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Original Research Article

Study of the Effectiveness of Fertilization Treatments in the Management of Tomato (*Solanum lycopersicum* L) Virus Diseases in South Togo

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Abstract: Faced with the problem of providing a balanced mineral nutrition to tomato plants in order to strengthen them to better resist viruses, this work proposed to study the effectiveness of fertilizers in the sustainable management of these in South Togo. Five fertilizers were tested on five tomato cultivars namely Caraïbo, Mongal F1, Petomech, Tropimech and Adakamenou during two great rainy seasons (GRS) of 2019 and 2020 following the split-plot design with fertilizers in main plots and cultivars in secondary plots. Weekly observation of virus incidence and severity according to a rating scale (1-5) indicated a very highly significant effect ($P < 0.001$) under the cultivars for both experiments. Caraïbo, Mongal F1 and Adakamenou were the least susceptible cultivars to virus diseases. Fertilizers only significantly impacted cultivar susceptibility to virus diseases in GRS 2019 where virus disease incidence was low and statistically identical (22.80%; 22.67%) under organic T2 manure (10 t ha^{-1} of manure) and low dose organo-mineral T3 manure (38 kg N, 15 kg P_2O_5, 15 kg K_2O ha^{-1} and 5 t ha^{-1} of manure). The effect of fertilizer-cultivar interactions on virus severity was significant ($P < 0.05$) in 2020 and very highly significant ($P < 0.001$) in 2019. The organomineral manure used at a low dose seems to be the best strategy for reinforcing the obtaining of satisfactory fruit yields.

Keywords: Tomato, fertilizer, viral diseases, South-Togo.

INTRODUCTION

For a long time, fertilization was considered an agricultural practice to compensate for the soil nutrient deficit in order to make it more fertile for crop production (Petit J and Jobin P, 2005). In recent years, research on fertilization strategies has given special attention to the management of virus diseases, particularly virus diseases of tomato plants. For example, Selman I and Grant S (1957) observed that nitrogen doses higher than optimal for tomato plant growth increase the symptoms of tomato spotted wilt virus disease (TSWV) and that the estimated virus content per number of lesions increases with increasing nitrogen doses. Later, the same authors also observed a reduction in the time between the inoculation of tomato plant tanning disease virus and the onset of symptoms when nitrogen doses were increased to a level slightly higher than optimal for tomato plant growth. The study by Selman I and Grant S (1957), which targeted only nitrogen (N), phosphorus (P) and magnesium (Mg), showed that symptoms of bronze-disease in tomato plants (TSWV) were related to nitrogen content. In Côte d'Ivoire the study by Bouet A and *al.* (2013) revealed the possibility of using nitrogen fertilizers to7T better manage rice yellow mottle virus (RYMV) disease as the study showed that the incidence of RYMV disease increases when nitrogen doses are below 30 t ha^{-1}, and above 30 t ha^{-1}, the incidence of the disease starts to fall. The study also showed that the combination of N and P was indifferent to the development of RYMV. Similarly, in Congo, similar studies conducted by Ogbe F O and *al.* (1993) to assess the impact of NPK fertilizers on African cassava mosaic virus disease resulted in the use of nitrogen at certain doses to manage this disease because they observed a significant positive correlation between this virus disease and the dose of nitrogen applied to the cassava crop; the increase in P and K had no effect on African cassava mosaic virus disease. Foliar sprays of different calcium fertilizer sources tested on tomato plants to assess their effect on tomato mosaic virus (ToMV) behaviour showed a decrease in ToMV concentration in the tissues of fertilized tomato plants (Eraslan F and *al.*,

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2007). The ability to manage the nutrients to be supplied to tomato plants to help them better resist virus infection is also of paramount importance because the nutritional factors that promote host plant growth also promote virus multiplication, and this is particularly true for nitrogen and phosphorus (Selman I and Grant S, 1957; Bouet A and *al*., 2013; Arnold W and *al*., 2013; Islam M and *al*., 2013). However, the rapid multiplication of the virus and the visible symptoms of infection may not necessarily correspond to an increase in nutrient supply to the host plant, since in fact, symptoms of viral infections sometimes disappear when nitrogen reserves are high, even if the whole plant is infected (Arnold W and *al*., 2013). Hence, it is noted that the visible symptoms of viral infection depend on the competition between the virus and the host cells for nitrogen, and for phosphorus (Selman I and Grant S, 1957; Bouet A and *al*., 2013; Arnold W and *al*., 2013; Islam M and *al*., 2013). This competition varies according to viral diseases and can be influenced by other environmental factors such as temperature, virus vectors and other nutrients including trace elements, etc. (Selman I and Grant S, 1957; Bouet A and *al*., 2013; Arnold W and *al*., 2013; Islam M and *al*., 2013). In West Africa, particularly in Togo, data related to the involvement of fertilizers in the management of tomato virus diseases are almost totally non-existent because related studies are scarce while new emerging viruses continue to be detected; not more than in the last three years, Mivedor A and *al*. (2017) discovered nine strains of Begomovirus in tomato fields in Togo. No one in the world of plant virologists is indifferent to the adverse impact that Begomoviruses cause in the enormous loss of tomato fruit yields. It then urges to find ways and means to sustainably and effectively manage these viruses through the application of fertilizers that could help plants to better resist these viruses while obtaining better sustainable yields. The work therefore proposed to study the effectiveness of fertilizers in the sustainable management of these virus diseases in south-Togo.

1. MATERIALS AND METHODS

Experimental site

The study was conducted at the Station of Agronomic Experimentation of the University of Lome, Togo (6°22'N, 1°13'E; altitude = 50 m, slope <1%). The climate of the site is equatorial, bimodal and guinean, allowing for two seasons of tomato cultivation, one from April to July (great rainy season) and the other from September to mid-December (little rainy season).

Plant material studied

The plant material consisted of five tomato cultivars: Caraïbo (V1), Mongal F1 (V2), Petomech (V3), Tropimech (V4) and Adakamenou (V5) which was the only local cultivar.

Fertilizing material and fertilization treatments studied

Five fertilization treatments were prepared using NPK 15 15 15 complex fertilizer, urea 46% N and cattle manure. These are:

- T0: 0 fertilizer;
- T1: 200 kg ha^{-1} of NPK 15 15 15 and 100 kg ha^{-1} of urea 46%N (76 kg of N, 30 kg of P_2O_5, 30 kg of K_2O ha^{-1});
- T2: 200 g of manure/plant (10 t ha^{-1} of cattle manure);
- T3: 100 kg ha^{-1} NPK 15 15 15; 50 kg ha^{-1} of urea 46% N and 5 t ha^{-1} of manure (38 kg of N, 15 kg of P_2O_5, 15 kg of K_2O ha^{-1} and 5 t ha^{-1} of manure);
- T4: 300 kg ha^{-1} of NPK 15 15 15; 67 kg ha^{-1} kg ha^{-1} of urea 46% N and 5 t ha^{-1} of manure (76 kg of N, 45 kg of P_2O_5, 45 kg of K_2O ha^{-1} and 5 t ha^{-1} of manure).

Of these fertilization treatments, T2 and T3 are the doses recommended by Gorobani A and *al*. (2017) as doses that make tomato cultivation in South Togo economically profitable.

The other fertilizer treatments were formulated taking into account the nutrient requirements of tomato plants (ADAB, 2001; Shankara N and *al*., 2005).

Experimental design

The experiment was conducted in the open field during the great rainy seasons of 2019 and 2020 using the split-plot design. Fertilization treatments were the main factor and cultivars were the secondary factor. The elementary plot was 2.4 m² (2 m x 1.2 m) and sheltered 15 plants according to the 40 cm x 50 cm cultivation pattern (40 cm between two successive feet of the same line and 50 cm between the lines), i.e. a density of 50,000 plants ha^{-1}. One main plot represented five elementary plots which are in fact subplots (Figures 1 and 2).

T0	T1	T2	T3	T4		T4	T0	T1	T2	T3		T3	T4	T0	T1	T2
V1	V2	V3	V4	V5		V2	V3	V4	V5	V1		V3	V4	V5	V1	V5
V2	V3	V4	V5	V1		V3	V4	V5	V1	V2		V4	V5	V1	V2	V1
V3	V4	V5	V1	V2		V4	V5	V1	V2	V3		V5	V1	V2	V3	V2
V4	V5	V1	V2	V3		V5	V1	V2	V3	V4		V1	V2	V3	V4	V3
V5	V1	V2	V3	V4		V1	V2	V3	V4	V5		V2	V3	V4	V5	V4
		Bloc 1						Bloc 2						Bloc 3		

Fig-1: Experimental design used in the first experiment (great rainy season 2019)

T0	T1	T2	T3	T4		T4	T0	T1	T2	T3
V2	V3	V4	V5	V1		V3	V4	V5	V1	V5
V3	V4	V5	V1	V2		V4	V5	V1	V2	V1
V4	V5	V1	V2	V3		V5	V1	V2	V3	V2
V5	V1	V2	V3	V4		V1	V2	V3	V4	V3
V1	V2	V3	V4	V5		V2	V3	V4	V5	V4
Bloc 1						Bloc 2				

Fig-2: Experimental design used in the second experiment (great rainy season 2019)

Application of fertilization treatments to tomato plants

The NPK 15 15 15 and the manure of each fertilizer were brought on the 14th day after transplanting the plants (as bottom manure) and the urea 46% N on the 28th day after transplanting them as supplementary manure. Finally, the application of fertilizers was done by bringing precise quantities of fertilizer per plant in the pots as follows (Picture 1 below):

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

Picture 1: photo illustrating the application of precise doses of fertilizer to plants

Variables associated with the experimentation and controlled: phytosanitary protection materials

While no plots were treated with the insecticide in the first experiment (great rainy season of 2019), insecticide treatments (Imidacloprid) were applied to all plots in the second experiment (great rainy season of 2020) and therefore constitute the associated but controlled variable in the second experiment (great season 2020). In both experiments, fungal treatments (mancozeb and rhidomil) were carried out to eliminate the effects of fungi.

Parameters measured

- ***Evaluation of the incidence and severity of viral infections***

Weekly observation of incidence (I%) and severity (Sm) of virus diseases was carried out on all plants of each cultivar for five weeks just two weeks after transplanting the plants (35th day after sowing). These two parameters were calculated using the following formula (Camara M and *al*., 2013).

$$I\% = \frac{NPI}{NTP} \times 100$$

with I%= Incidence in percent, NPI = number of infected plants, NTP = total number of plants.

$$Sm = \frac{\sum Si \times Ni}{\sum Ni}$$

with Ni is the number of plants with a grade of Si.

The grades "Si" were assigned to the plants according to the degree of virus symptoms they showed (Ikotun T and Hahn S, 1991). Thus, Si= **1** for non-visible symptoms; Si= **2** for visible symptoms of low intensity (25% of leaves are infected); Si= **3** for moderate symptoms (50% of leaves infected); Si= **4** for severe symptom (75% of leaves are infected) and Si= **5** for very severe symptom (75% to 100% of leaves infected). The Cultivars were then classified according to their resistance to virus diseases by taking as a starting point the classification of Camara M and *al*. (2013) who however adopted the scale of 0-4.

$1 \leq Sm \leq 2$ Resistant (R)	**$2 \leq Sm \leq 3$ Moderaly resistant (MR)**
$3 \leq Sm \leq 4$ Sensitive (S)	**$4 \leq Sm \leq 5$ Highly sensitive (HS)**

- ***Observation of evolution in the incidence of viral infections over time***

It was carried out first of all through the construction of trend curves between incidence and time. Finally, the curve of the rate of increase in the incidence of viral infections as a function of time was constructed after these rates were calculated according to the following formula by Tchoumakov A and Zaharova E (1990):

$$r = \frac{\log[x_2/(1-x_2)] - \log[x_1/(1-x_1)]}{t_2 - t_1}$$

with x = quantity of viral diseases at a given time t

- ***Evaluation of tomato fruit yield.***

The fruit yield was determined by the following formula.

$$R = P \times Dp$$

with R the yield ($t ha^{-1}$)
P= production per plant (t)
Dp= stand density (plant ha^{-1})

Statistical analysis of the data

Data analysis was performed using Genstat software edition 19.1 and Duncan's test was used to discriminate the data at the 5% threshold.

2. RESULTS

2.1 Sensitivity of cultivars to virus diseases

- ***Evolution of the incidence of virus diseases observed under the cultivars over time***

The following trend curves show the evolution of virus infections over time (Figures 3 and 4). The trend shows an increase in the number of infected plants as a function of time. In fact, from the beginning of cultivation to the end of production, two cultivars showed their very high susceptibility to virus infections: Petomech and Tropimech (Figures 3 and 4). These curves also show a strong correlation between the increase in the number of infected plants and time since all determination coefficients (R^2) tend towards 1.

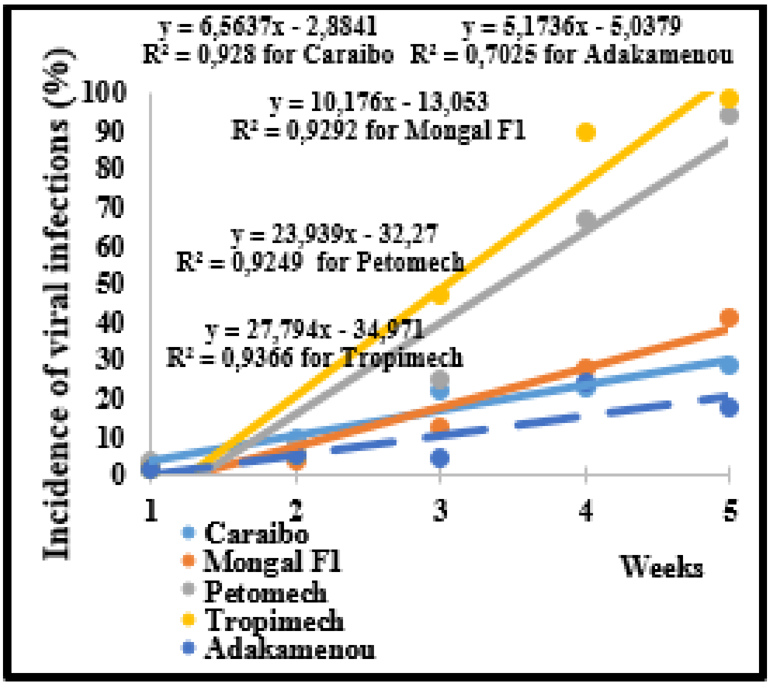

Fig-3: Trend curves showing the evolution of virus incidence over time in the great rainy season 2019

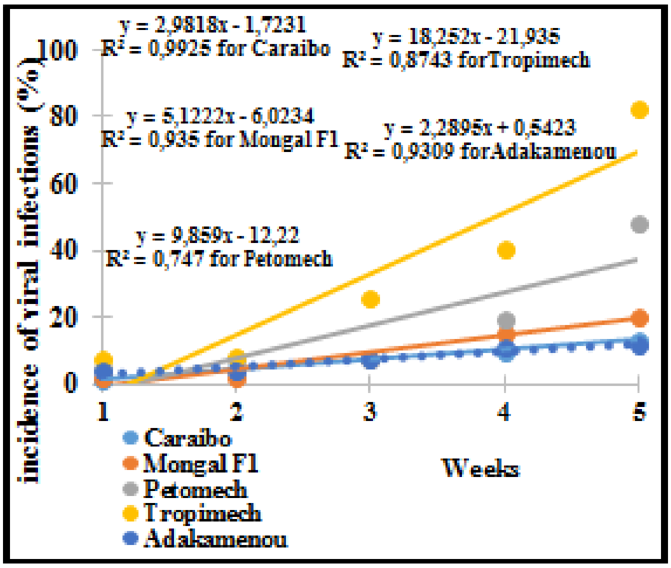

Fig-4: Trend curves showing the evolution of virus incidence over time in the great rainy season 2020

- ***Rate of increase of virus infections over time***

The rate of virus growth observed weekly under the cultivars was very diverse from one cultivar to another and from one experimental season to another (Table 1 and Table 2).

Table-1: Rates of spread of viral diseases over time in the great rainy season of 2019

Cultivars	Weeks (time)	**log** [x/ (1-x)]			r			**r** average
		Bloc 1	Bloc 2	Bloc 3	Bloc 1	Bloc 2	Bloc 3	
Caraïbo	S3	-1.87	-1.87	-1.56	-	-	-	-
	S4	-1.77	-1.25	-0.55	0.10	0.62	1.02	0.58 ± 0.46
	S5	-0.90	-0.44	-0.42	0.87	0.81	0.13	0.60 ± 0.41
	S6	-0.25	-0.97	-0.56	0.65	-0.54	-0.14	-0.01 ± 0.61
	S7	-0.67	-0.31	-0.28	-0.42	0.66	0.28	0.17 ± 0.55
Mongal F1	S3	-	-1.33	-1.56	-	-	-	-
	S4	-1.56	-1.50	-1.25	-	-0.17	0.31	0.05 ± 0.25
	S5	-1.06	-0.94	-0.63	0.50	0.56	0.62	0.56 ± 0.06
	S6	-0.56	-0.40	-0.32	0.50	0.54	0.31	0.45 ± 0.12
	S7	-0.46	-0.07	-0.10	0.10	0.47	0.22	0.26 ± 0.19
Petomech	S3	-1.38	-1.87	-1.20	-	-	-	-
	S4	-1.38	-1.04	-0.88	0.00	0.83	0.32	0,38 ± 0,42
	S5	-0.69	-0.54	-0.24	0.69	0.50	0.64	0,61 ± 0,10
	S6	0.68	0.09	0.22	1.37	0.63	0.46	0,82 ± 0,48
	S7	1.84	1.17	0.96	1.16	1.08	0.74	0,99 ± 0,22
Tropimech	S3	-	-1.25	-	-	-	-	-
	S4	-1.46	-1.15	-1.25	-	0.10	-	0.03 ± 0.06
	S5	-0.80	0.41	0.10	0.66	1.56	1.35	1.19 ± 0.47
	S6	0.57	1.15	1.38	1.37	0.74	1.28	1.13 ± 0.34
	S7	1.56	-	1.84	0.99	-	0.46	0.73 ± 0.50
Adakamenou	S3	-1.56	-1.87	-	-	-	-	-
	S4	-1.25	-1.25	-1.37	0.31	0.62	-	0.31 ± 0.31
	S5	-1.38	-1.35	-1.24	-0.13	-0.10	0.13	-0.03 ± 0.14
	S6	-0.30	-0.68	-0.58	1.08	0.67	0.67	0.80 ± 0.24
	S7	-1.06	-0.95	-0.27	-0.76	-0.27	0.31	-0.24 ± 0.53
x= quantity of virus diseases in the plot; r= rate of spread of virus infections								

Table-2: Rates of spread of viral diseases over time in the great rainy season of 2020

Cultivars	Weeks (time)	**log** [x/ (1-x)]		R		**r** average
		Bloc 1	Bloc 2	Bloc 1	Bloc 2	
Caraïbo	S3	-1.69	-	-	-	-
	S4	-1.24	-1.42	0.45	-	0.22 ± 0.32
	S5	-1.07	-1.10	0.17	0.32	0.24 ± 0.10
	S6	-1.06	-0.90	0.01	0.20	0.11 ± 0.14
	S7	-0.67	-0.99	0.39	-0.09	0.15 ± 0.34
Mongal F1	S3	-1.73	-1.81	-	-	-
	S4	-1.73	-1.81	0.00	0.00	0.00 ± 0.00
	S5	-0.99	-1.22	0.74	0.59	0.66 ± 0.11
	S6	-0.68	-0.80	0.31	0.42	0.36 ± 0.07
	S7	-0.57	-0.61	0.10	0.19	0.15 ± 0.06
Petomech	S3	-1.39	-1.28	-	-	-
	S4	-1.32	-0.91	0.07	0.36	0.22 ± 0.21
	S5	-1.00	-1.20	0.32	-0.28	0.02 ± 0.43
	S6	-0.80	-0.49	0.20	0.71	0.45 ± 0.36
	S7	0.00	-0.06	0.80	0.42	0.61 ± 0.27
Tropimech	S3	-1.44	-0.92	-	-	-
	S4	-1.15	-0.97	0.28	-0.05	0.11 ± 0.24
	S5	-0.54	-0.38	0.61	0.59	0.60 ± 0.01
	S6	-0.49	0.12	0.05	0.50	0.27 ± 0.32
	S7	1.38	0.33	1.88	0.21	1.04 ± 1.18
Adakamenou	S3	-1.25	-1.73	-	-	-
	S4	-1.10	-	0.15	-	0.07 ± 0.10
	S5	-1.07	-1.09	0.03	-	0.02 ± 0.02
	S6	-1.05	-0.82	0.02	0.27	0.15 ± 0.18
	S7	-1.14	-0.71	-0.09	0.11	0.01 ± 0.14

x= quantity of virus diseases in the plot; r= rate of spread of virus infections

In fact, under Caraïbo, the rate of spread averaging **0.27/week** increased from the beginning of week S3 until week S4 from which a plateau was observed for a whole week more or less until week S5 where this rate first regressed to zero from the beginning of week S6 and then regressed slightly afterwards (figure 5). In the second experiment, this rate, which average is **0.14/week**, increased only slightly from the beginning of S3 until the end of the observations (Figure 5.B).

Under Mongal F1, the rate of spread which average is **0.26/week** (first experiment) started to increase only from week S4 to quickly reach its peak at the end of a week (S5) where the rate starts to decrease (figure 5.A). The same curve was observed in the second experiment, except that the average rate was weakly reduced to be equal to **0.23/week** (Figure 5.B).

Under Petomech, the rate of spread averaging **0.56/week** (first experiment) only increased linearly until the end of the observations (Figure 5.A). In the second experiment, this rate, which averaged **0.26/week**, increased from S3 to S4, then fell from that point on and became practically nil from the beginning of week S5 and then rose again (Figure 5.B).

Under Tropimech, the rate of spread curve averaging **0.62/week** (first experiment) followed exactly the same pattern as that of Mongal F1 but only extremely above that of Mongal F1 from S4 onwards (Figure 5.A). The same trend was observed in the second experiment where there was a decrease in the average rate of increase of virus infections (**0.41/week**) except that from week S6, this rate has increased considerably (Figure 5.B).

Under Adakamenou, unlike the other cultivars, the rate of spread averaging **0.17/week** has two peaks (first experiment); one is reached at the beginning of week S4 and the other at S6. In the second experiment, this rate was very low (**0.05/week**) and also had two peaks; respectively at S4 and S6 (Figure 5.B). Finally, these results show that the rate of increase of virus infections was reduced in the second experiment (rainy season 2020).

So, for the both experimental seasons, the discrimination of the means ($P<0.05$) indicated a low speed of propagation of the virus diseases under Adakamenou, Mongal F1 and Caraïbo (0.20 ± 0.10; 0.25 ± 0.02 and 0.26 ± 0.13) against a high speed of propagation under Petomech and Tropimech (0.40 ± 0.11 and 0.51 ± 0.06).

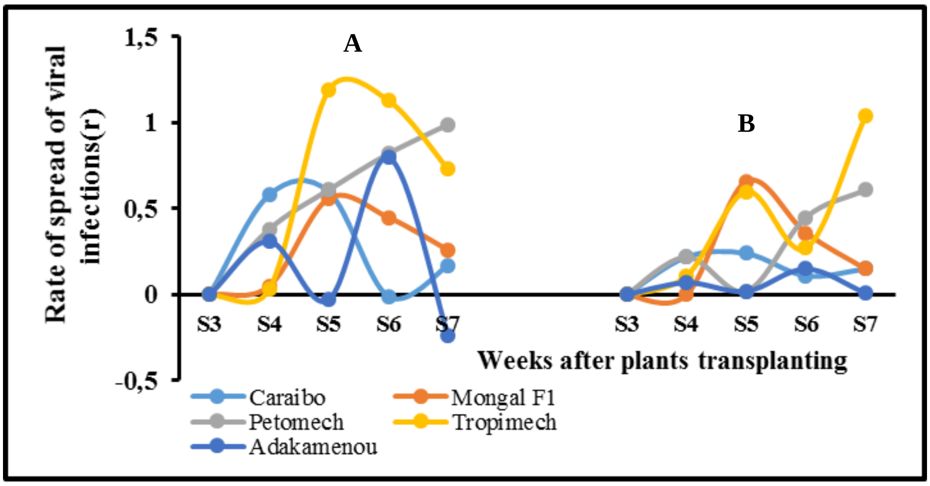

Fig-5: Curves of the rate of spread of viral infections over time in the great rainy season of 2019 (A) and in the great rainy season of 2020 (B)

- ***Average incidence and severity of virus diseases observed under the cultivars***

The analysis of variance test of the mean incidence and severity of observed virus infections (Table 3) revealed a highly significant effect (P<0.001) under the cultivars for both experiments.

Table-3: Average incidence and severity of virus diseases under the cultivars.

Cultivars	**Average incidence of viral infections**		**Average severity of viral infections**	
	Great Rainy Season 2019	Great Rainy Season 2020	Great Rainy Season 2019	Great Rainy Season 2020
Caraïbo	16.81 ± 13.09 a	7.22 ± 9.61 a	1.22 ± 0.22 a	1.19 ± 0.41 ab
Mongal F1	17.47 ± 8.91 a	9.34 ± 6.64 a	1.21 ± 0.21 a	1.18 ± 0.24 ab
Petomech	39.55 ± 8.23 b	17.36 ± 8.13 b	1.78 ± 0.30 b	1.35 ± 0.26 b
Tropimech	48.41 ± 9.75 b	32.82 ± 10.98 b	2.07 ± 0.28 b	1.69 ± 0.26 c
Adakamenou	10.48 ± 4.90 a	7.41 ± 4.46 a	1.20 ± 0.16 a	1.12 ± 0.15 a
Average	26.54 ± 16.45	14.83 ± 10.88	1.50 ± 0.40	1.31 ± 0.23
p-value	< 0.001***	< 0.001***	< 0.001***	< 0.001***

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off **** Very highly significant

Cultivar susceptibility to virus diseases was therefore highly related to the intrinsic characteristics of each cultivar. These results show that the cultivars expressed themselves differently towards virus diseases. Two groups of cultivars emerged.

- The first group is that of Caraïbo, Mongal F1 and Adakamenou. This is the group of resistant cultivars with a high capacity of resistance to virus diseases;
- The second is that of Tropimech and Petomech, which is the moderately resistant cultivars group, with a low virus resistance capacity.

However, considering the severity of virus diseases observed under the cultivars during the great rainy season of 2020, this ranking seems to be changed. Here, there is one cultivar, Tropimech, which has isolated itself and shown a higher severity than the others. Finally, the severity of virus diseases observed under Petomech tends to be close to that under Caraïbo and Mongal F1. Therefore, to refine the ranking, three groups emerged.

- The first group remains the same (that of Caraïbo, Mongal F1 and Adakamenou, which is the group least sensitive to virus infections) with a significant capacity for virus resistance. This is the group of tolerant cultivars;
- The second group is that of Petomech with a severity more or less similar to that under Caraïbo, Mongal F1. This is the virus-sensitive group;
- The Tropimech group presenting a very high virus severity compared to that observed under the other cultivars. This is the group most sensitive to virus diseases.

Finally, these results indicate that the cultivars were highly infected by virus diseases and the severity of these diseases was also very remarkable in the main season of 2019, compared to 2020, when a reduction in virus sensitivity was observed.

2.2 Effect of fertilization treatments on the susceptibility of cultivars to virus diseases

- ***Effect of fertilization treatments on the incidence and severity of virus infections***

According to the analysis of variance of virus incidence and severity (Table 4), fertilizer treatments did not significantly impact the susceptibility of cultivars to virus diseases, except for the 2019 rainy season when virus incidence was highly correlated with fertilizer treatments ($P < 0.001$). There, virus incidence was low and statistically identical (22.80%; 22.67%) under organic manure T2 (10 t ha^{-1} of manure) and under low dose organo-mineral manure T3. On the other hand, it was high and statistically identical under T0, T1 (76 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1}); and T4 (76 kg N, 45 kg P_2O_5, 45 kg K_2O ha^{-1} and 5 t ha^{-1} of manure). Overall, the sensitivity of the plants to virus infections in terms of incidence and severity was high during the 2019 experiment. Specifically for virus severity, this was reduced below T3 for both experiments.

Table-4: Incidence and severity of virus diseases under the effect of fertilization treatments

Fertilizers	Average incidence of viral infections (%)		Average severity of viral infection	
	Great Rainy Season 2019	Great Rainy Season 2020	Great Rainy Season 2019	Great Rainy Season 2020
T0	29.11 ± 14.70 b	17.34 ± 10.67 a	1.56 ± 0.38 a	1.38 ± 0.41 a
T1	29.83 ± 17.36 b	14.39 ± 9.37 a	1.51 ± 0.44 a	1.28 ± 0.24 a
T2	22.80 ± 17.38 a	16.25 ± 1410 a	1.44 ± 0.43 a	1.33 ± 0.26 a
T3	22.67 ± 16.72 a	10.76 ± 13.91 a	1.41 ± 0.38 a	1.25 ± 0.26 a
T4	28.31 ± 21.10 b	15.42 ± 15.70 a	1.59 ± 0.53 a	1.30 ± 0.15 a
Average	26.54 ± 3.52	14.83 ± 2.52	1.50 ± 0.08	1.31 ± 0.05
p-value	<0.001***	0.829^{NS}	0.427^{NS}	0.854^{NS}

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off NS= no significant **** Very highly significant

- ***Effect of fertilizer-cultivar interaction on the incidence of virus diseases***

According to the analysis of variance of virus incidence (Table 5), the interactions between fertilizers and cultivars only explained the variability in virus incidence in the 2019 main rainy season experiment ($P < 0.05$) since the differences were not significant in the second experiment ($P= 0.08$). A closer look at these incidences recorded in Table 3 shows that under the cultivars Caraïbo, Mongal F1 and Adakamenou, fertilized plants were less attacked by virus diseases compared to unfertilized plants. This is seen when we take the case of Mongal F1 fertilized (T2 x Mongal F1) where the viral infection rate was 10.17% compared to unfertilized Mongal where the rate was 27.37%. This observation is valid for both experiments but remains very credible during the 2019 experiment. It should also be noted that the incidence of virus diseases observed under the cultivar Adakamenou, whether under fertilized or unfertilized plants, did not vary greatly when considering either experiment. The use of fertilizers therefore reduced the rate of virus attack on the plants, especially under the three cultivars mentioned above.

Table-5: Incidence of virus diseases due to interactions between fertilizers and cultivars

Incidence of virus diseases due to interactions Fertilisant x Cultivar			
Fertilizers x Cultivars	Great Rainy Season 2020	Fertilizers x Cultivars	Great Rainy Season 2020
T3 x Caraïbo	8.70 ± 3.10 a	T2 x Caraïbo	0.00 ± 0,00 a
T2 x Caraïbo	9.33 ± 3.53 a	T4 x Caraïbo	0.00 ± 0.00 a
T4 x Caraïbo	9.33 ± 7.42 a	T3 x Adakamenou	2.00 ± 2.83 a
T3 x Adakamenou	9.46 ± 4.65 a	T3 x Mongal F1	2.50 ± 3.54 a
T2 x Mongal F1	10.17 ± 7.65 ab	T3 x Caraïbo	4.04 ± 0.57 a
T4 x Adakamenou	10.32 ± 5.51 ab	T0 x Adakamenou	4.77 ± 4.57 a
T0 x Adakamenou	10.36 ± 6.34 abc	T1 x Mongal F1	6.43 ± 5.05 a
T1 x Adakamenou	10.76 ± 4.30 abcd	T2 x Adakamenou	9.15 ± 3.51 a
T2 x Adakamenou	11.52 ± 7.36 abcd	T3 x Petomech	9.39 ± 8.57 a
T3 x Mongal F1	15.59 ± 12.64 abcde	T1 x Adakamenou	9.44 ± 0.79 a
T1 x Mongal F1	16.55 ± 4.32 abcde	T2 x Mongal F1	10.67 ± 0.94 a
T4 x Mongal F1	17.71 ± 6.10 abcde	T4 x Mongal F1	10.92 ± 4.13 a
T1 x Caraïbo	25.90 ± 10.70 bdef	T1 x Caraïbo	11.07 ± 5.56 a
T0 x Mongal F1	27.35 ± 6.99 ef	T4 x Adakamenou	11.69 ± 3.67 a
T0 x Caraïbo	30.77 ± 18.01 efg	T0 x Mongal F1	16.20 ± 11.29 a
T0 x Petomech	33.06 ± 7.88 fgh	T4 x Petomech	16.47 ± 15.21 a
T2 x Petomech	34.54 ± 7.59 fghi	T1 x Petomech	16.67 ± 7.07 a

T3 x Petomech	36.95 ± 3.89 fghij	T0 x Caraïbo	21.00 ± 12.73 a
T3 x Tropimech	42.67 ± 14.67 fghijk	T0 x Petomech	21.11 ± 1.57 a
T1 x Petomech	43.59 ± 6.22 hijk	T2 x Petomech	23.15 ± 3.63 a
T0 x Tropimech	44.00 ± 12.00 hijk	T0 x Tropimech	23.61 ± 16.11 a
T2 x Tropimech	48.44 ± 6.01 hijk	T1 x Tropimech	28.34 ± 9.23 a
T4 x Petomech	49.59 ± 3.81 ik	T3 x Tropimech	35.87 ± 0.69 a
T1 x Tropimech	52.33 ± 6.49 jk	T4 x Tropimech	38.00 ± 19.80 a
T4 x Tropimech	54.60 ± 8.30 k	T2 x Tropimech	38.27 ± 2.44 a
Average	26.54 ± 17.38	Average	14.83 ± 11.43
p-value	0,043*	p-value	0,080^{NS}

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off NS= no significant * Significant

- ***Effect of the interaction between fertilizers and cultivars on the severity of virus diseases***

Interactions between fertilizers and cultivars (Table 6) significantly impacted the severity of virus diseases. The effect of the interaction was highly significant during the year 2019. The interaction between fertilizers and cultivars can therefore explain the variability in virus severity observed under the cultivars for both experiments. The use of fertilizers has indeed reduced the severity of virus diseases especially under the three cultivars mentioned above (Caraïbo, Mongal F1 and Adakamenou). This is what we can see when we take for example the case of Caraïbo fertilized T3 x Caraïbo where the severity of virus diseases was low in the order of 1.10 and 1.04 compared to unfertilized Caraïbo T0 x Caraïbo where they were higher (1.50; 1.04) respectively during the two experiments. This observation is the same for Mongal F1 and Adakamenou.

Table-6: Virus severity due to fertilizer x cultivar interactions

Virus severity due to fertilizer x cultivar interactions			
Fertilizers x Cultivars	Great Rainy Season 2019	Fertilizers x Cultivars	Great Rainy Season 2020
T3 x Caraïbo	1.10 ± 0.02 a	T2 x Caraïbo	1.00 ± 0.00 a
T2 x Mongal F1	1.10 ± 0.09 a	T4 x Caraïbo	1.00 ± 0.00 a
T2 x Caraïbo	1.12 ± 0.04 a	T3 x Adakamenou	1.01 ± 0.01 a
T4 x Caraïbo	1.12 ± 0.12 a	T3 x Mongal F1	1.03 ± 0.04 a
T1 x Adakamenou	1.13 ± 0.04 a	T3 x Caraïbo	1.04 ± 0.02 a
T2 x Adakamenou	1.15 ± 0.04 a	T0 x Adakamenou	1.06 ± 0.04 a
T3 x Adakamenou	1.17 ± 0.08 a	T1 x Mongal F1	1.13 ± 0.07 abc
T3 x Mongal F1	1.19 ± 0.17 a	T2 x Adakamenou	1.13 ± 0.10 abc
T1 x Mongal F1	1.20 ± 0.06 a	T2 x Mongal F1	1.13 ± 0.08 abc
T4 x Mongal F1	1.21 ± 0.05 a	T1 x Adakamenou	1.16 ± 0.10 abc
T1 x Caraïbo	1.26 ± 0.11 a	T1 x Caraïbo	1.23 ± 0.19 abcd
T4 x Adakamenou	1.26 ± 0.22 a	T3 x Petomech	1.24 ± 0.24 abcd
T0 x Adakamenou	1.28 ± 0.32 a	T4 x Petomech	1.24 ± 0.17 abcd
T0 x Mongal F1	1.50 ± 0.37 ab	T4 x Mongal F1	1.25 ± 0.16 abcd
T0 x Caraïbo	1.50 ± 0.37 ab	T4 x Adakamenou	1.26 ± 0.19 abcde
T0 x Petomech	1.50 ± 0.37 ab	T1 x Petomech	1.28 ± 0.21 abcde
T3 x Petomech	1.68 ± 0.06 bc	T0 x Tropimech	1.36 ± 0.26 abcde
T1 x Petomech	1.73 ± 0.05 bcd	T0 x Mongal F1	1.38 ± 0.35 abcde
T2 x Petomech	1.74 ± 0.18 bcde	T0 x Petomech	1.46 ± 0.27 abcdef
T3 x Tropimech	1.92 ± 0.39 bcdef	T2 x Petomech	1.53 ± 0.39 bcdef
T0 x Tropimech	1.99 ± 0.31 bcdef	T1 x Tropimech	1.59 ± 0.38 cdef
T2 x Tropimech	2.09 ± 0.16 def	T0 x Caraïbo	1.67 ± 0.47 def
T4 x Tropimech	2.13 ± 0.37 ef	T4 x Tropimech	1.72 ± 0.52 ef
T1 x Tropimech	2.23 ± 0.20 f	T2 x Tropimech	1.85 ± 0.49 f
T4 x Petomech	2.24 ± 0.05 f	T3 x Tropimech	1.91 ± 0.53 f
Average	1.50 ± 0.40	Average	1.31 ± 0.27
p-value	<0.001***	p-value	0,018*

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off *** Very highly significant * significant

2.3 Tomato fruit yields

- ***Fruit yields recorded under cultivars***

Fruit yields (Table 7) were highly dependent on cultivars (P < 0.001) in two experiments. In the main rainy season 2019, these yields ranged from 6.63 to 31.56 t ha^{-1} and the best statistically identical yields were recorded under Caraïbo and Mongal F1. These two are followed by the local cultivar Adakamenou (16.08 t ha^{-1}). In contrast, in the 2020 rainy season, yields ranging from 6.88 to 42.62 t ha^{-1} increased slightly and the best statistically identical yields were recorded under Caraïbo and Mongal F1 and Adakamenou. The average yields in 2020 followed the same trend as those of the experiment in 2019. The cultivars Petomech and Tropimech did not perform better than the other cultivars. Caraïbo and Mongal F1 are twice as efficient as Adakamenou.

Table-7: Fruit yield recorded under the cultivars

Cultivars	**Fruit yield (t ha^{-1})**		
	Great Rainy Season 2019	**Great Rainy Season 2020**	**Average**
Caraïbo	31.56 ± 19.32 a	34.47 ± 9.70 a	33.06 ± 2.06 a
Mongal F1	28.47 ± 11.77 a	42.62 ± 19.24 a	35.55 ± 10.01 a
Petomech	6.63 ± 3.15 b	10.60 ± 7.08 b	8.62 ± 2.81 b
Tropimech	6.75 ± 6.03 b	6.88 ± 2.82 b	6.82 ± 0.09 b
Adakamenou	16.08 ± 3.15 c	18.67 ± 8.76 a	17.38 ± 1.83 c
Average	17.90 ± 11.76	22.65 ± 15.40	20.27 ± 13.43
p-value	< 0.001***	< 0,001***	< 0.001***

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off *** Very highly significant
V1(Caraïbo) V2(Mongal F1) V3(Petomech) V4(Tropimech) V5(Adakamenou)

- ***Effect of fertilizers on tomato fruit yields***

The effect of fertilizers on tomato fruit yields recorded in two experiments was significant but with different degrees of significance (Table 8). The best fruit yields (23.74 ± 1.20; 22.95 ± 4.36; 26.36 ± 7.50 t ha^{-1}) were recorded under T1 (76 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1}), T3 (38 kg N, 15 kg P_2O_5, 15 kg K_2O ha^{-1} and 5 t ha^{-1} of manure) and T4 (76 kg N, 45 kg P_2O_5, 45 kg K_2O ha^{-1} and 5 t ha^{-1} of manure). Since production with fewer inputs is necessary, the use of T1 and T3 fertilizers is to be preferred.

Table-8: Fruit yield recorded under the effect of fertilizers

Fertilizers	**Fruit yield (t ha^{-1})**		
	Great Rainy Season 2019	**Great Rainy Season 2020**	**Average**
T0	9.68 ± 6.42 a	17.07 ± 11.50 a	13.38 ± 5.23 a
T1	24.59 ± 16.81 b	22.89 ± 18.42 ab	23.74 ± 1.20 b
T2	14.31 ± 8.15 a	15.59 ± 9.36 a	14.95 ± 0.91 a
T3	19.86 ± 16.94 b	26.03 ± 23.76 bc	22.95 ± 4.36 b
T4	21.05 ± 18.18 b	31.66 ± 18.31 c	26.36 ± 7.50 b
Average	17.90 ± 5.89	22.65 ± 6.59	20.28 ± 5.75
p-value	< 0.001***	0.015*	< 0.001***

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off *** very highly significant *significant

- ***Effect of the interaction between fertilizers and cultivars on fruit yield***

Fruit yields observed under the interactions (Table 9) showed highly significant differences (P<0.01). The best treatments for the production of the different tomato varieties studied emerged. Thus, in this order of high to low yields, the:

- of Caraïbo under T4 or T3 in the first place and under T1 in the second place is efficient,
- of Mongal F1 under T1 or T4 in the first place and under T3 in the second place is effective,
- of the cultivar Adakamenou under T1 or T4 in first place and under T3 or T2 in second place is efficient

Table-9: Effect of Fertilizer-Cultivar Interactions on Fruit Yield

Tomato Fruit Yields under Fertilizer x Cultivar Interactions (t ha^{-1})			
Fertilisants x Cultivars	**Great Rainy Season 2019**	**Fertilizers x Cultivars**	**Great Rainy Season 2020**
T4 x Tropimech	4.08 ± 1.00 a	T0 x Petomech	4.90 ± 1.49 a
T0 x Petomech	4.47 ± 1.49 a	T2 x Tropimech	5.31 ± 2.85 a
T4 x Petomech	5.02 ± 0.39 a	T4 x Tropimech	5.78 ± 1.00 ab
T2 x Tropimech	6.68 ± 2.85 ab	T3 x Tropimech	6.53 ± 3.06 ab
T3 x Tropimech	6.93 ± 3.06 ab	T0 x Tropimech	7.37 ± 2.22 ab
T0 x Tropimech	7.29 ± 2.22 ab	T3 x Petomech	7.48 ± 2.42 ab
T2 x Petomech	7.44 ± 3.72 ab	T1 x Tropimech	8.40 ± 1.89 abc
T3 x Petomech	7.60 ± 2.42 ab	T1 x Petomech	9.79 ± 4.93 abcd
T1 x Tropimech	8.18 ± 1.89 abc	T4 x Petomech	9.87 ± 0.39 abcd
T0 x Caraïbo	8.61 ± 7.69 abc	T2 x Petomech	10.32 ± 3.72 abcd
T1 x Petomech	9.20 ±4.93 abc	T0 x Adakamenou	13.82 ± 0.79 abcd
T0 x Adakamenou	11.38 ± 0.79 abcd	T2 x Adakamenou	14.49 ± 2.66 abcd
T2 x Adakamenou	14.21 ± 2.66 abcd	T0 x Caraïbo	14.92 ± 7.69 abcd
T4 x Adakamenou	15.89 ± 4.57 abcd	T3 x Adakamenou	15.98 ± 7.68 abcd
T0 x Mongal F1	16.64 ± 9.67 abcd	T1 x Adakamenou	18.49 ± 8.57 bcd
T3 x Adakamenou	16.80 ± 7.68 abcd	T2 x Mongal F1	21.27 ± 8.30 cd
T2 x Caraïbo	19.61 ± 6.08 abcd	T4 x Adakamenou	21.76 ± 4.57 d
T1 x Adakamenou	22.11 ± 8.57 bcde	T2 x Caraïbo	21.84 ± 6.08 d
T2 x Mongal F1	23.61 ± 8.30 cde	T0 x Mongal F1	23.48 ± 9.67 e
T3 x Mongal F1	26.00 ± 4.38 de	T3 x Mongal F1	38.80 ± 4.38 f
T4 x Mongal F1	35.70 ± 10.49 e	T1 x Caraïbo	43.32 ± 9.38 f
T1 x Mongal F1	40.39 ± 11.50 ef	T1 x Mongal F1	44.19 ± 11.50 f
T3 x Caraïbo	41.96 ± 25.20 f	T4 x Mongal F1	44.59 ± 10.49 f
T1 x Caraïbo	43.08 ± 9.38 f	T4 x Caraïbo	45.26 ± 13.21 f
T4 x Caraïbo	44.53 ± 13.21f	T3 x Caraïbo	46.18 ± 25.20 f
p-value	0.008**	p-value	0.005**

The values in the same column followed by the same letters do not differ statistically by Duncan's test at the 5% cut-off ** highly significant

3. DISCUSSION

3.1. Sensitivity of cultivars to virus diseases

The strong correlation between the increase in the number of virus-infected plants and time shows that there are favorable conditions for virus infection of tomato plants in the study area. Seeds being healthy, this infection would be due to the transmission of viruses from one plant to another by insect vectors, especially adults of *Bemisia. tabaci* which snuck into the experimental plots and are able to transmit more than a hundred viruses (111 viruses), including Begomoviruses (90%), Criniviruses (6%), Ipomoviruses, Closteroviruses and Carlaviruses (Jones D, 2003; Fiallo-Olivié E, 2019).

Since plant resistance to diseases is generally related to their genetic characteristics, if Petomech and Tropimech were highly susceptible to virus diseases and Caraïbo, Mongal F1 and Adakamenou were less so, this indicates that Petomech and Tropimech are not endowed with virus resistance genes or at least fail to express their resistance in the study area compared to Caraïbo, Mongal F1 and Adakamenou which have sophisticated resistance genes. Camara M and *al*. (2013) observed that if the severity index of a virus disease under a cultivar is between 0 and 1 for the rating scale of 0 to 4, then that cultivar is resistant. This criterion corresponds well to Caraïbo, Mongal F1 and Adakamenou which have been experimentally resistant. According to the same authors, if this severity index is between 1 and 2 for the same rating scale (0 to 4), then the cultivar is moderately resistant. This score, which corresponds well to Petomech and Tropimech, is actually far from being moderately resistant, since these two cultivars were experimentally highly susceptible to virus diseases.

The susceptibility of the cultivars to virus diseases (incidence, severity and rate of virus increase) was reduced in the great rainy season of 2020, probably due to the insecticide treatments that were applied on all plots without exception. These insecticide treatments, which would have reduced the populations of insect vectors of viruses, particularly *Bemisia tabaci* (Adjata K and *al*., 2010; Horowitz A and *al*., 1997), but also, after their incorporation into tomato plants, would have prevented *B. tabaci* from remaining on the plants for a long time while eating. Blancard and Ryckewaert (2021) reported that it takes 15 min to half an hour for *B. tabaci* to transmit, for example, Tomato Yellow Leaf Curl Virus. Therefore, by preventing the latter from reaching 15 to 30 minutes on plants, it is prevented from transmitting viruses.

The increase in the rate of virus growth a few days after week S4 (just after the second fertilizer application) observed under the Mongal F1 and Tropimech cultivars which reached their peaks at S5 is explained by the second fertilizer application at that time (S4); the application which improved the nitrogen uptake by the plants from that time onwards, making the foliage of the plants very lush and therefore attractive to virus vectors including *B. tabaci* (Islam M and *al*., 2017).

If the rate of virus growth only increased under Petomech from the beginning to the end of the observations, this indicates that viruses prefer to attack Petomech more than others.

The decrease in the virus growth rate curve under Caraïbo and Adakamenou from week S4 is explained by the concealment or disappearance of some virus symptoms after the second fertilizer application since, in fact, viral infection symptoms sometimes disappear when nitrogen reserves are high, even if the entire plant is infected (Arnold W and *al*., 2013).

If this average rate of virus increase observed under Adakamenou remained unchanged under the condition of no insecticide treatment (experiment 2019) and insecticide treatment (experiment 2020), this therefore rules out the considerable impact of virus-carrying insects in virus transmission to the Adakamenou cultivar.

3.2 Effect of fertilization treatments on cultivar susceptibility to virus diseases

The incidence and severity of virus infections that were reduced under the fertilized plants of Caraïbo, Mongal F1 and Adakamenou show that the fertilizers played a role in reinforcing the resistance of the plants to virus infections. This also indicates that the effect of fertilizers is only very noticeable if the cultivars by their intrinsic characteristic are resistant to virus diseases.

If the T3 treatment (low dose organo-mineral fertilization) was the best fertilization strategy to reduce the incidence and severity of virus diseases, this shows first of all that excessively high doses, especially of N, P and K, increase the susceptibility of the plants to virus diseases and that the combination of low-dose organic and mineral fertilizers would delay the multiplication of the virus already present in the host. Arnold W et *al*. (2013), Islam M and *al*. (2017) observed that the application of high doses of mainly nitrogen fertilizer to tomato plants reduces the emission of eight volatile compounds from the plants, which repel pests, including the virus vector *B. tabaci*. By simply preventing the release of these compounds, more whiteflies, which are potential virus vector agents, can be attracted to the crop. In Spain, Jauset A and *al*. (2000) also observed that high doses of nitrogen applied to tomato plants contributed to an increase in the survival of the whitefly eggs studied, the size of pupal exuviae and the length of the female tibia. In Côte d'Ivoire, Bouet A and *al*. (2013) obtained similar results by studying the effect of increasing nitrogen doses on the development of aquatic rice yellow mottle virus (RYMV) when they observed that nitrogen at certain doses favoured the creation of a microclimate conducive to egg laying by RYMV insect vectors. Ogbe F and *al*. (1993) observed a significant positive correlation between increasing levels of N and the severity of symptoms of African cassava mosaic virus.

The low incidence of virus diseases (22.80%; 22.67%) observed in fact under organic manure T2 (10 t ha^{-1} of manure) and low dose organo-mineral manure T3 and the high incidence of virus diseases observed under T0, T1 (76 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1}) ; and T4 (76 kg of N, 45 kg of P_2O_5, 45 kg of K_2O ha^{-1} and 5 t ha^{-1} of manure) are due to the lack of fertilizer under T0 and its elevation under T1 and T4 of course that T2 and T3 would constitute optimal doses for the growth of the studied cultivars. Selman I and Grant S (1957) observed that higher than optimal nitrogen doses for tomato plant growth resulted in increased symptoms of tomato plant tanning disease (TSWV) and that the estimated virus content per number of lesions increased with increasing nitrogen doses.

The susceptibility of the cultivar Adakamenou to virus diseases in both fertilized and unfertilized plants did not vary greatly, showing that Adakamenou is more resistant than Caraïbo and Mongal F1 and does not necessarily need to be fertilized in order to increase its resistance to virus diseases. Mivedor A (2018) observed that Adakamenou was more resistant to begomoviruses compared to Mongal F1 according to his study also carried out in South Togo.

3.3. Tomato fruit yields

The cultivars Petomech and Tropimech do not perform better than the other cultivars. Caraïbo and Mongal F1 present a more or less equal performance and are twice as good as Adakamenou. Fondio L and *al*. (2013) observed in Côte d'Ivoire that Mongal F1 was more productive in the batch of nine cultivars evaluated, including Caraïbo. In South Togo, Gorobani A and *al*. (2017) also observed that Mongal F1 was one of the most productive varieties. The low yields recorded under Petomech and Tropimech of 8.62 t ha^{-1} and 6.82 t ha^{-1} are similar to those obtained by Sikirou R and *al*. (2007) in Benin of 7.5 and 7.6 t ha^{-1}.

The yield obtained under the cultivar Adakamenou (17.38 t ha^{-1}) is twice that obtained by Mivedor A (2018) (8.12 t ha^{-1}) and is not consistent with their results that Adakamenou was more productive than Mongal F1.

The highest yields were recorded under treatments T1 (76 kg N, 30 kg P_2O_5, 30 kg K_2O ha^{-1}), T3 (38 kg N, 15 kg P_2O_5, 15 kg K_2O ha^{-1} and 5 t ha^{-1} of manure) and T4 (76 kg N), 45 kg of P_2O_5, 45 kg of K_2O ha^{-1} and 5 t ha^{-1} of manure) and the lower levels recorded under T2 and T0 are explained by the high doses of N, P and K provided by T1, T3 and T4 ; of course these high doses were not detrimental to fruit production. This is understandable given the important role that these three major elements play in obtaining crop fruit yields (Sikirou R and *al*., 2007; Loue A, 1980; Sogbedji J and *al*., 2006; Sountoura F, 2011; Mihoub A, 2013). Thus, these results highlight the nutrient deficiency for the tomato crop in southern Togo (Gorobani A and *al*., 2017).

CONCLUSION

The study showed first of all that the resistance of tomato plants, as for any other plant in general, is mainly linked to their genetic properties and that their capacity to express their genetic resistance to virus diseases is affected by the environmental environment, particularly mineral nutrition. Nutrients then constitute one of the key factors of the environment through which cultivars show their resistance to virus diseases. Fertilization treatments used at low doses of fertilizers (mineral or organic) directly assimilable to the tomato plants constitute for them a reinforcement aiming at preventing the development of virus diseases. These fertilizers brought from the second week after transplanting of the plants reinforce at best their resistance to virus diseases. The treatments T2 (200 g manure/plant) and T3 (2 g NPK 15 15 15 + 100 g manure + 1 g urea 46% N / plant) are already the best fertilization treatments that can effectively strengthen the plants to better resist virus diseases. However, based on the best fruit yields, the choice of fertilization treatments T1 (4 g NPK 15 15 15 + 2 g urea 46% N / plant), T3 (2 g NPK 15 15 15 + 100 g manure + 1 g urea 46% N / plant) and T4 (high dose organo-mineral fertilizer: 6 g NPK 15 15 15 + 100 g manure + 1.34 g urea 46% N / plant) is to be preferred. In the vision of sustainability of better tomato fruit yields, T4 treatment should be excluded as it promotes the sensitivity of the plants to virus diseases. This being the case, the production of Caraïbo and Mongal F1 under T3 (2 g NPK 15 15 15 + 100 g cattle manure + 1 g urea 46% N / plant) fertilizers could therefore be recommended in South Togo.

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