatments on soil pesticide concentration in µg/g

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatments | Acetamipride | Imidacloprid | Lambda-cyalothrine | Cypermetrine | Abamectine |
| C10+100% | 1.1±0.53a | 0.85±0.21a | 2.28±0.35ab | 0.08±0.01a | 3.34±3.22 |
| C5+100% | 1.30±0.5a | 0.59±0.25a | 2.82±2.3ab | 0.1±0.02a | 0.12±0.02 |
| C0+100% | 0b | 0b | 0b | 0b | 0 |
| C10+75% | 1.10±0.23a | 0.86±0.26a | 2.30±0.9ab | 0.07±0.01a | 0.12±0.02 |
| C5+75% | 1.32±48a | 1.38±1.62a | 1.5±1.11ab | 0.08±0.02a | 0.11±0.01 |
| C0+75% | 0b | 0b | 0b | 0b | 0 |
| C10+50% | 0.97±0.31a | 1.06±0.47a | 3.53±3.44a | 0.08±0a | 0.09±0.01 |
| C5+50% | 1.57±0.39a | 1.38±1.62a | 2.32±0.23ab | 0.09±0.01a | 0.07±0 |
| CO+50% | 0b | 0b | 0b | 0b | 0 |
| P | 0 | 0.01 | 0.008 | 0 | 0.434 |
| Significance | \*\*\* | \* | \*\* | \*\*\* | ns |

ns: non-significant

\*\*\*: significative with P˂0,001

\*\*: significative with P˂0,01

\*: significative with P˂0,05

**3.1.8. Effect of treatments on yield in 2023 and 2024**

The results of the treatments applied to the tomato plots are shown in Figure 4. The results also show that the different treatments had no significant impact on the yields obtained. However, the C5+D75% treatment provided the best yields compared with the other treatments.

(b)

Figure 4: Effect of treatments on tomato yield in 2023 (a) and 2024 (b)

**3.1.9. Correlation between the different variables analyzed**

Figure (5) shows the principal component analysis of the dependent variables for the second year of experimentation, namely yield (R2), water productivity (Pro2), carbon content (C2), organic matter content (MO2), nitrogen (N2), phosphorus (P2), potassium (K2), sum of exchangeable bases (SB2) and cation exchange capacity. The results indicate that productivity and yield have high values on component 2. This implies that these two variables are highly correlated with each other and also with component 2. On the other hand, organic matter, carbon, nitrogen, the sum of exchangeable bases, and cation exchange capacity are strongly correlated with each other and also with component 1. Thus, these parameters would represent an indicator of soil fertility level likely to influence variables related to yield and water productivity, elements of Component 1.

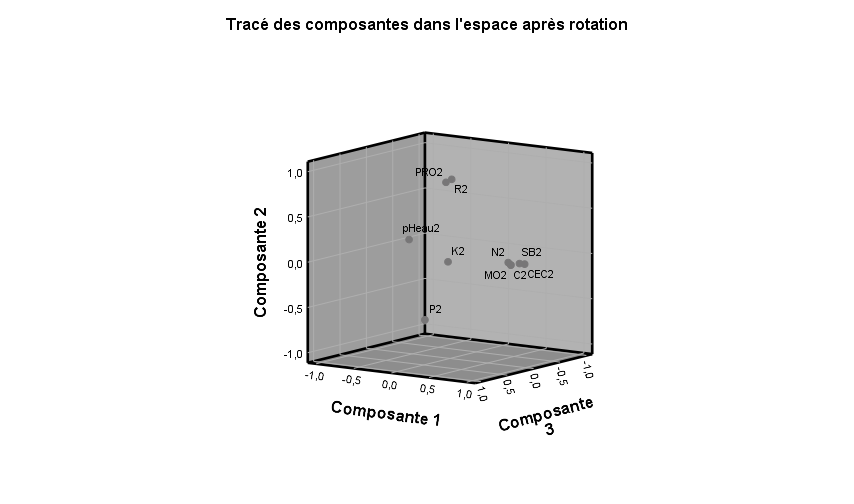


Figure 5: Graph of variables projected into the space of principal components

**3.2. Discussion**

Irrigation doses, combined with different compost rates, were applied as treatments on an experimental site under tomato cultivation. The effect of these different treatments on soil chemical parameters was evaluated over two years before the experiment was set up and after each harvest.

Results from the first year of experimentation show that a variation was recorded compared with control samples. However, the real impact of the treatments on soil chemical parameters only became perceptible in the second year of experimentation. In fact, during the first year of experimentation, it was observed that the addition of compost induced an increase in carbon and organic matter levels, irrespective of the irrigation level (D50%, D75%, and D100%). However, this increase was not significant. Other chemical parameters studied, such as NPK, exchangeable bases, CEC, and soil biological activity, also changed in comparison with the controls. However, the increase was very small. These results suggest that in supplemental irrigation, compost application induces a slow variation in soil chemical parameters in the short term. In their work, [16], [17] confirmed the slow change in these parameters in the short term following the application of compost. These results could be explained by the compost's C/N ratio of 19, which is responsible for the compost's slow to moderate mineralization. Furthermore, the difficulty in significantly raising carbon levels in the first year of experimentation could be explained by the low carbon sequestration capacity in tropical zones [18].

In the second year of experimentation, it was observed that compost application at 5 and 10 T/ha under supplemental irrigation resulted in a significant increase in carbon and organic matter, irrespective of the irrigation rate. However, this increase was particularly marked under the D75% irrigation regime, which recorded the highest increase at 73%. This trend was also observed for other chemical parameters, notably nitrogen, cation exchange capacity, and exchangeable bases. Several studies have highlighted the beneficial effect of compost on improving soil chemical properties [17], [19], [20], [21]. These results could be explained by compost's ability to limit nutrient leaching and improve the retention of mineral elements in the soil. [19] emphasized that the addition of organic matter helps to stabilize nutrients by reducing their leaching. Furthermore, it was observed that the D75% irrigation regime favored the accumulation of soil minerals after compost application. In contrast, D100% irrigation would have induced excessive moisture, resulting in increased leaching of mineral elements [19], [23]. This excess of water could also have created anaerobic conditions, thus limiting the mineralization process. Conversely, D50% irrigation generated insufficient humidity, restricting the release of mineralized carbon and nitrogen. Thus, D75% irrigation appears to have provided optimal conditions for both mineral release and retention in the soil. These observations translated into high yields in plots irrigated with D75% compared with other irrigation rates [24] (see figure 4).

The results also showed that potassium and sodium were not significantly impacted by the different treatments throughout the experimentation period. This observation could be explained by the fact that, in its inorganic form, the potassium provided by the compost is easily leached or rapidly assimilated by the plant. Finally, it was observed, particularly in the second year of experimentation, that the unamended plots recorded a better mineral content. This could be explained by the fact that the compost applied to the amended plots was partially washed down to the adjacent, unamended plots, favouring the accumulation of minerals in the latter. Runoff could thus have contributed to a redistribution of nutrients, indirectly influencing the results obtained under the various experimental conditions.

With regard to soil biological activity, the analyses revealed that it had been inhibited during the first year of the experiment. There was a decrease in overall respiration of nearly 57% compared to the control. This situation could be explained by the fact that the beneficial impact of compost on biological activity is generally noticeable in the medium to long term (6 months to several years), when stabilized organic matter becomes a source of energy and nutrients that can be easily used by soil microorganisms [25]. Furthermore, when compost is incorporated, soil microorganisms use the available carbon, but when nitrogen is not immediately accessible, their respiration temporarily decreases [26]. However, during the second year of the experiment, there was a 157% increase in soil respiration compared to the control. This increase can be attributed in part to climatic conditions, which were wetter and cooler than in the first year (see Figure 1) [27]. On the other hand, this increase could be due to the growth of microbial communities, thanks to the improved availability of substrates over time, induced by the addition of compost [28]. It was also observed that, during the second year of the experiment, the unamended plots had higher biological activity than the amended plots. These results contrast with the majority of studies, which have shown improved soil biological activity following the addition of compost. The results of this study could be explained by the incomplete mineralization of the compost. Compost provides stabilized organic matter, which is more difficult to decompose than fresh organic matter. [29] concluded in his study that the low respiration of amended soils was due to the recalcitrant carbon contained in compost, which is more difficult for microorganisms to degrade than fresh organic matter. Furthermore, the work of [30] has shown that fresh organic matter rapidly stimulates microbial respiration because it contains labile compounds (sugars, proteins). However, stabilized organic matter from compost can slow down this process. [31] showed that stabilized composts release their nutrients slowly, resulting in lower enzymatic activity and microbial respiration than those observed with fresh organic matter. Thus, in the present study, the organic matter in unamended soils could be less stable and therefore more easily degradable, inducing higher respiration, unlike compost, which contains recalcitrant carbon that is difficult for microorganisms to degrade. The results also showed that, overall, reducing water requirements by 50% led to better soil respiration compared to other irrigation doses. Several authors have shown that, in general, soil respiration increases with moisture; however, oxygen becomes limited when soil pores are completely saturated with water, which hinders the ability of soil organisms to breathe. According to [31], the optimal moisture content for maximum soil respiration is around 60% of field capacity, i.e., when approximately 60% of the pore space is filled with water. Above this threshold, soil respiration decreases due to insufficient aeration. When more than 80% of the interstitial space is saturated with water, soil respiration decreases to a minimum, and most aerobic microorganisms begin to use nitrate (NO) as a substitute for oxygen. Thus, in the present study, the D100% and D75% irrigation doses, applied as supplemental irrigation, would have induced moisture levels above 60% of field capacity, thereby limiting soil aeration and leading to a reduction in respiration. In contrast, the D50% irrigation dose allowed for better soil aeration, thereby promoting respiration.

With regard to pesticides, the results show that their presence in the soil was a function of the compost added. This result can be explained by the fact that the addition of organic matter favours the adsorption of pesticides by the soil [32], [33], [34]. Humic substances, major components of soil organic matter, play a crucial role in interactions with pesticides. Rich in functional groups such as carboxyls (-COOH) and phenols (-OH), they display significant chemical reactivity. These functional groups facilitate the formation of various bonds with pesticide molecules, including hydrogen bonds, van-der-Walls forces, hydrophobic interactions, and electrostatic interactions [35]. Furthermore, the results show that the application of compost at 5 and 10 t/ha would not significantly affect the variability of pesticide concentration in the soil. These results contrast with those of the majority of authors, who indicate that pesticide adsorption to organic matter increases with the amount of compost applied. [36] revealed that doubling the organic matter content of a soil by adding compost increased the adsorption coefficient of atrazine from 0.64 to 1.71 L/kg. This suggests that substantial additions of compost are required to induce significant variability in pesticide adsorption. Compost application would therefore represent a sustainable alternative for limiting groundwater and surface water contamination by pollutants, particularly pesticides.

Overall, the results indicate that from the second year onwards, certain practices, notably composting, lead to significant changes in soil fertilizing elements, underlining the importance of medium- and long-term management to optimize soil fertility. This study also highlights the crucial role of organic matter in soil sustainability. Finally, this work underlines the fact that the evolution of soil properties does not solely depend on agricultural practices, but is also influenced by other factors, such as climatic conditions. Soil temperature and humidity are particularly decisive factors, regulating microbial respiration and, consequently, the decomposition and mineralization of organic matter.

**4. Conclusion**

This study assessed the impact of compost application, combined with a reduction in irrigation rates, on soil fertility and pollution in a supplemental irrigation context. Results showed that the application of compost at doses of 5 and 10 t/ha led to a significant improvement in soil fertility after two years of experimentation. This improvement was reflected in a notable increase in several key chemical parameters, including exchangeable bases, nitrogen (N), phosphorus (P), potassium (K), and cation exchange capacity (CEC), highlighting compost's role in enriching the soil with essential nutrients. Furthermore, it was observed that this increase in soil fertility was particularly marked in the treatment receiving irrigation reduced to 25% of water requirements (D75%), resulting in higher yields in the plots amended under this irrigation rate. In addition, the results revealed that composting promotes the trapping of pesticides in the soil, limiting their leaching and potentially reducing groundwater pollution. Finally, the study also showed that, despite changes in soil fertility and contamination levels, the various agricultural practices tested had no significant effect on microbial respiration. These results suggest that the combination of composting and optimized irrigation management could be a promising approach to improving crop productivity while reducing water consumption. They also underline the essential role of organic matter in mitigating the environmental risks associated with pesticide use. Thus, a reasoned integration of compost and adapted irrigation management can sustainably improve soil fertility while limiting pollution risks, constituting a relevant agroecological strategy for a more sustainable and resilient agriculture.

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