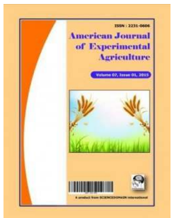

American Journal of Experimental Agriculture
11(3): 1-13, 2016, Article no.AJEA.22138
ISSN: 2231-0606

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Assessing the Resistance of Three Tomato Varieties to Bacterial Wilt and Stem Rot

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Authors' contributions

This work was carried out in collaboration between all authors. Author ZA designed the study, identified the plants, wrote the protocol, wrote the first draft of the manuscript and reviewed all drafts of the manuscript. Author SM reviewed the experimental design, performed the statistical analysis and reviewed all drafts of the manuscript. Authors CCA and JPND managed the analyses of the study and reviewed all drafts of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2016/22138
Editor(s):
(1) Mirjana Bulatovic-Danilovich, Consumer Horticulture, State Extension Master Gardener Program Coordinator, West Virginia University, USA.
Reviewers:
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Complete Peer review History: http://sciencedomain.org/review-history/13130

Original Research Article

Received 19th September 2015
Accepted 21st November 2015
Published 30th January 2016

ABSTRACT

The aim of this study was to compare the level of resistance of two new hybrids (*F1 Nadira* and *F1 Jaguar*) with the popularly known variety *Rio Grande* against *Pseudomonas solanacearum* (causal agent of bacterial wilt) and *Erwinia carotovora* (responsible of stem rot) under natural conditions. A randomized sample block design containing three treatments (*F1 Nadira*, *F1 Jaguar* and *Rio Grande*) with three repetitions was used. The research took place in Obala subdivision and in University of Yaounde 1, Faculty of Science, Department of Plant Biology, laboratory of

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Phytopathology and Microbiology in Cameroon during the 2010-2011 growing seasons. The resistance of each variety to the two bacterial diseases was assessed by determining incidence and severity of the diseases. Bacterial symptoms on tomato were identified by visual diagnostic. The incidence and severity of *P. solanacearum* ranged between 27-39% and 86-92% respectively on all tomato varieties tested; the hybrid *F1 Jaguar* proved to be less susceptible to bacterial wilt than the control *Rio Grande*. All the varieties tested had a similar susceptibility with incidence and severity up to 45 and 80% respectively, to *E. carotovora*. Overall, no significant differences on disease incidence were observed for the two diseases tested. However, the difference in yield between the tested varieties appears to be high. We recommend the use of the hybrid varieties based on their higher production potential of larger fruits and low disease incidence.

Keywords: Bacterial wilt; Erwinia stem rot; resistance; tomato varieties; Cameroon.

1. INTRODUCTION

In Cameroon, tomato is the most widely cultivated vegetable [1]. Its annual production in Cameroon was estimated at 76,000 t in 1999 [2] and at 500.000-1.000.000 t in 2008 [3]. Tomato is one of the most studied plants. Studies were conducted on: The effect of packaging on the quality and storability [4]; the effect of temperature on the quality and storability of Cherry tomato during commercial handling condition [5]; the ripening stage [6]; the ultraviolet light (UV-C) irradiation reducing postharvest fungal incidence of Cherry tomato [7]; volatile compounds [8,9]; arsenic effect and accumulation in plants [10].

In the past decades, attention has been focused on means of eliminating food insecurity and hunger worldwide. The targets of the first Millennium Development Goal between 1990 and 2015 are to reduce by halve, the proportion of people who suffer from extreme hunger and people whose income is less than US dollar ($1) a day [11]. Semi-urban agriculture as part of the solution is very important as it creates jobs, diversifies income and ensures food self-sufficiency [12]. Therefore, growing tomatoes could be one way of curbing unemployment and reducing rural exodus. However, growing tomatoes is not an easy task as this is plagued by many problems. Among these problems, attacks by diseases have been identified as the most important limiting factor to tomato production in many parts of the world especially when disease resistance cultivars are not available [13,14].

At a time when high yield tomato varieties are being propagated in the Obala subdivision (Cameroon), several tomato growers are skeptical to be part of such extension program. While some growers consider information on high-yielding tomato varieties as mere propaganda, others are simply not ready to spend money on buying seeds without first witnessing yield improvements in the varieties in question. They prefer to collect their seeds for the next planting season from the preceding one. Therefore examining all the factors that can influence crop yields remains crucial.

The low yield of tomato may be attributed to the susceptibility of the crop to diseases [15-18]. Bacterial diseases of tomatoes are considered the most destructive, affecting both field and greenhouse grown crops [19]. Although various types of resistance have been studied and several bacterial wilt-tolerant cultivars released, the resistance often breaks down outside the specific region where it was developed and is insufficient for use in heavily infested fields [20]. Most tomato varieties found at the Cameroon market were developed outside Cameroon. This study is dealing with three such varieties.

The main objective of this work was to compare the level of resistance of some new hybrids with the popularly known variety Rio Grande against bacterial wilt and *Erwinia* stem rot under natural conditions. Specifically, we wanted to evaluate growth parameters like the height, number of leaves and number of inflorescences as well as disease severity and incidence.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Plant material

Seeds of three tomato varieties (Rio Grande, F1 Nadira and F1 Jaguar) were bought from a Tropicasem outlet in Yaounde. The new F1 Nadira is an open field variety. Its average fruit weight is 90 grams. Resistant to TYLCV, Nadira was developed for use mainly in Sahel areas with an output of between 140 to 160 tons per acre. Its high resistance to heat makes it a good variety for the Far North Region of Cameroon and Tchad. It has a short cycle of between 65 and 70 days after planting and harvest can be spread out over 3 months.

F1 Jaguar fruits have a variable average weight of between 100-110 g, with a first harvest at 65 days after planting. Its excellent adaptation to high temperatures during the dry season, the firmness of its fruit, good tolerance to TYLCV, ensures a high productivity under relatively high virus incidence. It has a good foliar protection. Its average yield is 130-160 tons per acre.

The Rio Grande variety described as an excellent mid-early bush variety for outdoor is appreciated for its high productivity during the cool and dry season. It is vigorous with long cylindrical fleshy fruits, very firm averaging 95 to 100 g in weight. It is also resistant to *Verticillium* wilt, *Fusarium* wilt races 0 and 1 (*Fusarium oxysporium*) and *Alternaria* stem canker.

2.1.2 Chemicals

The fungicide used to control fungal diseases in this experiment was Ridomil Gold Plus 66 WP. It is a wide spectrum systemic and contact fungicide, used as wettable powder. One kilogram of Ridomil Gold Plus 66 WP contains 60 g of *metalaxyl-M* and 600 g of copper in form of cuprous oxide. The insecticide "Decis" 25 EC was used throughout the experiment. It is a contact and ingestion foliar insecticide whose active ingredient is *deltamethrine* at a concentration of 25 g/l.

Nematodes were controlled using "*Furaplant 10 G*". It is a broad spectrum *carbamate* pesticide that kills insects and nematodes on contact or after ingestion. To improve soil fertility, N.P.K. (20.10.10.) and urea fertilizers were used.

2.2 Methods

2.2.1 Experimental set-up

The field experiment took place in Obala (4°10'0" N, 11°31'60" E and elevation of 542 m above see level), one of the subdivision of the Centre region of Cameroon, where tomato is often cultivated.

The experimental design (Fig. 1) was a randomized sample block design with three replications. Each variety constituted a treatment. The different treatments were therefore: Variety Rio Grande as our control; Variety F1 Nadira and Variety F1 Jaguar.

Within a particular block, each treatment was separated from the neighboring one by 1 m and each block separated from its neighbor by 2 m.

2.2.2 Nursery

The nursery was made of three beds consisting of 2 m^2 surface area each. These corresponded to the three treatments used in this experiment. Before sowing, each bed was treated with Ridomil Gold Plus 66 WP, Decis 25 EC and furaplant. Seeds were sown in holes of about 2 cm deep. The distance between neighboring holes was 10 cm. The sowing consisted of depositing seeds in the holes and then covering them with soil. The beds were then watered with one watering-can-full per bed and then covered with palm leaves, which constituted the shade for the nursery. Care was taken to make sure the nursery was in a good state. This was done by: ensuring daily watering two times a day (morning and evening) with one watering-can per bed (2 liters per m^2) before germination and two per bed (4 liters per m^2) after germination; checking whether germination had started from the third day after sowing and raising the shade to a height of 40 cm above the bed once germination had started; removing the shade once germination was complete and removing weeds in between the sowing lines.

2.2.3 Site preparation and crop establishment

An open area with maximum duration of daily sunshine was chosen. The field was cleared and measured using a tape. The area was cleaned to allow for easy work when ploughing. Beds of 5 m long and 2 m wide were made for all the varieties. These beds were displayed according to our experimental design (Fig. 1). Each bed constituted an experimental plot.

Healthy plants were obtained four weeks after sowing in the nursery. Nursery beds were first watered before removing tomato plants. These plants were then transplanted in to holes of about 15 cm deep on field beds. Holes were dug in order to hold water for as long as possible for uptake by the young plants. Sufficient amounts of water were poured in transplanted holes to ease the adaptation of the young transplants. The process took place very early in the morning. Thereafter, little quantities of 'furaplant' were thrown round the young plants and 'Decis' 25 EC

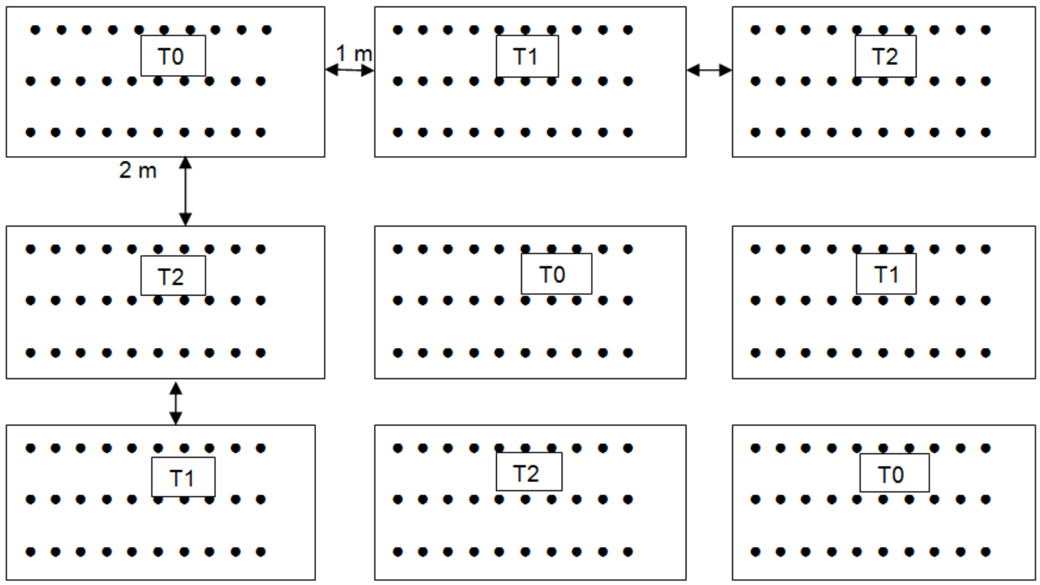

Fig. 1. Experimental design

●: Tomato plant; T0 *: Variety Rio Grande;* T1 *: Variety F1 Nadira;* T2 *: Variety F1 Jaguar*

was sprayed on the whole field to send away insects that could damage the young tomato plants. Tomato varieties were planted at a density of 0.5 × 0.8 m.

2.2.4 Crop management

Throughout the experiment, care was taken for tomato plants to grow in a clean environment. Weeding was done 15 and 30 days after transplanting. Insects and fungal diseases were controlled by spraying 'Decis' 25 EC and 'Ridomil' Gold Plus 66 WP. The application of these phytosanitary products was done once every week. The dosage was 50 g of 'Ridomil' Gold Plus 66 WP for 15 of water and 25 ml of 'Decis' 25 EC for 15 liters of water, both using a knapsack sprayer. Use of (PPE) Personal Protection Equipment (chemical-resistant rubber gloves, a mask and rubber boots) during all phytosanitary applications was assured. Tomato plants were staked to reduce the spread of diseases, especially fungal diseases.

Fertilizers were used to improve soil fertility. Barely a week after transplanting, N.P.K. (20.10.10.) fertilizer was applied and two weeks later, urea fertilizer was also applied. Two days following each application the soil was hoed around plants. The beds were watered quite often, to supplement rainwater and ensure sufficient water for the crop.

2.2.5 Data collection

2.2.5.1 Assessment of growth parameters

The growth parameters considered were: the height of plants measured weekly using a tape decameter; the number of leaves per plant was counted and recorded; flowering where the number of inflorescences per plant was counted and the percentage of plants bearing flowers determined.

2.2.5.2 Disease assessment

For this experiment, disease studies were limited to field observation of symptoms as described by the tomato disease identification key [21]. The resistance of tomato varieties was assessed for two bacterial diseases that cause overall plant decline (bacterial wilt caused by *Pseudomonas solanacearum*; *Erwinia* stem-rot caused by *E. carotovora*) [22].

Bacterial disease symptoms were identified by visual diagnostic. Samples of the diseases were taken to the laboratory for observation under the light microscope using the Gram staining method. The use of fungicide enabled us avoid fungal diseases. Each week the number of infected plants was recorded along with the degree of infection. As plants started dying the number of plants remaining was also considered and computed. All the plants in the field were considered. Disease severity and spread were determined using a widely adopted formulas. Disease spread is calculated by the following formula:

$p = n \div N \times 100$ [23]

where,

- p = disease frequency in the plot (expressed in %);
- n = number of infected plants in the plot;
- N = total number of plants (diseased and healthy) in the plot.

Disease severity is calculated by the formula: S $= \frac{\sum(a \times b)}{n} \times 100$ [23] where, S = mean infection intensity (%); ∑(a×b) = sum of the multiplication of the number of diseased plants (a) with the corresponding degree of infection (b) in %; n = total number of diseased plants.

2.2.5.3 Yield assessment

Fruits were harvested from more tolerant plants in the field. The harvest was progressive as the fruit got ripe (evidenced by the orange color) till the plants died off. Fruits were progressively harvested from successful plants in the field as they got ripe. All the fruits of one plant were weighed after harvest using an electronic balance of Sartorius brand with a precision 0.1 g to calculate the yield per plant. The number of successful plants was then used to calculate the yield per plot, the latter used to calculate the yield per hectare. The percentage increase in yield of the hybrid varieties compared to the variety Rio Grande was determined by the formula [15]:

Percentage increase $= [(Y_{hybrid} - Y_{Rio\ Grande}) / Y_{hybrid}] \times 100$, where,

Y_{hybrid} represents the yield of a hybrid variety; $Y_{Rio\ Grande}$ represents the yield of the variety Rio Grande.

2.2.6 Data analysis

Data was analyzed using the computer program, software analysis system (SAS), which uses the analysis of variance (ANOVA) and the test of Student-Newman-Keuls at 5% to compare the means. Whenever there was a significant difference between the means the least significant difference (LSD) method was used to separate them.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Development of plants in the nursery

The behavior of seeds of all the varieties was normal. A week after seeds had been sown; germination had reached almost 100% (Fig. 2). The sanitary state of seedlings was good, no damping-off of seedlings was observed. Atmospheric conditions were favorable for the proper growth of plants.

Four weeks after sowing in the nursery, plants were ready to be transplanted. The application of fertilizers in the nursery favoured the growth of plants. The most vigorous plants were selected for transplanting in order to obtain an even establishment of the crop.

3.1.2 Development of plants in the field after transplanting

3.1.2.1 Evolution of the height of tomato plants in the field with respect to varieties

Data for plants height for different tomato varieties were collected at 7 DAT, 14 DAT, 21 DAT and 28 DAT. At 7 DAT there was no significant difference between the varieties. The heights of plants at this date were 13.73±1.46 cm, 17.27±1.33 cm and 14.8±1.56 cm for variety Rio Grande, variety F1 Nadira and variety F1 Jaguar.

At 14 DAT, the difference in heights of the three varieties becomes significant at P =.05. The mean heights of plants were 19.7±0.92 cm, 31.14±7.00 cm and 21.39±1.18 cm for variety Rio Grande, variety F1 Nadira and variety F1 Jaguar respectively. At 21 DAT the growth in length of plants still showed a significant difference between varieties. The mean heights of plants were 28.25±1.94 cm, 34.99±0.94 cm and 31.85±0.72 cm for the three varieties respectively, with P =.05.

At 28 DAT the differences in height between varieties was not very significant (Fig. 3). However the variety F1 Nadira had the greatest height (46.33±2.30 cm) compared to 41.20±3.33 cm for variety Rio Grande and 44.16±3.75 cm for variety F1 Jaguar.

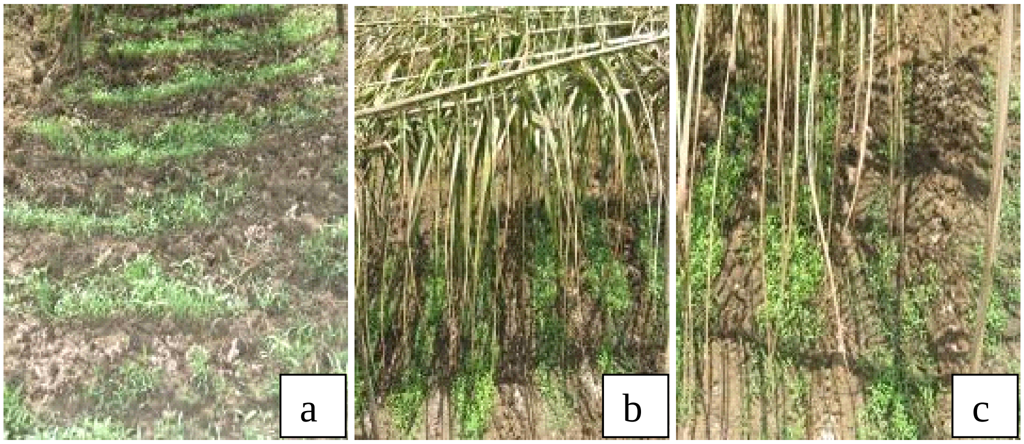

Fig. 2. State of germination in the nursery a week after seeds had been sown a – variety Rio Grande; b – variety F1 Nadira; c – variety F1 Jaguar

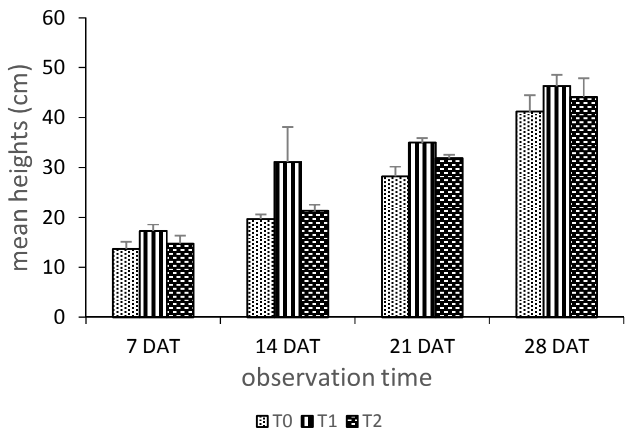

Fig. 3. Mean heights of plants for each variety observed over a 28 days period. DAT: Days after Transplanting; T0: variety Rio Grande; T1: variety F1 Nadira; T2: variety F1 Jaguar

3.1.2.2 Evolution of the number of leaves of tomato varieties

The data show the average number of leaves per plant recorded after transplanting at seven days intervals (Fig. 4). The data show that varieties F1 Nadira and F1 Jaguar develop more leaves than the control (Variety Rio Grande).

At 7 DAT, variety Rio Grande had 3.97±0.53 leaves, variety F1 Nadira 4.03±0.24 leaves and variety F1 Nadira 3.92±0.18. However, these differences are not significant at $P = .05$.

At 14 DAT, 21 DAT and up to 28 DAT, the values recorded show a continuous tendency for the hybrid varieties to bear more leaves than the control, variety Rio Grande, with variety F1 Nadira producing the greatest number of leaves (Fig. 4). Though Snedecor's F hypothesis ($P = .05$), suggest that there is no significant difference at 14 DAT, a significant difference is observable at 21 DAT. This significant difference continues to be observed at 28 DAT where the average numbers of leaves are 9.03±1.38, 12.81±0.60 and 10.99±0.70 for Rio Grande, F1 Nadira and F1 Jaguar respectively. Variety F1 Nadira according to these results, produce the highest number of leaves.

3.1.3 Evolution of bacterial diseases in the different varieties

3.1.3.1 Evolution of bacterial wilt caused by Pseudomonas solanacearum

The average incidence of bacterial wilt appear to increase with time for all the varieties during the period of study (Fig. 5). At 14 DAT, symptoms of bacterial wilt could be seen on some plants for all the varieties. Microscopic observations also revealed the presence of elongated rods typical of *P. solanacaerum*. As time elapsed, more and more plants were affected by the disease irrespective of the varieties. The differences between varieties in the disease incidence were not significant up to 21 DAT. At 28 DAT there was a significant difference between the varieties in the level of disease incidence. The incidence was 27.50±6.61, 35.83±2.88 and 39.16±6.29% on varieties F1 Jaguar, F1 Nadira and Rio grande respectively. Based on the F test of Snedecor, and using LSD analysis, variety F1 Nadira is different from Rio Grande but similar to F1 Nadira.

The degree of severity of bacterial wilt up to 28 DAT showed a high levels of the disease on all varieties (Fig. 6). The first symptoms were seen when collecting data on the field 14 DAT. At 14 DAT some differences in severity of the disease symptoms among the observed varieties started to appear: Rio Grande-56.61±24.00, F1 Nadira-39.86±26.94 and F1 Jaguar-53.47±24.03%. However these differences were not significant at *P* =.05, at 21 DAT there was a similar appearance of disease severity as at 14 DAT with slight differences favoring variety F1 Nadira which had the least severity reading, but there was an overall increase for all the varieties. At 28 DAT severity readings above 80 % were recorded (92.80±0.48% for Rio Grande, 86.21±13.92% for F1 Nadira and 92.83 ± 4.27 % for F1 Jaguar), with no significant difference between them.

3.1.3.2 Evolution of Erwinia stem rot

Symptom of *Erwinia* stem rot was present on some plants for all the varieties in this experiment. Observation of samples under the light microscope revealed the presence of round bacteria typical of *Erwinia carotovora*. These were observed from 14 DAT (Fig. 7). The disease incidence increased with time for all varieties. Statistical analysis revealed no significant differences between the varieties at each date since F_{cal} was always less than F_{read}. At 21 DAT, disease spread was high on varieties Rio Grande and F1 Nadira than on variety F1 Jaguar (Fig. 7).

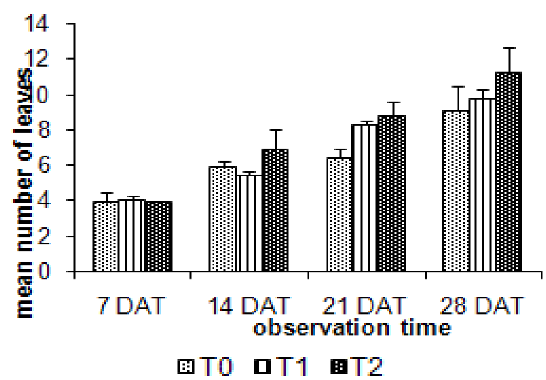

Fig. 4. Mean number of leaves produced over time for the three tomato varieties

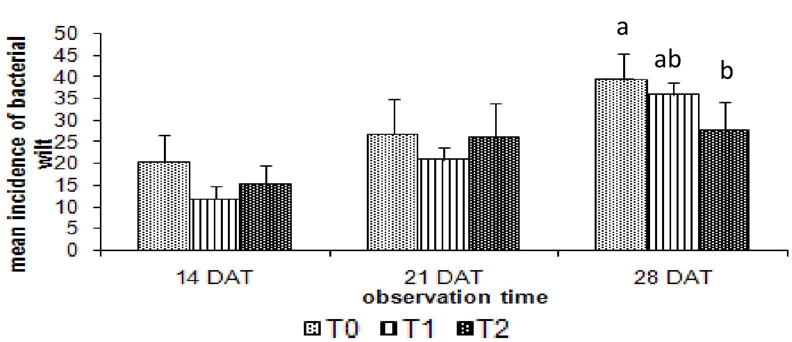

Fig. 5. Mean incidence (%) of bacterial wilt per variety with respect to time. DAT: Days after Transplanting. T0: Rio Grande; T1: F1 Nadira; T2: F1 Jaguar. Values with different letters are significantly different

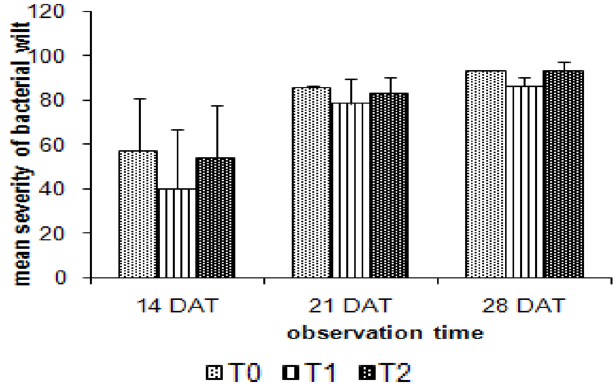

Fig. 6. Mean severity (%) of bacterial wilt per variety with respect to time. DAT: Days after Transplanting. T0: Rio Grande; T1: F1 Nadira; T2: F1 Jaguar

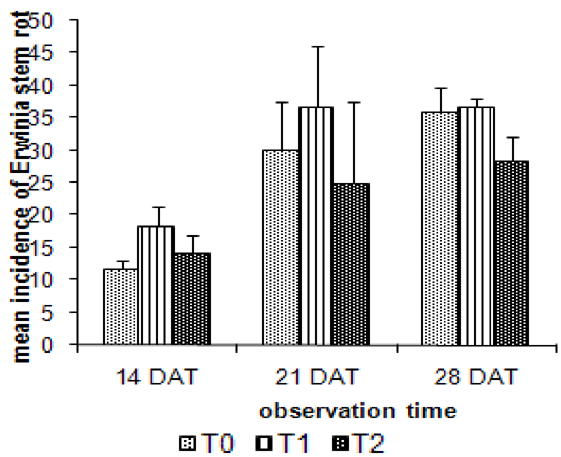

Fig. 7. Mean incidence (%) of *Erwinia* stem rot per variety with respect to time. DAT: Days after Transplanting. T0: Rio Grande; T1: F1 Nadira; T2: F1 Jaguar

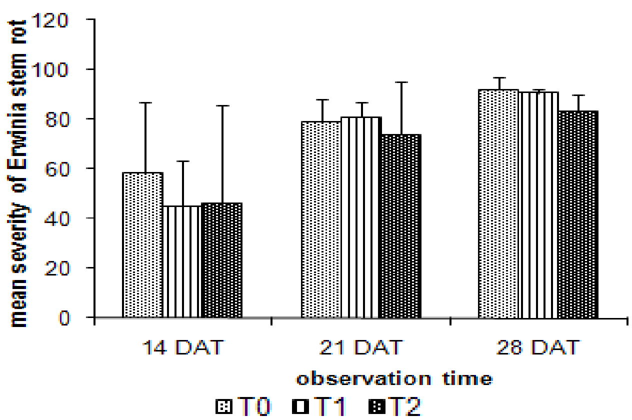

Fig. 8. Mean severity (%) of *Erwinia* stem rot per variety with respect to time. DAT: Days after Transplanting. T0: Rio g Grande; T1: F1 Nadira; T2: F1 Jaguar

The severity of *E. carotovora* increased with time for all the varieties (Fig. 8). As early as 14 DAT we already had severity values above 40% (58.50±28.27%, 45.00±18.41% and 45.92±40.13% for Rio Grande, F1 Nadira and F1 Jaguar respectively). Within four weeks after transplanting we recorded severity levels of more than 80% but there were no significant differences between varieties.

3.1.4 Impact of diseases on the crop

The impact of diseases on the crop was determined by calculating the percentage of dead plants during each observation in the field (Fig. 9). No damage was caused to any of the varieties during the first week after transplanting. At 14 DAT we noticed a decrease in the number of plants on the field for all the varieties. The differences between varieties were not significant till the last date of data collection (28 DAT). The number of plants in the field decreased with time irrespective of varieties (Fig. 9). The disappearance of plants in the field as days went by, was due to the rapid overall plant decline caused by these diseases (Fig. 10).

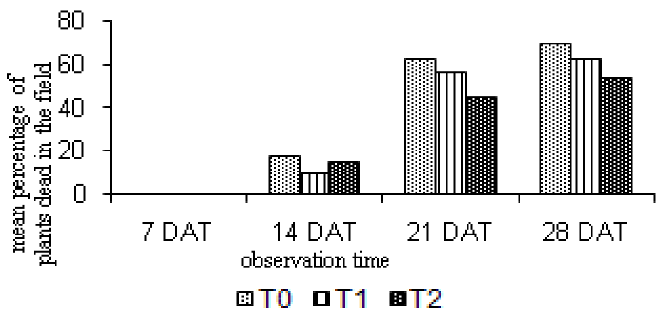

Fig. 9. Mean percentage of plants dying in the field for each variety with respect to time. DAT: Days after Transplanting. T0: Rio Grande; T1: F1 Nadira; T2: F1 Jaguar

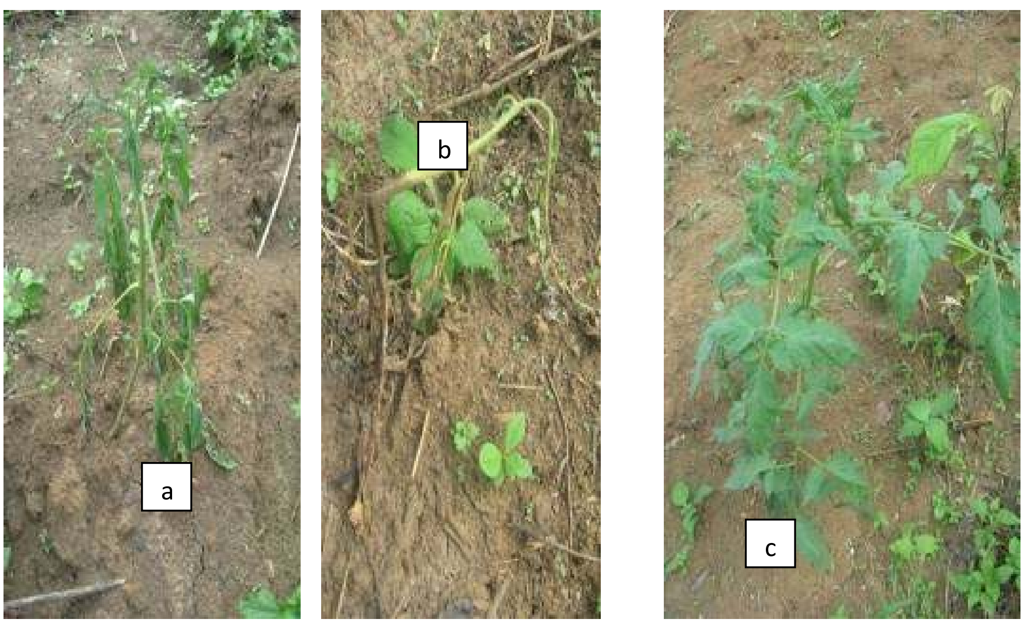

Fig. 10. Severity of *Pseudomonas solanacearum* and *Erwina* diseases on tomato plant 14 DAT; a - symptom of bacterial wilt caused by *P. solanacearum* on a young tomato plant; b – symptom of *Erwinia carotovora* causing blag leg on a young tomato plant; c – healthy young tomato plant

3.1.5 Factors of yield

3.1.5.1 Flowering of tomato varieties

The first appearance of flowers on plants of all the varieties was observed 14 DAT. The mean percentages of plants bearing flowers were not significantly different between varieties at any date. At 28 DAT, 100% of flowering was observed on all the plants in the field (Fig. 11).

3.1.5.2 Yields of the various varieties

Yields of marketable tomato fruits in tons per hectare were also obtained in this essay (Table 1). It can be seen from the table that the yields of marketable fruits vary with respect to the different varieties. The yields of 4.9, 17.5 and 30.1 t/ha for the varieties Rio Grande, F1 Nadira and F1 Jaguar respectively are significantly different. Although it was shown that diseases have a serious impact on all the varieties, the hybrid varieties remain interesting due to their high yields.

3.2 Discussion

Data for the number of leaves, height of plants, disease severity, disease incidence and yield were collected in order to monitor the behavior of each tomato variety in the experimental field. A similar study [24] showed that disease parameters are the main indices to characterize the resistance of plant species under natural conditions. Looking at the evolution of the number of leaves and that of the height of plants within four weeks, the hybrid varieties grew more than the control, Rio Grande, though the differences were not significant. This result may be explained by the short observation time. Nevertheless, the transplanting density used, took into account the later development of hybrid varieties that occupied more space throughout their growing cycle than the control. This was due to their genotypes confirming results of similar studies on groundnut [25].

The appearance of bacterial wilt and *Erwinia* stem rot on the varieties during the second week after planting in the field shows that these varieties can all be affected by the disease very early in the growing season under field conditions. The fact that the severity of these two diseases rapidly reached high levels for all the varieties is a strong indication that both pathogens were very virulent on the affected plants. A similar observation was made by [26] in their work on bacterial wilt in tomato. They found that plants started wilting 10-12 days after transplanting. Looking at the severity of the disease alone might not help determine the degree of resistance of these varieties to the disease.

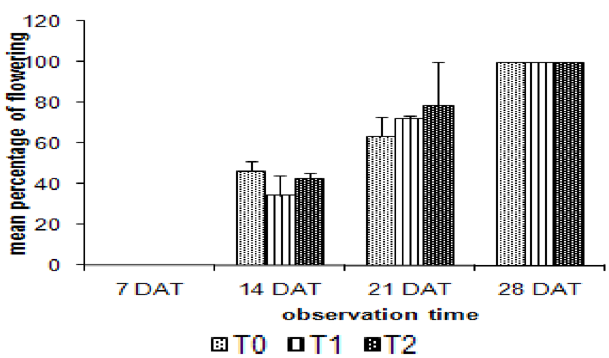

Fig. 11. Mean percentage of plants flowering in the field per variety with respect to time

Table 1. Yields of marketable tomato fruits per variety

Yield parameters	**Variety Rio grande: control**	**Hybrid F1 Nadira**	**Hybrid F1 Jaguar**
Average weight of fruit (g)	62.3±3.10a	90.5±5.21 b	124±21.05 c
Yield (kg/20 m^2)	9.81±1.09 a	35.29±2.94 b	60.21±18.56 c
Yield (t/ha)	4.9 a	17.5 b	30.1 c
Percentage increase compared to the control	-	257.1%	514.2%

Data in the same line followed by different letters are significantly different according to the test of Student-Newman-Keuls at the level of 5%

The incidence of bacterial wilt on the varieties showed a significant difference between varieties in the fourth week after transplanting. Variety F1 Jaguar, therefore, appears to be more resistant than the control (Rio Grande). For *Erwinia* stem rot, the incidence of the disease did not show a significant difference amongst varieties according to the analysis of variance. It can however be seen that the variety F1 Jaguar in the fourth week had an incidence of less than 30% making it less sensitive to the disease than the other varieties. Considering the incidence and severity of both diseases at 28 DAT, it is obvious that infected plants end up dying. This could also suggests high pathogen concentrations in the soil, since, [27] classified tomato and potato as moderately resistant to *Erwinia* spp. because rot symptoms occurred only when dosage levels of pathogens where raised to 10^6 and 10^8 cfu/ml. Disease incidences of more than 30% caused by *E. carotovora* on the varieties Rio Grande and F1 Nadira are epidemiologically important. This is contrary to [28] who said that bacteria do not reach populations that are epidemiologically significant except in diseased plants.

The high disease severity recorded on infected plants and their absence on some plants in the field suggest that the resistance mechanism of tomato to these diseases is vertical [29]. Vertical resistance is one in which the biochemical key of the bacteria matches with the biochemical lock of the host. Such resistance is broken when disease appears [30].

The impact of both diseases could be seen clearly in the field for all the varieties. As time elapsed, the number of plants in the field decreased for all the varieties due to wilting and consequent dying of infected plants. These results agree with [19] who stated that bacterial diseases can be some of the most serious and destructive diseases affecting both field and greenhouse-grown crops.

The consequences of such bacterial infections are felt more when their effects on production are considered. Considering the number of plants left on the field for all the varieties, no significant differences could be seen between them. However, when harvested products are compared, great differences appear. The yield of the hybrid varieties is significantly different from that of the variety Rio Grande, with the hybrid F1 Jaguar being greater than all. These hybrids express their heterotic effect on the yields.

4. CONCLUSION

The main threats considered for this study were bacterial wilt caused by *Pseudomonas solancaerum* and *Erwinia* stem rot caused by *Erwinia carotovora*. Results from this study show that tomato plants of all the varieties tested can be infected by these diseases with almost the same disease severity. For bacterial wilt, the variety F1 Jaguar proved to be less susceptible than the control, Rio Grande, while F1 Nadira was not significantly different from the latter. Statistical analysis revealed that all the three varieties tested were vulnerable to *Erwinia carotovora*. Disease incidence was above 30% for all three varieties. Interestingly, the varieties showed high potentials to produce fruits. Variety F1 Jaguar with the lowest disease incidence should be more economically viable. Based on our findings, we recommend that the two new varieties be used by tomato growers. Careful selection of production should also be considered.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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