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Evaluation of the Effect of Variable Fertilization Formulas on the Severity of Viral Diseases of Five Tomato Cultivars in Southern Togo Using a Linear Model

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMG did research protocol, data collection, data processing, analysis, and wrote first draft of the manuscript. Author DKA directed the research through initiation to setting up the research protocol and the interpretation of the results. Authors ASM and KAD did research protocol, Author JMS reviewed and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

One of the solution approaches to tomato viral diseases is undoubtedly the cultivation of tolerant cultivars. However, the environment in which these tomatoes are grown must allow them to favorably express their resistance to viruses. The soil nutrients brought or not are part of this

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environment. The objective of this study is to find ways and means from fertilization to create favorable conditions for the resistance of tomato cultivars to viruses. To do this, two experiments were conducted at the agronomic experiment station of the University of Lomé during the long rainy seasons of 2019 and 2020 under five tomato cultivars (Caraïbo, Mongal-F1, Petomech, Tropimech and Adakamenou) under the conditions of five fertilization formulas, T0 (0 fertilizer), T1 (200 kg NPK 15 15 15 and 100 kg urea 46% ha^{-1}), T2 (10 t cattle manure ha^{-1}), T3 [(T1+T2)/2] and T4 (300 kg NPK 15 15 15, 67 kg urea 46% ha^{-1} and 5 t ha^{-1} of cattle manure). The split-plot design was used where the fertilizers were in main plots and the cultivars in sub-plots. The linear regression of virus severities observed during the experiment according to a rating scale from 1 to 5 made it possible to describe the behavior of the cultivars. The regression's lines slopes varied from 10.55% to 43.72% under the unfertilized plants; from 2.92% to 12.4% under fertilized Caraïbo plants; from 6.70% to 9.80% under fertilized Mongal-F1 plants; from 26.77% to 49.46% under fertilized Petomech plants; from 48.77% to 63.55% under fertilized Tropimech plants and from 5.22% to 16.76% under fertilized Adakamenou plants. It follows that the behavior of a tomato cultivar with respect to viruses differs according to the fertilization formula that has been given to it and that taking fertilization into account would be essential in the management plans for tomato viruses.

Keywords: Tomato (Solanum lycopersicum L.); fertilization; viral diseases; severity.

1. INTRODUCTION

Viral diseases are one of the obstacles to tomato production. To better manage them, it is important to bring together a large set of technological packages, in particular the use of tolerant cultivars and the management of nutrients to be provided to tomato plants in order to help them better resist these viral diseases. This is because mineral nutrition is one of the important aspects of plant physiology and pathophysiology, even though the relationship between this nutrition and viral disease is little known [1].

It is currently undeniable that nutritional factors that promote host plant growth also promote virus multiplication and this is particularly true for nitrogen and phosphorus [2-4]. The question then arises as to what dose(s) and what type of fertilizer to be combined with tomato's cultivars in order to strengthen their resistance to viruses. This work therefore evaluated the behavior of five tomato cultivars with respect to viruses under different fertilization schemes in southern Togo; South Togo, which is under pressure not only from insect pests such as *Bemisia tabaci* [5] but also viruses [6] resulting in low yields of cultivated tomatoes.

2. MATERIALS AND METHODS

The experiment was conducted in the open field at the Lome agronomic experiment station in two repetitions. The first in the long rainy season of the year 2019 and the second during the long rainy season of the year 2020 following a split-plot design where the fertilizers were in the main plots and the cultivars (Caraïbo, Mongal-F1, Petomech, Tropimech and Adakamenou) in secondary plots (Fig. 1). Each elementary plot (1.2 m x 2 m) housed 15 plants which were transplanted according to a 50 cm x 40 cm cultivation scheme after 21 days in the nursery.

Bloc 1

T0	T1	T2	T3	T4
V1	V2	V3	V4	V5
V2	V3	V4	V5	V1
V3	V4	V5	V1	V2
V4	V5	V1	V2	V3
V5	V1	V2	V3	V4

Bloc 2

T4	T0	T1	T2	T3
V2	V3	V4	V5	V1
V3	V4	V5	V1	V2
V4	V5	V1	V2	V3
V5	V1	V2	V3	V4
V1	V2	V3	V4	V5

Bloc 3

T3	T4	T0	T1	T2
V3	V4	V5	V1	V5
V4	V5	V1	V2	V1
V5	V1	V2	V3	V2
V1	V2	V3	V4	V3
V2	V3	V4	V5	V4

V1= Caraïbo ; V2= Mongal-F1 ; V3= Petomech ; V4= Tropimech ; V5= Adakamenou

Fig. 1. Schema of design used at experimentation

Fertilizers were brought to the plants by pocket in the following way:

- T0: (0 engrais);
- T1: (4 g de NPK 15 15 15 + 2 g of urea 46% N) $plant^{-1}$;
- T2: (200 g of cattle's manure) $plant^{-1}$;
- T3: (2 g de NPK 15 15 15 + 100 g of cattle's manure + 1 g of urea 46% N) $plant^{-1}$;
- T4: (6 g of NPK 15 15 15 + 100 g of cattle's manure + 1.34 g urea 46%N) $plant^{-1}$.

These fertilization treatments were formulated taking into account the requirements of tomato plants in terms of nutrient export [7] but also taking into account the recommendations of Gorobani et al. [8] on the economic profitability of Mongal-F1 tomato cultivation in Southern Togo.

2.1 Viral Diseases Severity Observation and Data Collection

Virus severities were observed weekly on a scale of 1 to 5 [9].

Concerning the virus severity observation scale, it is: 1= no visible symptoms; 2 = visible symptoms of low intensity (25% of leaves are infected); 3= moderate symptoms (50% of leaves infected); 4= severe symptom (75% of leaves are infected) and 5= very severe symptom (75% to 100% of leaves infected).The mean severity index was calculated using the following formula from Camara et *al*. [10] where "ni" is the number of plants having expressed a virus severity "si".

$$Sm = \frac{\sum [Si \ x \ ni]}{\sum ni}$$

2.2 Analysis of Collected Data

Linear regression was used to analyze the evolution of virus severities over time by comparing the slopes of the regression lines. Genstat edition 19 software was used for the discrimination of the means at the 5% threshold after the analysis of variance test was positive. As for the assessment of the slopes of the regression lines, there is a divergence between the assessments of the slopes. Some believe that the slope of a regression line is low if it is less than 8% [11]. For others, it is low when it is between 5 to 15% [12]. In this work, the assessment of the slopes of the regression lines was made according to the following criteria:

- slope < 10% (low slope),
- 10% ≤ slope ≤ 25% (average slope),
- 25% < slope ≤ 50% (high slope),
- 50 < slope ≤ 90% (very high slope).

The higher the slope, the greater the variation in virus severities over time.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Trend curves showing the evolution of virus severities under unfertilized plants of the five cultivars

When the cultivars were not fertilized, the severities of the viruses intensified over time (Fig. 2) and the slopes of the linear regression lines were average under Mongal-F1 (10.55%), Adakamenou (11.83%), and Caraïbo (13.65%); high under Petomech (29.97%) and Tropimech (43.72%). It therefore follows that Mongal-F1, Adakamenou and Caraïbo would be naturally more resistant to viruses than the other Petomech and Tropimech.

3.1.2 Trend curves showing the evolution of virus severities under fertilized Caraïbo

At the level of fertilized Caraïbo, the slope reflecting the inclination of the regression line was raised under the exclusively mineral T1 fertilizer (12.4%); low under exclusively organic T2 (3.33%), organo-mineral manures at high and low doses T4 and T3 (3.33%; 2.92%). It therefore follows that the Caraïbo cultivar behaved in different ways vis-à-vis viruses under different fertilization schemes and that T2, T4 and T3 fertilizers would seem to be the best fertilizers to strengthen Caraïbo in its resistance to viruses since without fertilization (Fig. 3), the slope of the straight line was on average around 13.65%, close to that observed under T1.

3.1.3 Trend curves showing the evolution of virus severities under fertilized Mongal-F1

At the level of the fertilized plants of Mongal-F1 (Fig. 4), the slope reflecting the inclination of the regression line was average under the organo-mineral fertilizer at high dose T4 (12.73%); low under exclusively mineral T1 (9.80%), exclusively organic T2 (8.94%) and low-dose organo-mineral T3 (6.70%) manures. Compared to the non-fertilized plants (T0 x Mongal-F1), the result is that the T1, T2 and T3 fertilizers would seem to be the best fertilizers to strengthen Mongal-F1 in its resistance to viruses.

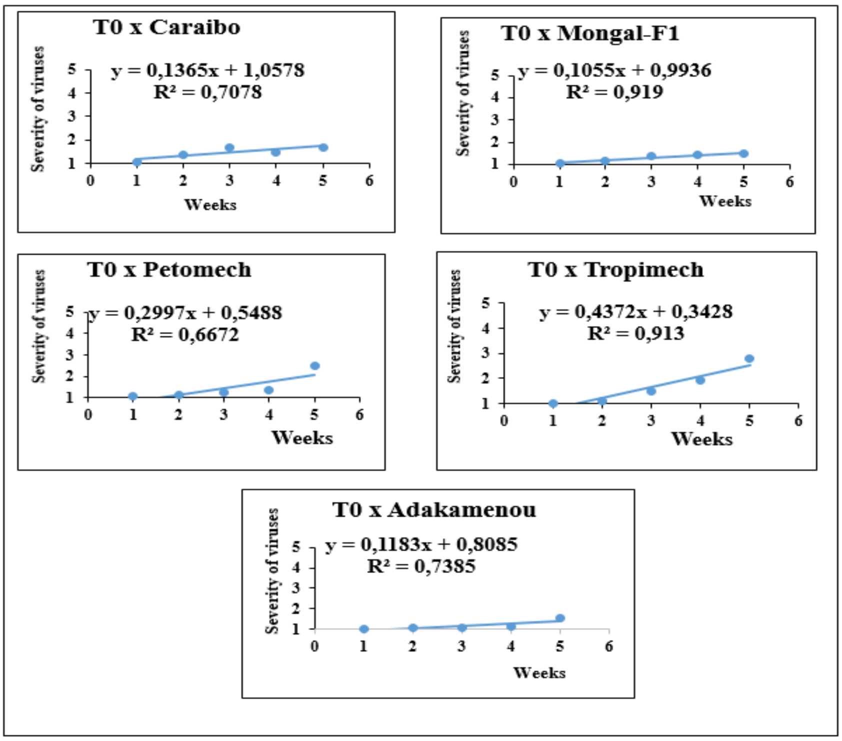

Fig. 2. Linear model describing the evolution of virus severities under the five unfertilized cultivars

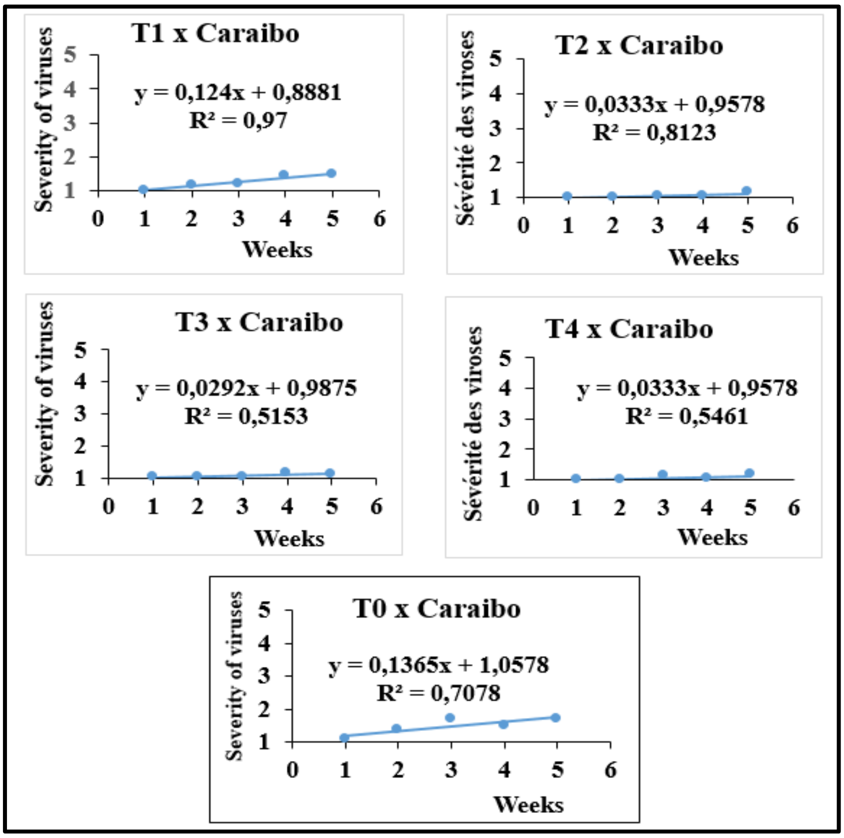

Fig. 3. Linear model describing the evolution of virus severities under Caraïbo under different fertilization conditions

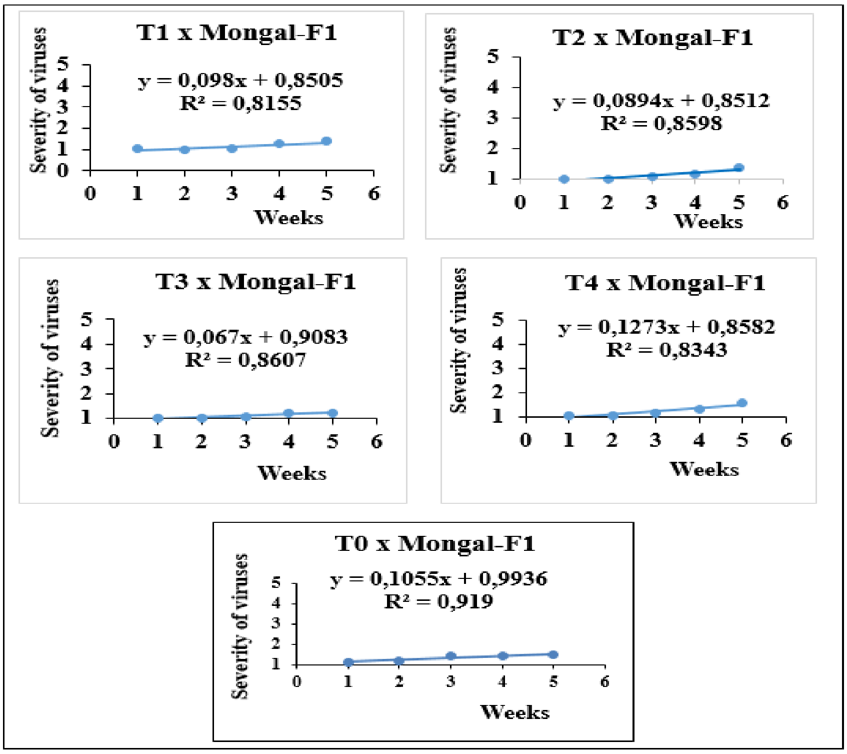

Fig. 4. Linear model describing the evolution of virus severities under Mongal-F1 under different fertilization conditions

3.1.4 Trend curves showing the evolution of virus severities under fertilized Petomech

The evolution of the severities of viral diseases observed under Petomech according to a linear model (Fig. 5) made it possible to affirm that they intensified rapidly as a function of time compared to Caraïbo and Mongal-F1 observed above. Indeed, the slope reflecting the inclination of the regression line was high under organo-mineral manures at high dose T4 (49.46%) and exclusively organic T2 (43.54%), average under organo-mineral manures low-dose T3 (29.47%) and exclusively mineral T1 (26.77%). T3 and T1 fertilizers would therefore seem to be the best fertilizers to strengthen Petomech in its resistance to viruses even if this reinforcement of these two fertilizers (T3 and T1) is weak and this, compared to non-fertilized plants (T0 x Petomech).

3.1.5 Trend curves showing the evolution of virus severities under Tropimech

At Tropimech (Fig. 6), the slopes reflecting the inclination of the regression lines were very high under the exclusively organic T2 (63.55%) and mineral T1 (61.41%) manures, and high under the manures organo-mineral at low T3 (49.93%) and organo-mineral at high dose T4 (48.77%). No slope was low or medium under this cultivar. It would follow that the production of Tropimech with any manure put in place should be prohibited since all the slopes were even greater than that observed under the unfertilized plants of Tropimech (43.72%).

3.1.6 Trend curves showing the evolution of virus severities under fertilized Adakamenou

The increase in virus severity under Adakamenou (Fig. 7) was low when it was fertilized by T3, T1 and T4 because there, the slopes reflecting the inclination of the regression lines were low (5.22 %, 6.83% and 8.03%) and average under T2 (16.76%). This means that T3, T1 and T4 reinforced Adakamenou in its resistance to viruses when we even observe that the slope of the line under the unfertilized plants was 11.83%.

3.1.7 Average severity of viruses under the effect of fertilizers

According to the analysis of variance, it appears that the fertilizers did not have a significant effect on the severity of the virus disease plants. This shows that the involvement of fertilizers in strengthening tomato plants to better resist viruses was not significant. However, the interaction between fertilizers and cultivars had a significant effect, indicating that the interactions between fertilizers and cultivars significantly influenced the resistance of tomato plants to viruses (Table 1).

Given the low severities observed, the following interactions are to be recommended first. These are: T3 x Caraïbo; T4 x Caribbean; T2 x Caribbean; T3 x Adakamenou; T3 x Mongal-F1; T2 x Mongal-F1; T2 x Adakamenou; T1 x Adakamenou; T1 x Mongal-F1 and T0 x Adakamenou. Finally we recommend in second place: T4 x Mongal-F1 and T1 x Caraïbo and T4 x Adakamenou.

3.2 Discussion of the Results

3.2.1 Severity of viruses under unfertilized plants

If Mongal-F1, Adakamenou and Caraïbo were more resistant to virus infections than the two other cultivars (Petomech and Tropimech), this shows that they possess intrinsic (genetic) characteristics which enable them to resist virus infections than the other two cultivars. Gorobani et *al*. [13] observed that the Petomech and Tropimech cultivars were very susceptible to virus infections compared to Mongal-F1, Adakamenou and Caraïbo which are less susceptible to virus infections. Mivedor [6] observed that Adakamenou was more resistant than Mongal-F1; which is in line with our results since through our results, Adakamenou was actually more resistant than Mongal-F1 and Caraïbo even though these three cultivars (Mongal-F1, Adakamenou and Caraïbo) are among the resistance.

3.2.2 Severity of viruses under fertilized plants in Caraïbo

T2, T4 and T3 fertilizers would seem to be the best fertilizers to strengthen Caraïbo in its resistance to viral infections shows that Caraïbo does not need exclusively mineral fertilizer (T1) to reinforce its resistance to viral infections.

3.2.3 Severity of viruses under fertilized Mongal-F1 plants

T1, T2 and T3 fertilizers would seem to be the best fertilizers to strengthen Mongal-F1 in its resistance to viral infections shows that high-dose organo-mineral fertilizer (T4) would be harmful to Mongal-F1 during its resistance to viral infections.

Table 1. Average severity under the effect of interactions between fertilizers and cultivars

Interactions between fertilizers and cultivars	Average severity between years 2019 and 2020
T3 x Caraïbo	1,05 ± 0,03 a
T4 x Caraïbo	1,06 ± 0,06 a
T2 x Caraïbo	1,06 ± 0,07 a
T3 x Adakamenou	1,09 ± 0,04 a
T3 x Mongal-F1	1,11 ± 0,09 a
T2 x Mongal-F1	1,12 ± 0,08 a
T2 x Adakamenou	1,14 ± 0,05 a
T1 x Adakamenou	1,15 ± 0,03 a
T1 x Mongal-F1	1,17 ± 0,03 a
T0 x Adakamenou	1,17 ± 0,17 a
T4 x Mongal-F1	1,23 ± 0,06 ab
T1 x Caraïbo	1,25 ± 0,13 ab
T4 x Adakamenou	1,26 ± 0,20 ab
T0 x Mongal-F1	1,44 ±0,20 bc
T3 x Petomech	1,46 ± 0,17 bc
T0 x Petomech	1,48 ± 0,13 c
T1 x Petomech	1,51 ± 0,16 c
T0 x Caraïbo	1,59 ±0,27 c
T2 x Petomech	1,64 ± 0,26 cd
T0 x Tropimech	1,68 ± 0,13 d
T4 x Petomech	1,74 ± 0,26 d
T1 x Tropimech	1,91 ± 0,08 e
T3 x Tropimech	1,92 ± 0,31 e
T4 x Tropimech	1,93 ± 0,33 e
T2 x Tropimech	1,97± 0,07 e

Values followed by the same letters do not differ significantly at the 5% level according to Duncan's test

3.2.4 Severity of viruses under fertilized Petomech plants

T3 and T1 manures seem to be the best manures to reinforce Petomech in its resistance to viral disease shows that Petomech would not need high-dose organo-mineral manure (T4) as well as exclusively organic manure (T2) for reinforcement of its resistance to viruses.

3.2.5 Severity of viruses under fertilized Tropimech plants

The production of Tropimech with one or the other of the four (4) manures put in place should be prohibited and that by indulgence, organo-mineral manures at low and high doses (T3 and T4) could be used for its production. Only organo-mineral fertilizers would strengthen the cultivar even if this reinforcement is not so great.

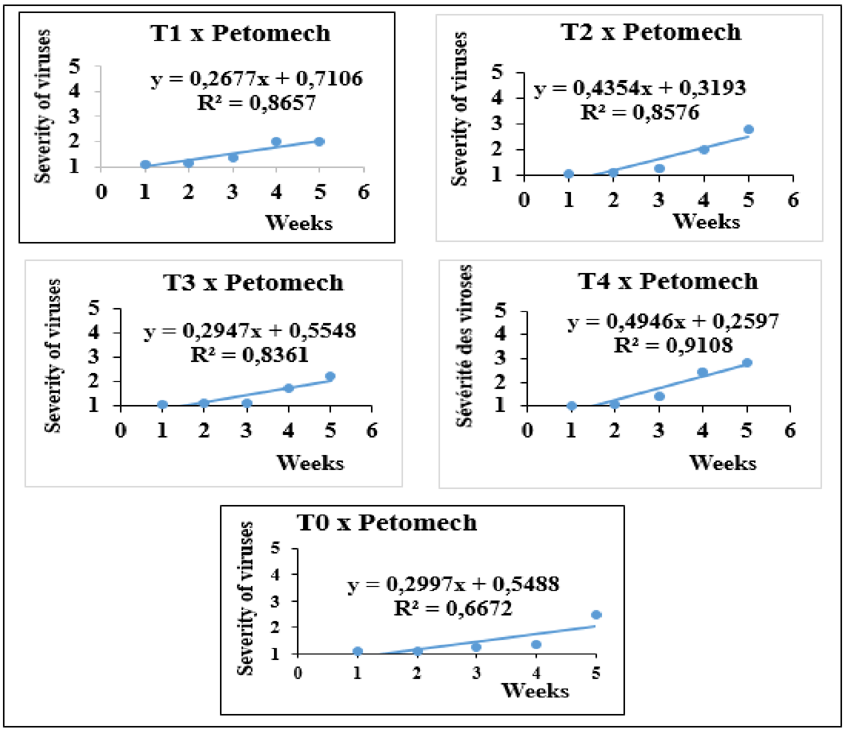

Fig. 5. Linear model describing the evolution of virus severities under Petomech under different fertilization conditions

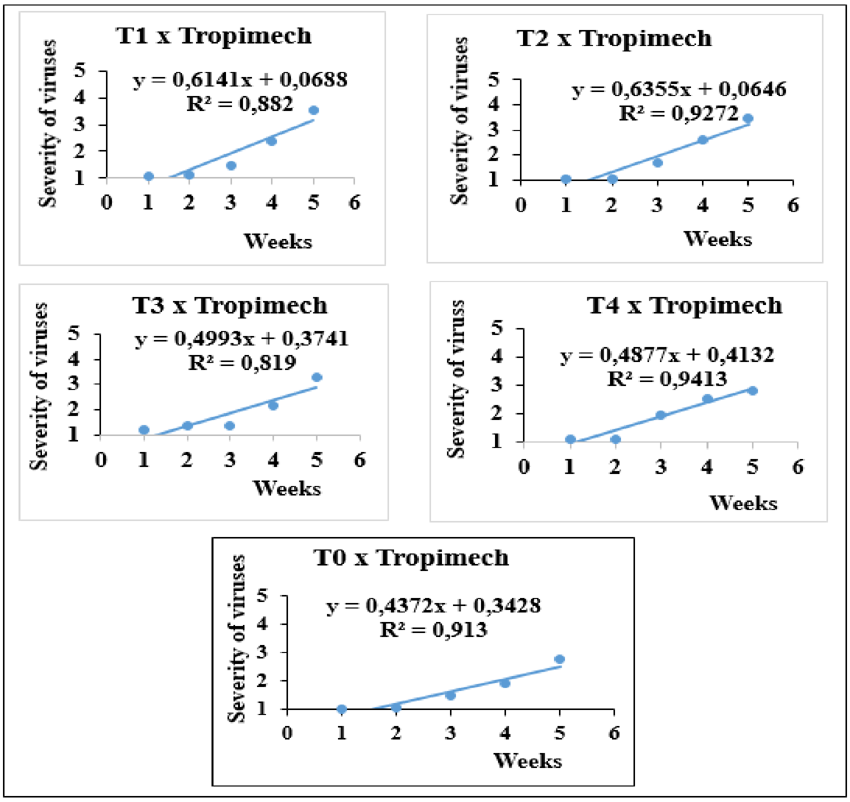

Fig. 6. Linear model describing the evolution of virus severities under Tropimech under different fertilization conditions

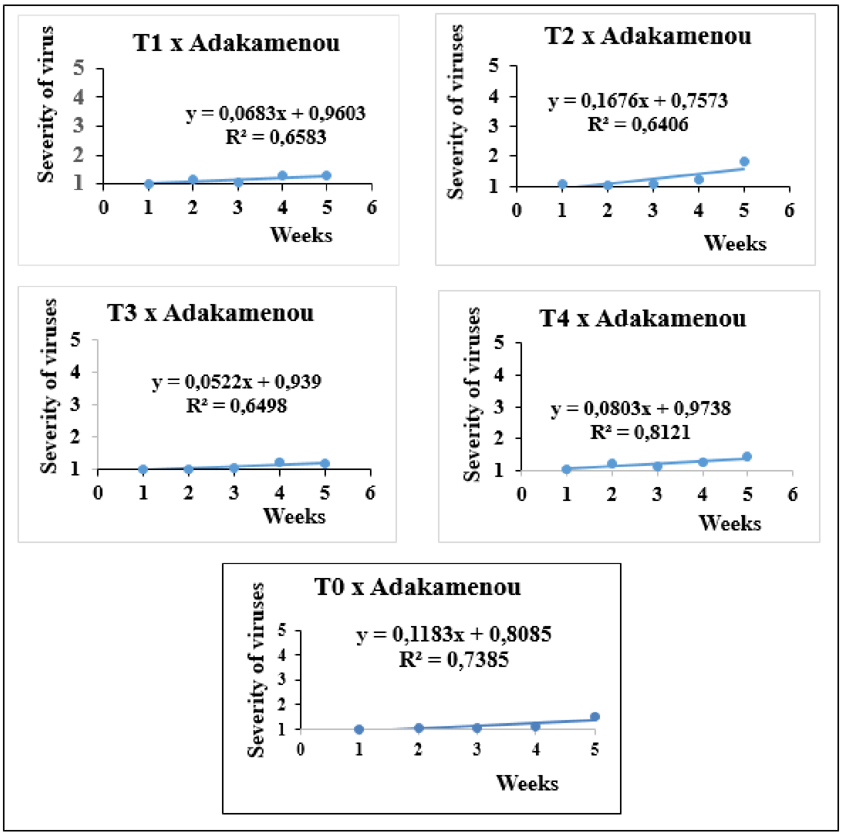

Fig. 7. Linear model describing the evolution of virus severities under Adakamenou under different fertilization conditions

3.2.6 Severity of viruses under fertilized Adakamenou plants

T3, T1 and T4 reinforced Adakamenou in its resistance to viral infections shows that the exclusively organic manure used at this dose (T2) would be harmful to Adakamenou during its resistance to viral infections.

3.2.7 Severity of viruses under the effect of interactions between fertilizers and cultivars

The factors that promote the growth of host plants also promote the multiplication of viruses and this is particularly true for N and P [3]. This justifies the fact that the interaction between fertilizers and cultivars had a significant effect on the severities of the viruses that we observed in the fields even though these fertilizers alone had no significant effect.

4. CONCLUSION

The study showed that the resistance of the tomato cultivars studied is linked first of all to their genetic properties. Then, it made it possible to realize that the fertilizers that farmers provide to tomato plants have a notorious influence on their susceptibility to viruses since some of these fertilizers, whether exclusively organic, mineral or organo-mineral, contribute to the reinforcement or to the decline in resistance of a type of tomato cultivar. Finally, it made it possible to realize that the organo-mineral fertilizer used at a low dose (T3) is positioned as the best in reinforcing the resistance of the five tomato cultivars.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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