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Effect of Potassium Carbonate used to Improve Phytosanitary and Agronomic Parameters of Tomato (*Solanum lycopersicum* L.) Crops

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KKG, KKFJM and KKD wrote the experimental protocol, managed search for funding the work, performed the statistical analysis and wrote the draft of the manuscript. Authors YKJE and FKKR managed the implementation of the experiment, collected and recorded the data from the experiment. Author KD correct the draft of the manuscript and managed the bibliographic research. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study aims to evaluate the effect of potassium carbonate (58 p.c) on agronomic and phytosanitary parameters in tomato crops.

Place and Duration of Study: This study was carried out from May to September 2020 at N'gattakro, a village near the international airport in the city of Yamoussoukro, center region of Côte d'Ivoire.

Methodology: Five doses of potassium carbonate (PC:T1= 2 Kg/ha; T2 = 3 Kg/ha; T3 = 4 Kg/ha; T4 = 5 Kg/ha; T5 = 6 Kg/ha), a reference control (TR1= IVORY (mancozeb 80%) and an untreated

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control were tested in a Fisher's complete block design with 4 replicates in a commercial garden plot.
Results: As results T4 and T5 potassium carbonate improved the tomato yield. These doses promoted the yield of 5.02±0.09 and 6.92±0.16 t/ha compared to the control (3.405±0.1 t/ha). Moreover, at these doses, there was a low manifestation of toxicity. In addition, 6kg/ha of PC showed a *fusarium* wilt infection rate of 1.38±0.71% compared to 3.62±0.90% for the control.
Conclusion: Potassium carbonate (58%) at 6 kg/ha can be an alternative solution to chemical control of fungal diseases in tomato cropping.

Keywords: Tomato; potassium carbonate agronomic; phytosanitary.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most produced vegetables in the world. In 2019, tomato production was estimated at about 181 million tons of fresh fruit [1]. In Côte d'Ivoire, tomatoes are grown in several regions [2]. Production in 2019 was estimated at 37351 tons for a need of 100,000 tons per year [1,3]. It plays a very important socio-economic role. Indeed, the cultivation of tomato is one of the main activities of a large segment of the population in rural and peri-urban areas, especially young people and women [2]. However, several abiotic and biotic factors make the practice of tomato cultivation difficult in tropical countries like ours. Indeed, all stages of development of tomato are affected by pests, parasitic diseases especially fungal [4]. Among these, damping-off, wilting, fungal leaf diseases, crown rot and fruit rot are the most abundant and devastating [5]. In tropical regions, they provoke yield losses and also reduce the quality of tomato production [6]. In view of the losses caused by these parasitic fungal infections, it is necessary to control these diseases to limit their damage, in order to obtain abundant crops of good quality. In addition to good agricultural practices, vegetable farmers often use chemical pesticides. However, the abusive and continuous use of agrochemicals is a source of residues of active ingredients of these pesticides in the produced foodstuffs and environmental pollution. These chemical molecules are also harmful to beneficial organisms and induce resistance mechanisms in pest populations [7,8]. Thus, the search for an alternative solution to chemical control of fungal pathologies of tomato becomes an imperative. In this regard, some salts such as calcium chloride, sodium carbonate, sodium benzoate, potassium sorbate, potassium carbonate, etc... are presented as an adequate solution. Because they have antifungal and antibacterial activities against different pathogens, demonstrated by several works [9,10,11]. In addition, the salts have a broad antimicrobial spectrum, are easy to apply and relatively low-cost. They are readily available and already approved for human food use. All these properties facilitate and accelerate the phytosanitary use of these salts, especially potassium carbonate [10]. However, in Côte d'Ivoire, very few works have been done on the antimicrobial efficacy of salts, especially potassium carbonate. This study aims to evaluate the impact of potassium carbonate on the agronomic and phytosanitary parameters of tomato crops in the field.

2. MATERIAL AND METHODS

2.1 Study Site

This study was carried out from May to September 2020 in N'gattakro, a village near the international airport of the city of Yamoussoukro, center Côte d'Ivoire. Indeed, the Yamoussoukro area belongs to the semi-deciduous dense rainforest domain with a bimodal rainfall regime ranging between 1300 and 1750 mm [12]. The climate corresponds to the transitional equatorial regime, characterized by two rainy seasons, from mid-April to July and from September to November, and two dry seasons, from August to September and from December to mid-April. The average temperature is about 26°C, with relative air humidity ranging from 75 to 85%, dropping to 40% during the harmattan (drought) period. The region is marked by a succession of several types of soil, ranging from reddish soils more or less gravely, fine to medium texture, well-draining; to yellow-brownish or brownish soils, more or less gravely, medium texture, with rapid drainage [13].

2.2 Materials

2.2.1 Plant material

Tomato plants (*Lycopersicon esculentum* L.) of Cobra variety were used in this trial. The plants were obtained from a 21-day nursery and transplanted to the experimental plot. This variety ensures productivity and reliability for producers in tropical and Sahelian zones. It produces abundant uniform fruits of square shape.

2.2.2 Products used

The control products used during this experiment consisted of:

- Potassium carbonate 58% supplied by Callivoire society used at 5 different doses: T1 = 2 Kg/ha; T2 = 3 Kg/ha; T3 = 4 Kg/ha; T4 = 5 Kg/ha; T5 = 6 Kg/ha.

- The synthetic fungicide, IVORY 80% (Mancozeb: 800g/kg), registered in Côte d'Ivoire on vegetable crops was used as a reference control (TR1) at 3 Kg/ha.

2.3 Methods

2.3.1 Experimental design

The trial was set up in a Fisher randomized complete block design with 4 replicates, each dose of the Potassium Carbonate was considered as the test or treatment (Fig. 1). The elementary plot has an area of 24 m^2 (6 m x 4 m) with 0.5 m separation between each of the elementary plots of the same block. Eeach elementary plot has 6 tomato rows. However, in order to minimize border effects, only the four internal lines were considered for the different observations and measurements. The transplanting of tomato plants was done on July 07, 2020. The plants were spaced 0.40 m apart in the row and 1 m between two rows. The total number of tomato plants for this trial is 1680 or 10 feet × 6 lines × 7 treatments × 4 replicates according to the design (Fig.1).

B : Block; T : Treatment; T0: control; TR: Reference (IVORY 80% (Mancozèbe : 800 g/kg); T1; T2; T3; T4 et T5: Potassium carbonate treatment 58%

2.3.2 Effectiveness of potassium carbonate at the field

2.3.2.1 Applying of the products

The different doses of potassium carbonate and the synthetic fungicide was applied with a 15-liter sprayer. A volume mixture of 1.6 liters per elementary plot was sprayed, i.e. approximately 45 liters for the entire plot. Treatments were started one week after transplanting in the field and were repeated every 7 days. The foliar application of the different doses were done during the whole tomato cycle from field transplanting to harvest.

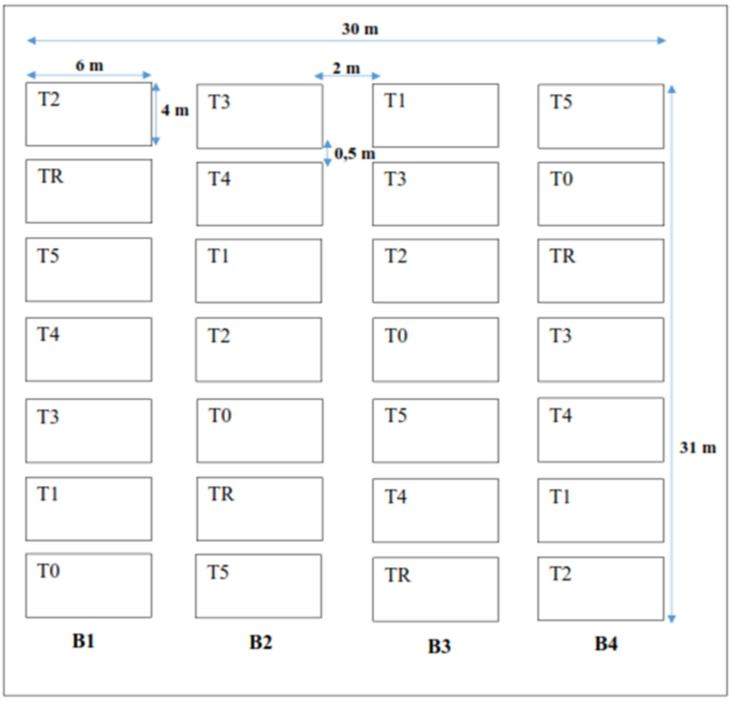


Fig. 1. Experimental device

2.3.2.2 Agronomic assessment

The evaluation of the agronomic parameters was carried out on the various stages of tomato plants development. It was done on ten (10) plants taken randomly on the four internal lines in each elementary plot. The evaluated parameters were: phytotoxicity, flowering rate, plant height and tomato yield.

- Phytotoxicity was assessed 7 days after each treatment according to the method described by Coulibaly *et al* [14]. It consisted in assessing the damage or toxicity caused by the products on plant leaves according to a rating scale of 1 to 4, with: 1 = very bad effect (death of the plants); 2 = bad effect (total burning of the leaves); 3 = moderately good (burning of the majority of the leaves); 4 = good (non-significantly effect on the leaves). As for the flowering rate, it was noted on 10 tomato plants from each elementary plot and then calculated according to the formula described by Soro [15]:
-

Flowering rate (%) = (Number of flowering plants)/(Total number of plants assessed)×100

- Plant height was measured at the flowering stage using a tape measure from the collar to the junction of the last leaf and the floral bunch according to Soro [15].

- Yield parameters Fruits were harvested weekly. So, the number, weight of healthy and spoiled fruits were determined. These values were used to calculate the net potential yields and the yield of healthy and spoiled fruits for each treatment according to Fondio *et al* [16]:

Rdt (t/ha) = (MFS/A X 10,000) / (MTFX SM)

Rdt = Yield; MFS/A= Mass of healthy or spoiled fruits; MTF= Total mass of fruits; SM= Microplot area

- Determination of fruit rigidity Determination of fruit firmness per elementary plot was done at the first harvest from ten (10) randomly selected healthy fruits. The firmness of the fruits was determined by digital pressure, and scores were assigned according to a scale of 1 to 5 [14]: 1= completely soft fruits, 2= soft fruits, 3= medium firm fruits, 4= firm fruits, 5= very firm fruits.

2.3.2.3 Assesment of phytosanitary parameters

Incidence and severity of fungal leaf diseases.
Fungal leaf diseases symptoms encountered in the elementary plots were described. The total number of plants and those affected by fungal foliar diseases were counted and then the incidence was calculated according to Raju and Naik. [17]:

I (%) = (NPI/NTP) X100

I (%) = Incidence; NPI= number of infected plants; NTP = total number of plants

From each plot, 10 diseased plants were randomly selected. On these plants, the severity of the foliar diseases was scored based on the symptom rating scale proposed by Vakalounakis and Fragakiadakis [18]; with:

0: healthy plant; 1: slightly affected; 2: visible and severe disease; 3: plant death

The severity index was calculated according to the following formula [19]:

IS = (NE x NPI/ NPE x NTP) X100

IS = Severity index; NE = Scale score; NPI = Number of infected plants

NPE= higher score; NTP= total number of plants;

2.3.3 Statistical analysis

All the data collected were analyzed with the software statistica 7.1.For all the parameters evaluated, the analysis of variance (one factor ANOVA) was performed. In case of significant difference between the studied parameters, the Newman-Keuls test was used for the separation of the means at the 5% threshold.

3. RESULTS

3.1 Effect of Potassium Carbonate (PC) on Agronomic Parameters

3.1.1 Phytotoxicity on tomato plants

As result, the different doses of PC (58%) applied did not cause bad phytotoxic effects on tomato crops (Fig. 2). Statistical analysis shows that, treatments (T1, T2, T3, T4 and T5) of Potassium Carbonate 58% and TR1 had similar scores, with averages between 2.9 and 4 (Fig. 2).

3.1.2 Plants Height and flowering rate

The means heights and flowering rates of the different tomato plants were evaluated (Figs. 3 and 4). Data Analysis showed that there was no significantly difference ($P<0.05$) between treatments for height and flowering rate. The height of the treated plants with the different doses of potassium carbonate 58%, IVORY (mancozeb 80%) and untreated control varied from 45 to 61 cm. Concerning flowering, the data analysis showed that there was no significant difference between the treatments. The rates were respectively, 60% for T2 (3kg/ha) and 74% for the control. Plants treated with 5 of 6kg/ha of potassium carbonate had the highest flowering rate (73%). T2 (3kg/ha) had the lowest flowering rate (60%). The other treatments T1, T4 and T3 had average rates of 68, 65 and 60% respectively. The effect of all these treatments was statistically similar to that of the synthetic fungicide which was 70% (Fig. 4).

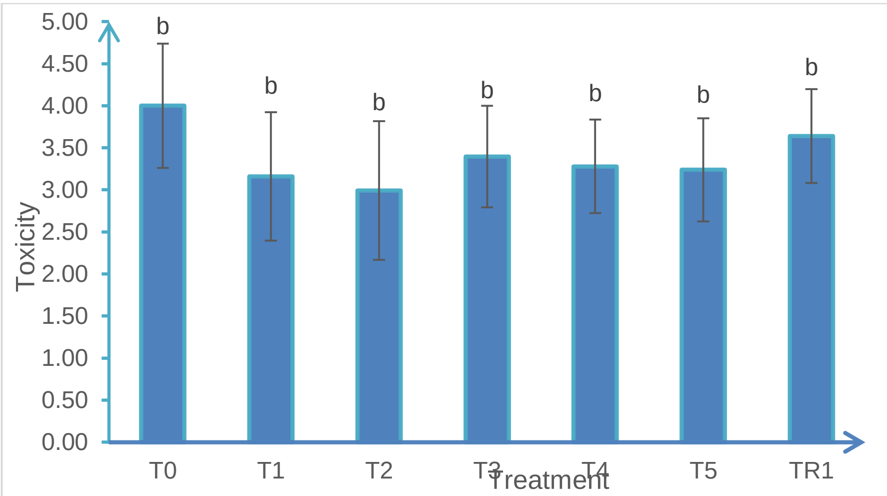


Fig. 2. Toxicity level of the products on the leaves according to the treatments
Histograms with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).

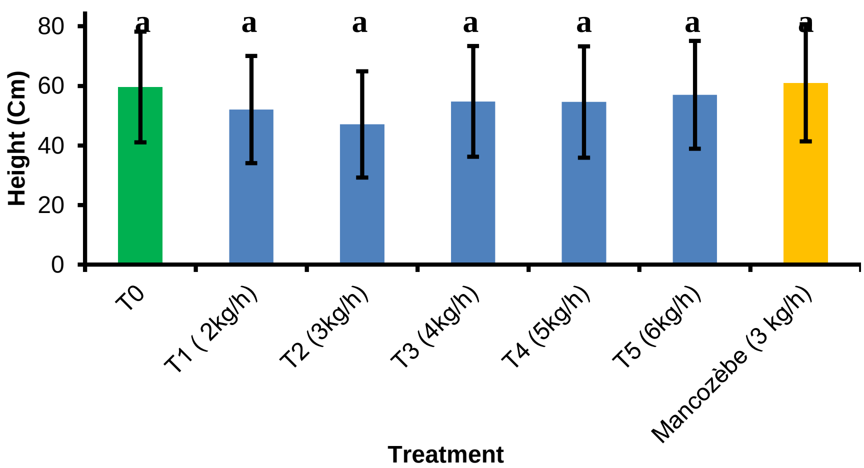


Fig. 3. Plant heights according to treatments
Histograms with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).

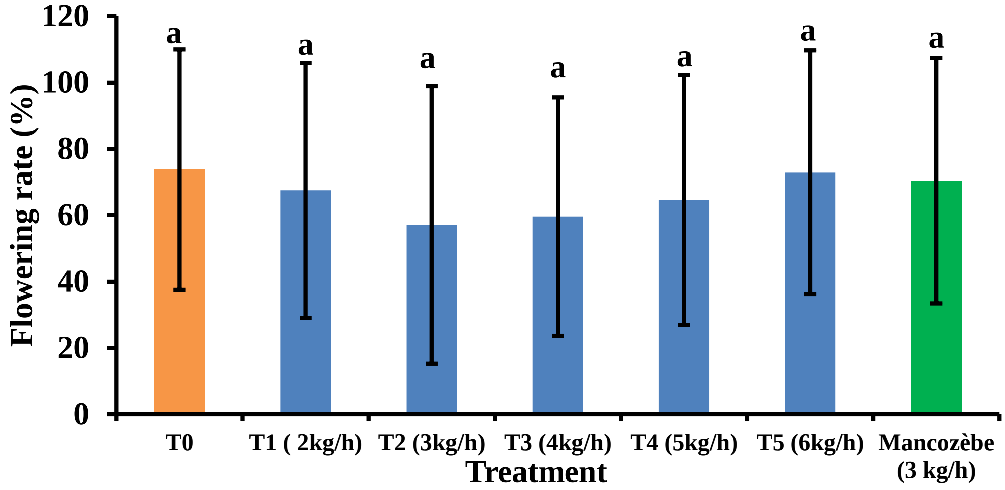


Fig. 4. Flowering rate of tomato plants after treatments

Histograms with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).

3.2 Effect of Treatments on Phytosanitary Parameters

3.2.1 Incidence and severity of fusariosis

Table 1 shows the incidence of *Fusarium* as a function of treatments. Data analysis showed highly significant differences between treatments for *Fusarium* incidence. The treatments were screened into three groups. The mean incidences in the control (T0) and T1 plants were the highest with 3.62±0.90% and 3.12±1.53%, respectively. On the other hand, treatments T3, T4 and T5 recorded very low incidences, with averages between 1.32±0.74 and 1.92±1.66%. As for the severity index, the potassium carbonate treatments show low averages between 0.35±0.10 and 0.79±0.38%. In contrast, the control (T0) treatment had the highest disease severity with 3.58±0.90% (Table 1).

3.2.2 Incidence and severity of *Alternaria*

Statistical analysis showed significant difference between treatments for *Alternaria* incidence rates (Table 2). The incidence of *Alternaria* ranged from 7.47±1.33 to 16.21±1.2%. It was lower in plants treated with the reference TR1 (7.47±1.33%) and higher in control plants T0 (16.21±1.2%). As for T2 (3kg/ha), T3 (4kg/ha), T4 (5kg/ha) and T5 (6kg/ha), they had intermediate incidence values, ranging from 9.03±1.4 to 10.84±1.2% (Table 2). The evaluation of the disease severity index showed the level of infection of the affected plants. It was low in plants treated with potassium carbonate 58% (T1 to T5), with values ranging from 0.53±0.10 to 0.72±0.07%. On the other hand, the untreated plants, T0 were severely attacked (Table 2).

Regarding the number of infected fruits, T2, T3 and T4 recorded the lowest number of fruits varying between 5 and 7. As for T1 and T5, they had a high number of attacked fruits ranging between 8 and 11 (Table 2).

3.3 Analysis of Yield Components

Yield results are reported in Table 3. All rates of potassium carbonate 58% applied resulted in improved production compared to the untreated control. However, the greatest improvement was obtained with the T5 treatment which yielded 6.92±0.16 t/ha. However, the reference control TR1 had a higher yield (10.96± 1.26 t/ha) than the other treatments (Table 3). Statistical analysis reveals four groups. The first group consisting of T0 and T3, the second group is represented by T5; the third group is represented by the reference control TR1; and T1, T2 and T4 constitute the last group. All treatments in the same group had statistically identical yields (Table 3). Regarding fruit firmness, all treatments were statically equal. They recorded fruit firmness between 2.72±0.92 and 3.7±0.19. Regarding the yield of spoiled fruits, the control had the highest value (0.3 ± 0.09 t/ha). However, all treatments had statistically the same averages. Regarding healthy fruits, all treatments had statistically identical yields except the reference control TR1 (Table 3).

Table 1. Average incidence and severity of *Fusarium* wilt disease

Treatment	Incidence Average	Severity Index
T0	3.62±0.90 a	3.58 ±1.03 a
T1	3.12±1.53 a	0.78 ±0.56 b
T2	2.10±1.64 ab	0.73 ±0.46 b
T3	1.92±1.66 b	0.79 ±0.38 b
T4	1.32±0.74 b	0.78 ±0.35 b
T5	1.38±0.71 b	0.35 ±0.10 b
TR1	1.87±1.55 b	0.36 ±0.25 b

Values in a column with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).

Table 2. Incidence and severity averages of *Alternaria* disease

Treatments	Incidence (%)	Severity (%)	Average number of diseased fruits
T0	16.215±1.2a	0.98±0.11a	9.75±1.4a
T1	12.48±1.5b	0.72±0.07b	8.08±1.7a
T2	9.03±1.4bc	0.53±0.10b	5.0±1.2b
T3	9.52±1.3bc	0.54±0.08b	6.5±0.9c
T4	10.84±1.2bc	0.68±0.07b	6.3±1.4c
T5	9.35±1.5bc	0.54±0.08b	9.25±1.7a
TR1	7.47±1.33c	0.43±0.06b	10.66±0.6a

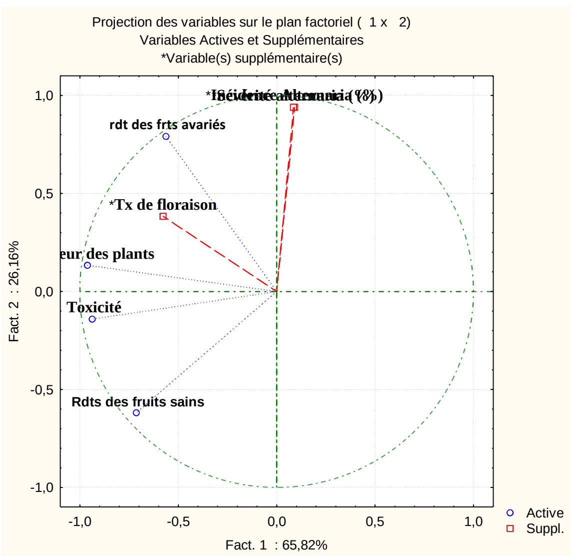
Values in a column with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).

Table 3. Firmness and yield of harvested spoiled and holy fruits according to treatments

Treatments	Fruit yield (t/ha)	Firmness	Yield FS (t/ha)	Yield FH (t/ha)
T0	3.405±0.1a	3.75±0.16a	0.3 ± 0.09 b	3.0 ± 2.6 a
T1	4.42±0.12ab	3.65±0.2a	0.1 ± 0.05 a	4.5 ± 1.0 ab
T2	4.23±0.2ab	2.72±0.92a	0.1 ± 0.07 a	4.2 ± 1.3 ab
T3	4.40±0.16a	2.75±0.92a	0.1 ± 0.02 a	4.4 ± 0.5 ab
T4	5.02±0.09ab	3.55±0.19a	0.1 ± 0.06 a	5.0 ± 1.9 ab
T5	6.92±0.16b	3.7±0.19a	0.2 ± 0.09 a	6.9 ± 1.1 ab
TR1	10.96±1.26c	4.25±0.14a	0.2 ± 0.03 a	10.66 ±3.2 b

***FS**: Spoiled fruits; **FH**: Healthy fruits*

Values in a column with the same letter are not significantly different at the 5% threshold (Newman-Keuls test).



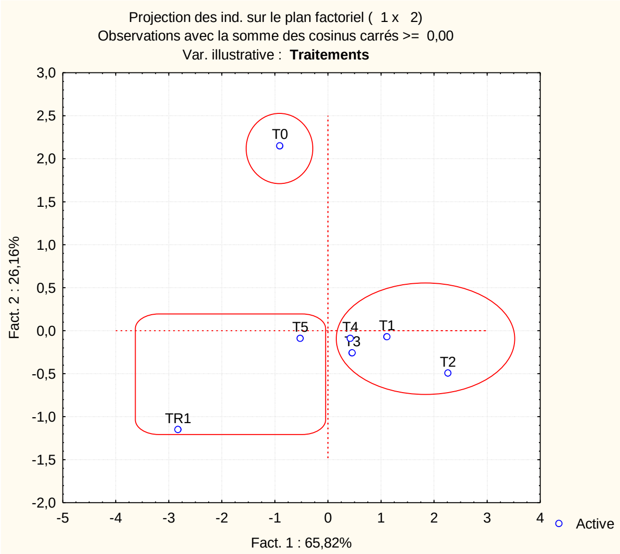


Fig. 5. Correlation circle (a) and treatment dispersion (b) from PCA of potassium carbonate treatments 58 %

3. 4 Classification of Treatments

A principal component analysis (PCA) was used to screen the treatments on the basis of growth, yield and phytosanitary parameters. Axes 1 and 2 were sufficient to characterize the treatments evaluated. These axes contributed 92% of the observed variation (Fig. 5). Healthy fruits yield, toxicity, spoiled fruits yield, plant height and flowering were strongly and negatively correlated with axis 1. This axis was used to divide the treatments into three groups. The group (A) is constituted by TR1 and T5 (6kg/ha) characterized by better growth parameters (height, flowering and toxicity), better yield with a strong inhibiting action of fungal diseases. And those formed by treatments T4 (5kg/ha), T3 (4kg/ha), T2 (3kg/ha) and T1 (2kg/ha) are of medium (B) and low (C) performances (Fig. 5).

4. DISCUSSION

Abiotic and biotic factors make it difficult to grow tomatoes in tropical countries. Potassium Carbonate is used for the control of plant pests. The doses of potassium carbonate 58% used were not toxic to tomato plants. Our results are in disagreement with those reported by Ilhan *et al* [20], who tested these products on apple plants. These authors showed that the dose of 2% of sodium bicarbonate applied on plants every 10 days is phytotoxic. This difference in results could be explained by the fact that the toxicity varies according to the plant material. The analysis of the average heights and the flowering rate showed that there was no significant difference. These results indicate that potassium carbonate would not affect the growth, development and flowering of tomato plants. Our results are in agreement with the work of Türkkan [21] on the evaluation of the inhibitory effect of organic and inorganic salts against *Ilyonectria liriodendri*, the causal agent of kiwi root rot disease. This author found that Sodium benzoate, Potassium benzoate, Sodium metabisulphite and Potassium sorbate at 0.10 (w/v) did not affect the root length of Kiwi seedlings.

Potassium carbonate 58% was effective against *Fusarium* and *Alternaria*. The rate of 6 kg/ha was the most effective. This rate resulted in higher yields of healthy fruit and lower yields of spoiled fruits. This result shows that carbonate has a fungicidal effect and is effective in protecting tomato plants from foliar diseases.

Our results are in agreement with those of Affia [10], who showed that potassium carbonate has antifungal and antibacterial activities against different pathogens and are non-toxic to the environment and to users. However, the results do not coincide with those of Delisle-Houde *et al* [22]. These authors reported that sodium carbonate, sodium bicarbonate, potassium sorbate did not significantly reduce the severity of black spot and black vein disease of lettuce.

Potassium carbonate treatments had a significant effect on plant production. Regarding fruit firmness, there was no significant difference between treatments. This proves that the product does not affect the quality of the fruits.

Potassium carbonate 58% had significantly the same effect as mancozeb 80% at 6 kg/ha against leaf diseases. Indeed, the chemical fungicide mancozeb can be detrimental to beneficial insects and induce resistance mechanisms in pest populations [8]. In these circumstances, potassium carbonate is an alternative solution to chemical control of fungal pathologies in tomato production; it has antifungal properties, and it is nontoxic for both, the environment and for the users, as signified by the work of Affia [10].

5. CONCLUSION

In sum, the application of potassium carbonate at 58% at the rate of 6 kg/ha, improves agronomic parameters and controls *Fusarium* wilt and *Alternaria at the rate of 6 kg/ha.* In the context of environmental protection and sustainable agriculture, potassium carbonate 58% is a solution and can be used as an alternative or integrated to chemical control of fungal plant pathologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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