Effects of introduced tomato varieties and chemical fungicides on the incidence and severity of Late blight, caused by *Phytophthora infestans* (Mont. de Bary) in the Western region in Cameroon

Abstract

Late blight, caused by *Phytophthora infestans*, is the main constraint to tomato production and exportation in Cameroon. The objective of this study was to evaluate the impact of three chemical fungicides in the control of tomato Late blight in the field for the improvement of tomato production in the west region of Cameroon. Seedlings of 7 tomato varieties produced in the nursery were transplanted into pits each containing 100 g of fowl droppings and 30 g of the nematicide Carbofuran 5 %. Maintenance and chemical fertilizers were applied whenever necessary. From the 21st day after transplanting, the different fungicides were applied every four days. Data were collected on the incidence, severity of the disease at different stages of plant growth and development and on yields. The results showed that the AVTO1219 and AVTO1311 varieties were less sensitive to Late blight. The control plants of AVTO1219 variety showed incidences of 7.7, 11.7 and 16.7 % and severities of 1.7, 14.9 and 17.2 % in the vegetative, flowering and fruiting phases respectively. Control plants of CLN1462A, CLN1464A, CLN1464B, RIOGRANDE2 and RIOGRANDE+ varieties showed incidence of 100 % from the flowering phase. Control plants of varieties AVTO1213 (17.29 tons/ha) and AVTO1311 (11.33 tons/ha) produced the highest yields. Bonsoin was the most effective fungicide. These results suggest that to improve tomato production, Late blight resistant varieties should be used and effective fungicides applied as treatments.

Key words: tomatoes, fungicides, incidence, severity, Late blight, *Phytophthora infestans*

Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown around the world and is the second next to potato and it belongs to the family Solanaceae. It originated from tropical Mexico to Peru (Keskse *et al.,* 2019). Tomato is a source of minerals, vitamins, lycopene and health benefits in reduce cancer and heart disease (Farheen *et al*., 2018; Micah *et al*., 2018)**.** Economically, it is the fourth most important crop in the world after rice, wheat, and soybean (Hagos *et al.,* 2020). In Cameroon, the production of tomato increases and become a source of cash income for producers, and retains its importance for daily household consumption.

The production of the crop is attrition by several biotic and abiotic factors. Among biotic constraints, fungal diseases are major factors affecting production and productivity as well as the quality of the crop. Many fungal diseases like late blight, fusarium wilt, are attacking this crop, and can cause 15-95% crops loss both in lowland and highland areas of the tropics (Ephrem, 2015; Getachew, 2017). Late blight of tomato, caused by *Phytophthora infestans*, is one of the most serious diseases of this crop. It is present all over the world where tomato cultivation exists and even remains the main limiting factor for tomato production worldwide (Bastin, 2020). Late blight can also cause damage to other wild and cultivated Solanaceae, especially *Solanum tuberosum, S. melongena, S. torvum* and *S. nigrum* (Ashenafi *et al.,* 2017; Mideros *et al.,* 2018; Kassaw *et al.,* 2021). In Cameroon and in the West Region in particular, tomato farmers have noted this through disease outbreaks, once in the field, this disease increased the difficulties of maintaining Late blight-free tomato plots (Goufo *et al.,* 2010). This disease is responsible for damages, affecting mainly the aerial parts of the plant (leaves, stems, flower or fruits). Generally, lesions on the leaves first appear as irregular dark spots that widen as new lesions develop. On the upper surface of the attacked leaves, a lighter green halo often surrounds the necrotic area, on the lower surface, a milky white ring sporulation develops around the lesions, if the humidity is favourable for the development of the pathogen. Stem lesions are elongated, greyish-brown to black in colour and often encircle the stem. These lesions are often found in the axils of bracts and at the apex of stems (Randriantsalama *et al.,* 2014; Hagos *et al.,* 2020). On the floral clusters (or inflorescences), the disease causes browning and then the fall of many flowers. On the fruits, Late Blight is characterized by irregular brown patches with a tan and shiny appearance. Thus, the fruit has a bumpy appearance with an interior corky texture and a brown colour and may also incure the appearance of white fuzz on the infected parts (Peerzada *et al.,* 2013; Keskse *et al.,* 2019). Infected unripe green fruits turn brown on the surface. These lesions develop and become enlarged brown and leathery in appearance. Hence, only those partially attacked will mature (Ashenafi *et al.,* 2017; Bastin, 2020). It can cause up to 90% of crop losses in cool and wet weather conditions, most prevalent during the rainy season and cause yield losses of up to 100% and fruit losses up to 30-60% (Savazzini and Galletti, 2015; Kassaw *et al.,* 2021).

Management of late blight requires aggressive measures that include combined use of cultural, scouting, sanitation, and most importantly the combination of host plant resistance with application of fungicides. Many growers also use different fungicides like Mancozeb, Agrolaxyl, Metalaxy, copper, phosphorus acid and Ridomil for the control of late blight of tomato (Randriantsalama *et al.,* 2014; Abdelhak *et al.,* 2016; Njoroge *et al.,* 2019). Among

many alternative measures available, use of resistant varieties has been the most important and a cost-effective approach for the management of the disease (Getachew, 2017).

Therefore, this study was conducted to evaluate the effect of fungicides and tomato varieties for the management of Late Blight tomato and to evaluate the efficacy of fungicides and their effect against Late Blight on tomato varieties as well as to evaluate the effect of the integrated management options on the yield of tomato.

Materials and methods

Description of the experimental site

The field experiment was conducted under the main rainy season in the West Region of Cameroon, Ndé Division, precisely in the Bangangté Sub-division. This region is the main tomato production basin (Aghofack-Nguemezi *et al.,* 2015). Bangangté is located between latitude 5°5' and 6°5' North and between longitude 10°5' and 11°5' East. It has an average altitude of 1432 m (PNDP, 2015) and belongs to the agro-ecological zone of the Western Highlands of Cameroon, which is characterized by a humid tropical climate with two seasons, a short dry season and a long rainy season. Temperatures vary between 14º and 28º C with an annual average of 22 °C. Rainfall varies between 1400 and 2500 mm per year. The soil is fertile and has a sandy-clay texture; with a slightly acidic pH (CTFC, 2013).

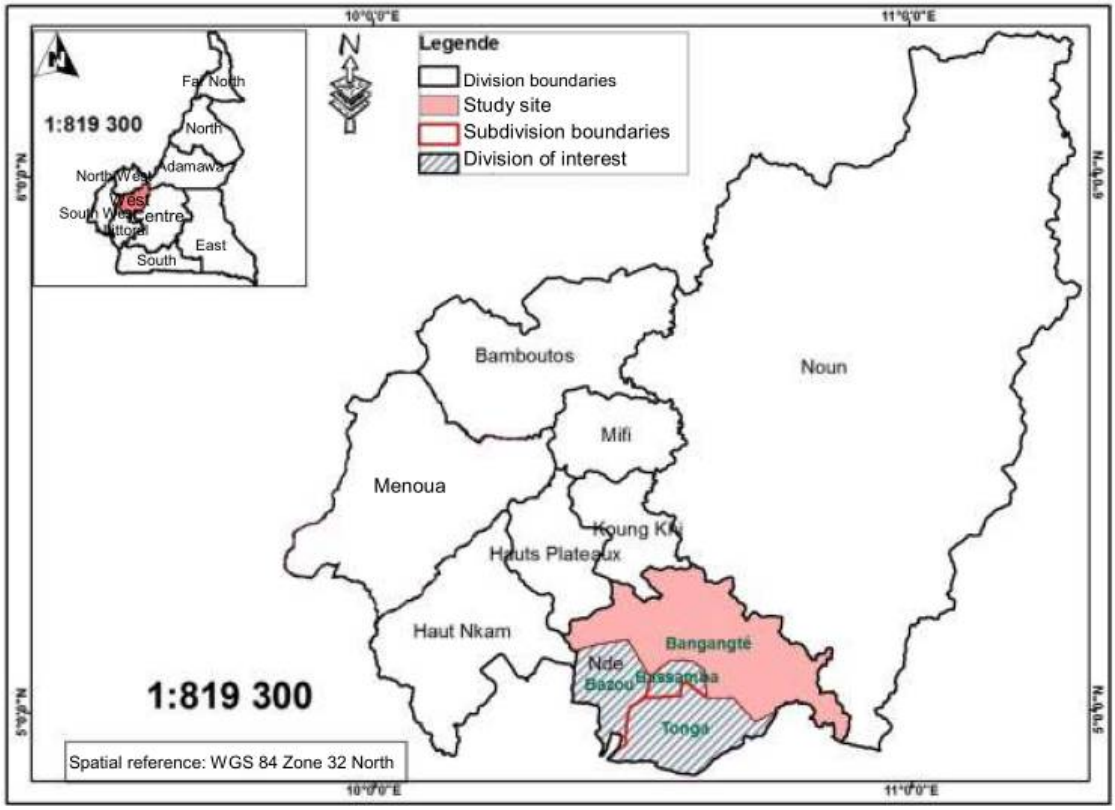

Figure 1. Location map of the study area

Planting materials and fungicides

The experiment included two factors: tomato varieties and fungicides. Tomato varieties AVTO1219, AVTO1311, CLN1462A, CLN1464A and CLN1464B (exotic) and RIOGRANDE+ and RIOGRANDE2 (local) were obtained from World Vegetable Center of Yaounde. The Three chemical fungicides, one systemic Bonsoin (Chlorothaloni 30 % and Cymoxanil 6 %) and two contact: Mancostar (Mancozeb 80 WP) and Plantineb (Plantneb 80 WP), were used. These fungicides were purchased from a phyto-sanitory center in the town of Bangangté.

Experimental design and treatment

Tomato seedlings of 12 to 15 cm in height, previously produced in the nursery, were transplanted inside pits 50 cm apart and containing 100 g of fowl droppings as a background fertilizer (Fondio *et al.,* 2013) and 30 g Carbofuran 5 % (nematicide) (Aghofack-Nguemezi *et al.,* 2015). These pits were made on 5 m long and 1 m wide ridges. 7 days after transplanting (DAT), Yara Mila (12-11-18) and Urea (46 % N) fertilizers were applied at the manufacturer's rate as starter fertilizer. Plant maintenance was carried out whenever necessary through weeding, hoeing and ridging. At 37 (DAT), Yara Mila (12-11-18) and potassium sulphate (50 % K20 -12 % S) were applied at a concentration of 240 Kg/ha (Fondio *et al.*, 2013; Mekonen and Tadesse, 2018). Staking of the plants was done using bamboos before fruiting i.e. 40 DAT. The insecticide Tamega was applied at 7 DAT; as well as once a week from the fruiting period until the ripening of tomato fruits at the concentration of 1 l/ha. From the 21st DAT, phyto-sanitory treatments were made every four days with the different fungicides at the manufacturer's concentration (2.5 kg/ha) to control Late Blight (Keskse *et al.*, 2019). The experiment was laid out in a randomized complete block design, split-plot arrangement with 24 treatments replicated thrice.

Data collection

Disease incidence and severity

Data on the disease incidence and severity of Late blight of tomato were collected at three stages of tomato plant development. These developmental stages were: vegetative phase (38 DAT), flowering phase (50 DAT) and fruiting phase (62 DAT). Disease incidence was recorded by counting of plants that showing visible symptoms of late blight in the central rows and the data were expressed as a percentage of the total assessed plants. The disease incidence was calculated with the following formula (Camara *et al.,* 2013):

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected tomato plants}}{\text{Total number of tomato plants examined}} \times 100$$

Disease severity was assessed on the central two rows and recorded at different stages of development. Ten plants were selected randomly from each experimental plot, and then five leaves of each plant were used to determine the disease severity. Severity of late blight was recorded on the basis of 0-5 rating scales as described by De Putter et al. (2019) where scale 0 = no symptoms, 1 = Nearly 10 % of the leaves of the whole plant are infected, 2 = Nearly 25 % of the leaves of the whole plant are infected, 3 = Nearly 50 % of the leaves of the whole plant are infected, 4 = Nearly 75 % of the leaves of the whole plant are infected and 5 = All the leaves of the plant are infected and death of the plant. severity (S) was calculated by the following formula:

$$\text{Disease severity (\%)} = \frac{\sum(Xi \times ni)}{N.Z} \times 100$$

Where:

Xi = Severity i of disease in tomato plant

ni = Number of tomato plants with severity i

N = Total number of examined tomato plant

Z = Highest score of the scale, 5

Area under disease progressive curve and disease progress curve (AUDPC)

The effect of varieties and chemical fungicides combinations on disease severity data was integrated into area under disease progress curve (AUDPC), as described by Campbell and Madden (1990).

$$\text{AUDPC} = \sum_{i=1}^{n} 0.5\,(x_{i+1} + xi)\,(t_{i+1} - t_i)$$

Where, n is the total number of assessments, 'ti' is the time of the i^{th} assessment in days from the first assessment date; '*x*i' is percentage of disease severity at i^{th} assessment. AUDPC is expressed in percent-days because the severity (x) was expressed in percent and time (t) in days. AUDPC was expressed in percent-days because the severity (x) was expressed in percent and time (t) in days. The rates of disease progress in time was determined by recording the severity of Late Blight at 4 days' interval right from the appearance of the first disease symptoms (28 DAT) till the maturity of the crop in the different treatments.

Assessment of yield

At maturity, tomato fruits were harvested from the central three rows on each plot of each treatment. Additionally, the weights of marketable yield of tomato fruits per plot were recorded. Tuber yield per plot was converted into yield of tons per hectare.

Data analysis

Data on disease parameters (disease incidence, disease severity and AUDPC) and yield component were subjected to analysis of variance (ANOVA). The means were separated through the test of Student Newman-Keuls (SNK) at a 5 %. This was done using SPSS software version 21.0.

Results

Effect of tomato varieties and chemical fungicides on Late Blight incidence

Late blight of tomato was present at all stages of development of the plant. Incidence of this disease varied according to the fungicide applied, the tomato variety used, as well as the developmental stage of the plant (table 1). At the vegetative phase (38 DAT), the lowest incidence with Bonsoin was obtained with the AVTO1219 variety (3.3 %) and the highest with the RIOGRAND+ variety (15.7 %). Statistical analyses showed that the incidence obtained with Bonsoin on the AVTO1219 (3.3 %) and AVTO1311 (7.3 %) varieties were significantly identical and lower than those obtained on the other varieties. Meanwhile Plantineb, CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties had significantly identical and higher incidences than AVTO1219 (7.3 %) and AVTO1311 (9.3 %) varieties in the Student Newman-Keuls test at 5 % probability threshold. On the other hand, within the same variety, no significant difference was observed between plants of the AVTO1219 (7.7 %) and AVTO1311 (8.7 %) varieties sprayed with the different fungicides according to Student Newman-Keuls test at 5 % probability threshold. With the RIOGRANDE+ variety, the highest incidence was observed in Plantineb (50.7 %) and the lowest in Bonsoin (15.7 %) and Mancozeb (22.3 %)

For the untreated plants, the smallest incidences were obtained with the AVTO1219 (7.7 %) and AVTO1311 (8.7 %) varieties and the highest with the CLN1462A (61.6 %) and RIOGRANDE2 (62.7 %) varieties respectively.

Table 1. Incidence of Late blight (%) on different tomato in the vegetative phase (38 DAT) with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantineb	Control
AVTO1219	$3,3 \pm 5,8^{bA}$	$1,7 \pm 2,9^{cA}$	$7,3 \pm 8,7^{bA}$	$7,7 \pm 7,6^{bA}$
AVTO1311	$7,3 \pm 6,4^{abA}$	$6,7 \pm 7,6^{bcA}$	$9,3 \pm 8,1^{bA}$	$8,7 \pm 5,5^{bA}$

CLN1462A	13,0 ± 7,0^{aC}	26,5 ± 8,5^{aBC}	38,7 ± 19,5^{aAB}	61,6 ± 10,4^{aA}
CLN1464A	17,0 ± 3,6^{aB}	22,7 ± 7,0^{abB}	31,7 ± 4,1^{aB}	56,3 ± 13,3^{aA}
CLN1464B	9,0 ± 5,2^{abC}	22,3 ± 13,8^{abBC}	32,2 ± 15,4^{aB}	54,3 ± 6,8^{aA}
RIOGRANDE+	15,7 ± 2,0^{aB}	29,4 ± 9,0^{aB}	50,7 ± 8,1^{aA}	51,0 ± 18,7^{aA}
RIOGRANDE2	12,7 ± 2,5^{abC}	23,7 ± 12,4^{abC}	45,6 ± 4,6^{aB}	62,7 ± 7,6^{aA}

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

In the flowering phase, incidence of Late blight showed significant difference between the different treatments. Two groups were observed; One group consisted of the AVTO1219 and AVTO1311 varieties, characterized by the smallest incidences. These incidences ranged from 5.3 to 14.3 %. The second group composed of the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties, characterized by larger incidences ranging from 16 to 56.8 % (Table 2). The varieties AVTO1219 and AVTO1311 showed significantly identical incidences between fungicides. These incidences varied from 5.3% to 9.0 % for the AVTO1219 variety and from 7.3 % to 14.3 % for the AVTO1311 variety. With the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties, Student Newman-Keuls test at 5 % threshold showed that these different varieties could be grouped into two. The first group made of plants sprayed with Mancozeb and Plantneb, characterized by higher incidences that varied from 40.1 to 56.8 %. The second group of plants sprayed with Bonsoin characterized by lower incidences, ranging from 16 to 22.7 %. With the control plants, all plants of CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties were affected by the disease (100 %). The varieties AVTO1219 (11.7 %) and AVTO1311 (20.3 %) showed the lowest incidence.

Table 2. Incidence of Late blight (%) on different tomato in the flowering phase (50 DAT) with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantneb	Control
AVTO1219	6,0 ± 8,7^{bA}	5,3 ± 9,5^{bA}	9,0 ± 8,5^{bA}	11,7 ± 7,6^{cA}
AVTO1311	7,3 ± 6,4^{bA}	12,7 ± 11,5^{bA}	14,3 ± 4,0^{bA}	20,3 ± 2,5^{bA}
CLN1462A	22,7 ± 8,7^{aC}	54,0 ± 18,1^{aB}	53,0 ± 15,1^{aB}	100 ± 0,0^{aA}
CLN1464A	19,3 ± 1,2^{aC}	44,7 ± 4,1^{aB}	45,9 ± 17,1^{aB}	100 ± 0,0^{aA}
CLN1464B	16,0 ± 5,3^{abC}	40,1 ± 11,5^{aB}	56,8 ± 16,7^{aB}	100 ± 0,0^{aA}
RIOGRANDE+	18,7 ± 4,0^{aC}	49,7 ± 8,1^{aB}	54,0 ± 12,1^{aB}	100 ± 0,0^{aA}

RIOGRANDE2	$20,0 \pm 5,0^{aC}$	$44,0 \pm 9,8^{aB}$	$51,3 \pm 11,8^{aB}$	$100 \pm 0,0^{aA}$

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

According to table 3, during fruiting, plants sprayed with Mancozeb showed the highest incidences with CLN1462A (70.3 %) and RIO GRANDE 2 (63.1 %) varieties and lowest incidences with AVTO1311 (12.7 %) and AVTO1219 (9.3 %) varieties Bonsoin the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties showed significantly identical and higher incidences than the AVTO1219 (6.7 %) and AVTO1311 (7.3 %) varieties. These incidences ranged from 18.5 % to 26.7 %. With Plantneb, the highest incidence was observed on the CLN1464B variety (76.7 %) followed by CLN1464A (69.3 %) and RIOGRANDE2 (65.3 %) varieties. The AVTO1219 variety showed the lowest incidence (12.7 %). Within the same variety CLN1462A, the incidences were 70.3, 57.3 and 26.7 % for Mancozeb, Plantneb and Bonsoin sprayed plants respectively. With the CLN1464B variety, the highest incidence was obtained on the Mancozeb fungicide (76.7 %) and the lowest on plants sprayed with the fungicide Bonsoin (18.7 %). The Mancozeb (12.7 %) and Plantneb (17.7 %) fungicide sprayed plants of the AVTO1311 variety showed significantly similar and higher incidences than the Bonsoin sprayed plants (7.3 %) according to the Student Newman-Keuls test at 5 % threshold. Plants of the RIOGRANDE2 variety sprayed with Bonsoin showed the lowest incidence (20 %) and the plants of the same variety sprayed with Mancozeb showed the highest incidence (63.1 %).

The plants of the varieties CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 showed significantly identical and highest incidence of 100 %. While the AVTO1219 and AVTO1311 varieties showed the lowest incidences of 16.7 % and 24.3 % respectively.

Table 3: Incidence of Late blight (%) on different tomato in fruiting phase (62 DAT). with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantneb	Control
AVTO1219	$6,7 \pm 7,6^{bA}$	$9,3 \pm 9,0^{cA}$	$12,7 \pm 11,0^{bA}$	$16,7 \pm 5,8^{cA}$
AVTO1311	$7,3 \pm 6,4^{bB}$	$12,7 \pm 11,0^{cAB}$	$17,7 \pm 2,5^{bAB}$	$24,3 \pm 5,1^{bA}$
CLN1462A	$26,7 \pm 2,9^{aD}$	$70,3 \pm 2,1^{aB}$	$57,3 \pm 11,4^{aC}$	$100 \pm 0,0^{aA}$
CLN1464A	$19,3 \pm 1,2^{aD}$	$55,0 \pm 7,9^{bC}$	$69,3 \pm 5,5^{aB}$	$100 \pm 0,0^{aA}$
CLN1464B	$18,7 \pm 1,2^{aD}$	$52,3 \pm 4,9^{bC}$	$76,7 \pm 7,6^{aB}$	$100 \pm 0,0^{aA}$
RIOGRANDE+	$18,5 \pm 4,5^{aC}$	$55,2 \pm 8,7^{bB}$	$65,3 \pm 5,7^{aB}$	$100 \pm 0,0^{aA}$

RIOGRANDE2	$20,0 \pm 5,0^{aC}$	$63,1 \pm 4,0^{abB}$	$61,7 \pm 6,4^{aB}$	$100 \pm 0,0^{aA}$

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

Effects of chemical fungicides and tomato varieties on the severity of Late Blight

Severity varied according to the fungicide applied, the tomato variety and the development stage of the plant (table 4, 5 and 6). During the vegetative phase, with plants sprayed with Plantneb, the highest severity was observed on plants of the RIOGRANDE+ variety (17 %) and the smallest on the CLN1464B variety (5.8 %) followed by the AVTO1219 (2.3 %) and AVTO1311 (1.7 %) varieties. With Bonsoin fungicide, the CLN1462A, CLN1464A, CLN1464B, RIO GRANDE + and RIO GRANDE 2 varieties showed severities between 2.4 and 5.3 %. These different severities were higher than those of the AVTO1219 (1.3 %) and AVTO1311 (1 %) varieties. Within the AVTO1219 and AVTO1311 varieties, the severities of the sprayed plants regardless of the fungicide applied were significantly identical according to Student Newman-Keuls test at 5 % probability threshold. With the CLN1462A variety, plants sprayed with Mancozeb (6.9 %) and Plantneb (7.2 %), showed similar and higher severities than plants sprayed with Bonsoin (3.9 %). Plants sprayed with Bonsoin (5.3 %), Plantneb (5.8 %) and Mancozeb (6.8 %) had the lowest severity.

With the control plants the highest severities were obtained on the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties. These severities ranged from 8.9 % to 15.8 %. The AVTO1219 variety showed the lowest severity (1.9 %) and CLN1464A variety showed the highest severity (15.8 %).

Table 4: Severity of Late blight (%) on different tomato in vegetative phase (38 DAT) with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantneb	Control
AVTO1219	$1,3 \pm 2,3^{bA}$	$1,7 \pm 2,9^{bA}$	$2,3 \pm 2,1^{cA}$	$1,7 \pm 1,5^{cA}$
AVTO1311	$1,0 \pm 1,0^{bA}$	$2,0 \pm 3,5^{bA}$	$1,7 \pm 1,5^{cA}$	$5,0 \pm 3,0^{bA}$
CLN1462A	$3,9 \pm 1,8^{abB}$	$6,9 \pm 1,5^{abA}$	$7,2 \pm 3,1^{bA}$	$8,9 \pm 2,8^{abcA}$
CLN1464A	$2,4 \pm 1,4^{abB}$	$7,3 \pm 1,5^{abB}$	$7,4 \pm 0,9^{bB}$	$15,8 \pm 5,0^{aA}$
CLN1464B	$5,3 \pm 1,6^{aB}$	$6,8 \pm 3,1^{abB}$	$5,8 \pm 0,5^{bB}$	$14,3 \pm 4,1^{aA}$
RIOGRANDE+	$3,5 \pm 0,9^{abB}$	$6,6 \pm 1,7^{abAB}$	$8,8 \pm 2,3^{bAB}$	$12,8 \pm 7,7^{abA}$
RIOGRANDE2	$2,9 \pm 1,5^{abB}$	$13,5 \pm 10,6^{aAB}$	$17,0 \pm 1,8^{aA}$	$12,9 \pm 4,9^{abAB}$

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

During flowering, Bonsoin sprayed plants showed varying degrees of severity. The highest severities were observed on the RIOGRANDE+ variety (20.4 %) followed by the varieties RIOGRANDE2 (16.8 %) and CLN1462A (14.6 %) and the lowest on the AVTO1219 and AVTO1311 varieties where each had a severity of 1.5 %. With the Mancozeb sprayed plants, the 5 % threshold Student Newman-Keuls test showed the existence of two homogeneous groups. The group composed of the AVTO1219 and AVTO1311 varieties, whose peculiarity is the presence of the smallest severities of 3.3 %. The other group is made up of the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties, characterized by the highest severities (ranging from 22.6 % to 35.8 % respectively). Within the AVTO1311 variety, the highest severity was observed in the Plantneb sprayed plants (7.8 %) and the lowest in plants sprayed with Bonsoin (1.5 %). Plants sprayed with the fungicide-Mancozeb (3.3 %) had intermediate severities.

Control plants showed higher severities than the plants sprayed with the different fungicides. The highest severities were obtained on the CLN1462A, CLN1464A, CLN1464B, RIO GRANDE + and RIO GRANDE 2 varieties. These severities ranged from 14.9 % to 69.6 %. The AVTO1219 variety showed the lowest severity (14.9 %) and Rio Grande 2 variety showed the highest severity (69.6 %).

Table 5: Severity of Late blight (%) on the different tomato in the flowering phase (50 DAT) with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantneb	Control
AVTO1219	$1,5 \pm 2,6^{cB}$	$3,3 \pm 2,9^{bB}$	$5,0 \pm 4,5^{cB}$	$14,9 \pm 3,0^{bA}$
AVTO1311	$1,5 \pm 2,6^{cC}$	$3,3 \pm 2,9^{bBC}$	$7,8 \pm 3,3^{cB}$	$15,1 \pm 2,6^{bA}$
CLN1462A	$14,6 \pm 9,7^{abB}$	$25,6 \pm 14,5^{aB}$	$24,9 \pm 10,1^{abB}$	$50,6 \pm 18,5^{aA}$
CLN1464A	$10,6 \pm 3,9^{bB}$	$22,6 \pm 12,1^{aB}$	$33,3 \pm 18,5^{abB}$	$62,3 \pm 10,5^{aA}$
CLN1464B	$11,0 \pm 1,1^{bB}$	$25,4 \pm 7,2^{aAB}$	$29,3 \pm 27,7^{abAB}$	$59,2 \pm 26,1^{aA}$
RIOGRANDE+	$20,4 \pm 4,8^{aB}$	$35,8 \pm 5,7^{aB}$	$36,4 \pm 7,2^{aB}$	$64,1 \pm 16,2^{aA}$
RIOGRANDE2	$16,8 \pm 4,6^{abB}$	$33,3 \pm 12,1^{aB}$	$34,3 \pm 21,6^{abB}$	$69,6 \pm 18,0^{aA}$

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

During fruiting, plants sprayed with Plantneb showed the highest severities on the RIOGRANDE+ (39.9 %) and CLN1462B (38.4 %) varieties while the lowest severities were

obtained with the AVTO1219 (5 %) and AVTO1311 (7.8 %) varieties. With the fungicide Mancozeb, the CLN1462A, CLN1464A, CLN1464B, RIOGRANDE+ and RIOGRANDE2 varieties had significantly similar and higher severities than the AVTO1219 (4.3 %) and AVTO1311 (3.6 %) varieties. These severities ranged from 30.1 % to 41.9 %. Within the RIOGRANDE+ and AVTO1311 varieties, the lowest severities were obtained with Bonsoin sprayed plants. These severities were 1.5 % and 23.1 % for the AVTO1311 and RIOGRANDE+ varieties respectively. For the AVTO1219, CLN1462A, CLN1464A, CLN1464B and RIOGRANDE2 varieties, the control plants showed the highest severity and the plants sprayed with the different fungicides the lowest.

The control plants showed that the ROIGRANDE+ (98.5 %) and RIO GRANDE 2 (91.5 %) varieties had the highest severities and the AVTO1219 (17.2 %) and AVTO1311 (15.1 %) varieties the lowest (Table 6).

Table 6: Severity of Late blight (%) on the different tomato in fruiting phase (62 DAT) with respect to the chemical fungicides and the tomato varieties used

Varieties	Bonsoin	Mancozeb	Plantneb	Control
AVTO1219	$1,5 \pm 2,6^{bB}$	$4,3 \pm 2,9^{bB}$	$5,0 \pm 4,5^{cB}$	$17,2 \pm 1,5^{cA}$
AVTO1311	$1,5 \pm 2,6^{bC}$	$3,6 \pm 2,9^{bBC}$	$7,8 \pm 3,3^{cB}$	$15,1 \pm 2,6^{cA}$
CLN1462A	$19,8 \pm 13,7^{aB}$	$30,7 \pm 16,7^{aB}$	$26,5 \pm 9,7^{bB}$	$85,4 \pm 9,5^{bA}$
CLN1464A	$15,9 \pm 1,5^{aB}$	$30,1 \pm 6,8^{aB}$	$35,5 \pm 17,4^{abB}$	$90,8 \pm 8^{abA}$
CLN1464B	$16,8 \pm 2^{aB}$	$38,7 \pm 12,2^{aB}$	$38,4 \pm 29,9^{aB}$	$96,8 \pm 2,8^{abA}$
RIOGRANDE+	$23,1 \pm 6,3^{aC}$	$41,9 \pm 6,6^{aB}$	$39,9 \pm 7,5^{aB}$	$98,5 \pm 2,6^{aA}$
RIOGRANDE2	$19,2 \pm 2,4^{aB}$	$36,2 \pm 10^{aB}$	$37,3 \pm 18,7^{abB}$	$91,5 \pm 11,2^{abA}$

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

Area Under Disease Progress Curve (AUDPC)

Area under disease progress curve (AUDPC) was highly affected by the tomato varieties. The severity of Late Blight was seen to increase with time. The smallest severity

was observed on the 28th DAT and the highest severity was observed on the 62nd DAT whatever the variety (Figure: 2). The AVTO1311 and AVTO1219 varieties were the most sensitive to the disease compared to other varieties, showing the smallest AUDPC whatever the number of DAT. This AUDPC at 62 DAT was 62.2 % and 68.9 % respectively for AVTO1311 and AVTO1219 varieties. The RIOGRANDE+ and CLN1464B varieties with the AUDPC of 393.8 % and 387.1 % respectively were highly sensitive to the disease.

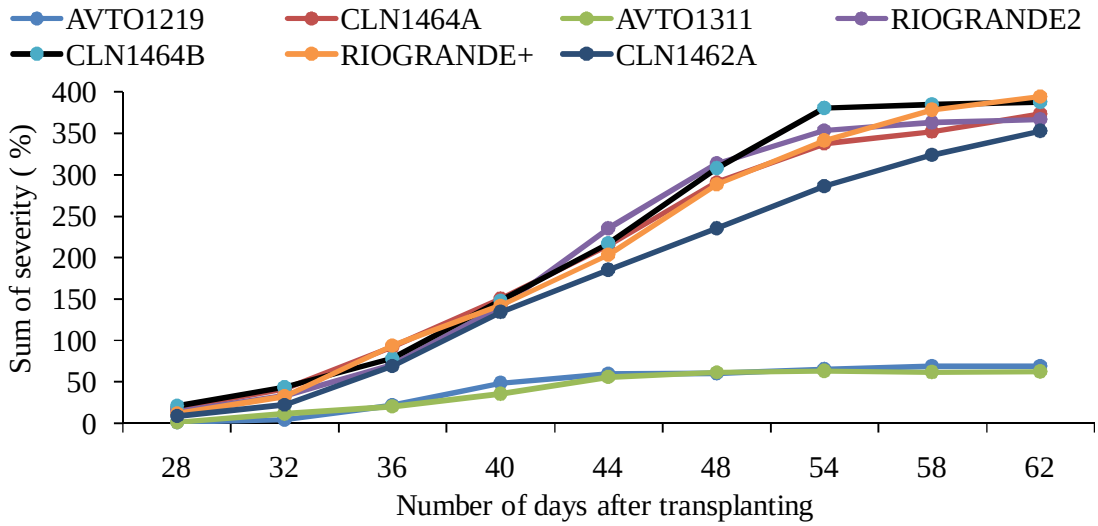

Figure 2: Area under the disease progression curve of different tomato varieties

The disease progress curves of tomato late blight (severity versus day after transplanting) for each chemical fungicide were presented separately.

Figure 3, 4 and 5 shows the sum of severity of Late Blight increases with time. The smallest severity was observed on the 28th DAT and the highest severity was observed on the 62nd DAT whatever the variety. The CLN1464B and AVTO1311 varieties were the least sensitive to the disease compared to other varieties, showing the smallest AUDPC whatever the number of DAT. This AUDPC at 62 DAT was 63.5 % and 6 % respectively for CLN1464A and AVTO1311 varieties. The RIOGRANDE + and CLN1464A varieties with the AUDPC of 92.3 % and 79.3 % respectively were highly sensitive to the disease.

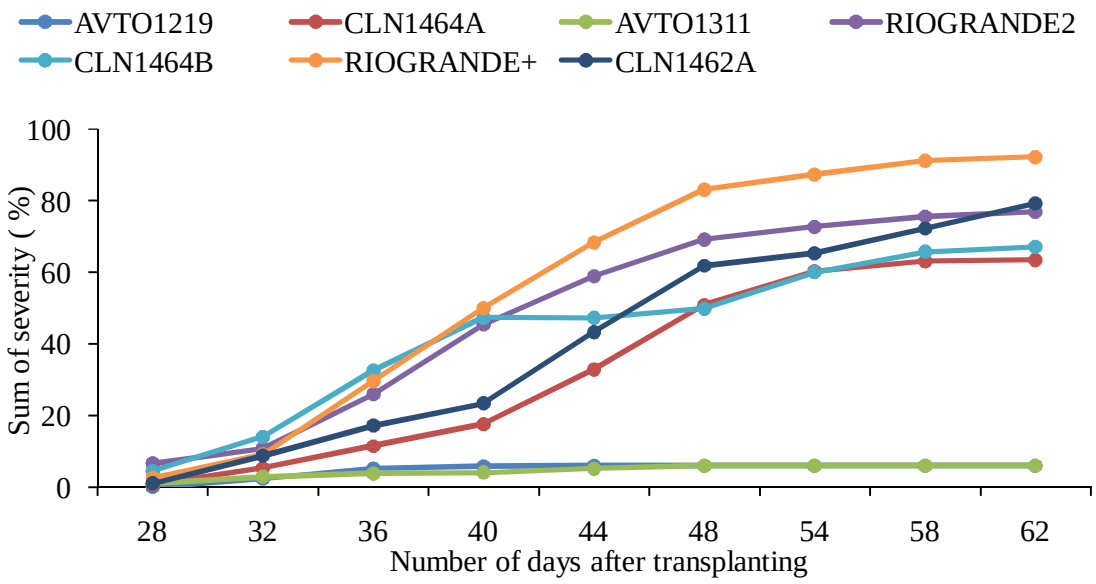

Figure 3: Area under the disease progression curve of different tomato plant treated by Bonsion

Chemical fungicide Mancozeb significantly reduced disease severity compared to the control (Figure 4). The tomato varieties AVTO1219 and AVTO1311 showed the lowest AUDPC at 62 DAT. The AUDPC was 13.1 %. Meanwhlie the RIOGRANDE+ and CLN1464A varieties with the AUDPC of 170.8 % and 160 % respectively were highly sensitive to the disease at 62 DAT.

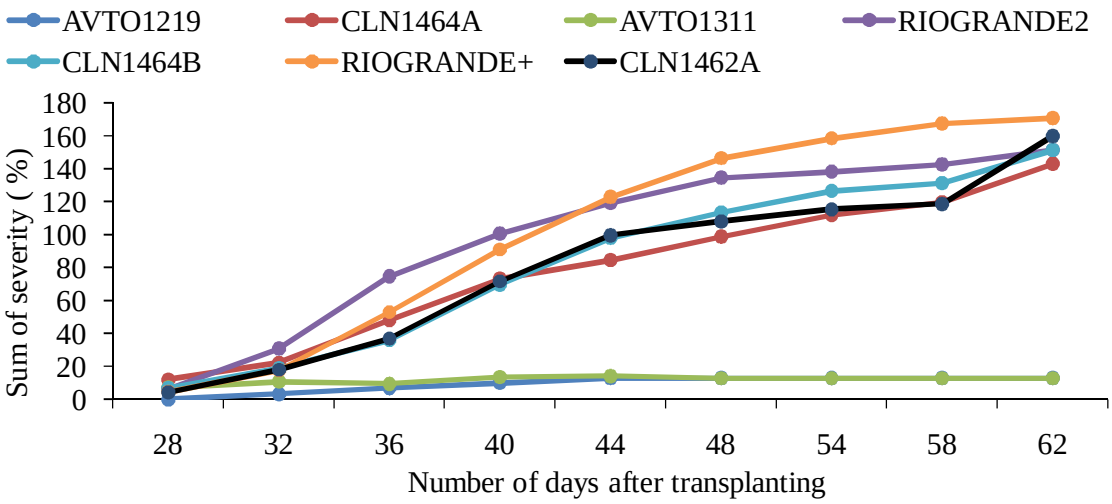

Figure 4: Area under the disease progression curve of different tomato plant treated by Mancozeb

The AUDPC of tomato plants treated with Plantineb varied according to tomato variety and DAT (Figure 5). AVTO1311and AVTO1219 varieties were the least sensitive to

the disease compared to other varieties, having the smallest AUDPC of 31.1 % and 20.1 % respectively at 62 DAT. Meanwhlie the CLN1464B and RIOGRANDE+ varieties with the AUDPC of 190.3 % and 178.8 % respectively were highly sensitive to the disease at 62 DAT.

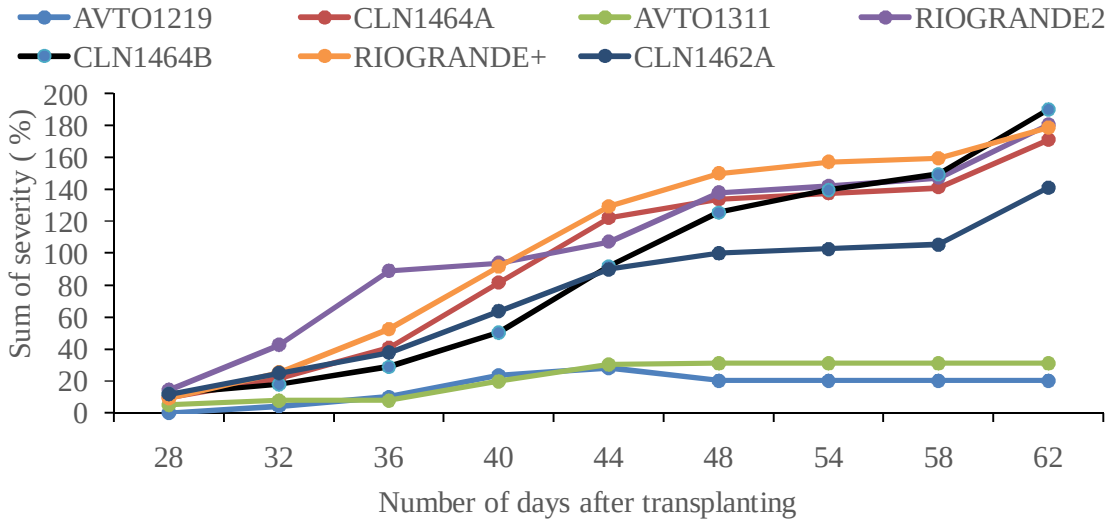

Figure 5: Area under the disease progression curve of different tomato plant treated by Plantineb

Effects of chemical fungicides and tomato varieties on the yields

All fungicides resulted in higher yields than the controls. These yields varied according to tomato variety and fungicide applied (Table 7). With the fungicides Bonsoin and Mancozeb, the varieties CLN1462A and CLN1464A showed significantly higher yields than the other varieties. These yields ranged from 46.37 tons/ha to 53.99 tons/ha. The RIOGRANDE2 variety showed the lowest yields. Yields were 35.7 and 30.56 tons/ha for Bonsoin and Mancozeb fungicides respectively. Of the plants treated with Plantineb, CLN464A showed the highest yield (45.33 tons/ha) and AVTO1311 the lowest (23.59 tons/ha).

As for the yield of the control plants, the variety AVTO1219 showed the highest yield (17.29 tons/ha), followed by AVTO1311 (11.33 tons/ha) and CLN464A (3.27 tons/ha). CLN464B and RIOGRANDE+, with yields of 1.87 and 1.83 tons/ha respectively, were the lowest yielding varieties.

Tableau 7 : Effects of tomato varieties and chemical fungicides on the yields (tons/ha)

	Treatment			
Varieties of tomato	Control	Bonsoin	Mancozeb	Plantineb
AVTO1219	17.29 ± 2.45^{aC}	40.57 ± 1.67^{bA}	37.90 ± 5.81^{bcA}	25.67 ± 3.73^{cB}

AVTO1311	11.33 ± 3.89^{bC}	35.90 ± 2.21^{cA}	39.60 ± 3.54^{bcA}	23.59 ± 1.78^{cB}
CLN1462A	2.37 ± 1.04^{cdD}	53.99 ± 0.73^{aA}	47.99 ± 2.81^{aB}	37.26 ± 0.79^{bC}
CLN1464A	3.27 ± 0.62^{cC}	50.65 ± 2.05^{aA}	46.37 ± 2.42^{aAB}	45.33 ± 1.67^{aB}
CLN1464B	1.87 ± 0.42^{dC}	35.80 ± 1.84^{cA}	38.26 ± 1.75^{cA}	29.37 ± 1.39^{cB}
RIOGRANDE+	1.83 ± 0.07^{dD}	38.96 ± 1.93^{cAB}	$41.99 \pm 0.87_{bA}$	35.76 ± 0.58^{bB}
RIOGRANDE2	2.66 ± 1.03^{cdD}	35.70 ± 3.67^{cA}	30.56 ± 2.45^{dB}	27.57 ± 1.06^{cC}

a,b,c: means assigned the same lower case letter in the same column; as well as A,B,C: means assigned the same upper case letter in the same row are not significantly different according to Student Newman-Keuls test at 5 %.

Discussion

Late blight caused by *Phytophthora infestans*, is a major constraint to tomato production. The incidence and severity of Late blight varied according to the chemical fungicide applied, the tomato variety used and the developmental phases. All fungicides have a negative effect on the development of Late blight by inducing lower incidences and severities than those observed in control plants. these results could be due to the fact that the fungicides used were contain of active substances that may have inhibited the development of *Phytophtora infestans* the causal agent of the disease. These results are similar to those of the works of Randriantsalama *et al*. (2014), who showed that some fungicides such as Mancozeb, Bonsoin, and Plantneb have an inhibitory effect on the development of *P. infestans*, causal agent of Late Blight in Solanaceae. The finding of this study is in line with work of Getachew (2017), reported that 68.85% infestation from protected plot and 90.97% infestation from unprotected plot. Similarly, Ashenafi *et al.* (2017) research result, the maximum (91.5%) disease incidence was showed from the unsprayed control of susceptible potato variety (Jalene). Of all the fungicides, Bonsoin was the most effective in the management of the disease the disease. In line with Hagos *et al.* (2020), who found that frequently applied fungicides by far reduced disease severity as compared to the less frequently sprayed fungicides and unsprayed plots of tomato. This result could be explained by the fact that not all fungicides used in this study had the same active substance and may have behaved differently towards *P. infestans*. In addition, Bonsoin could contain an active substance to which *P. infestans* would have be more sensitive to, compared to the other fungicides (Ashenafi *et al.*, 2017).

From one phase of development to another, the incidence and severity of the disease increased. Thus, the highest incidence and severity was obtained in the fruiting phase. This could be due to the contamination of new plants over time. These results corroborate those of

Keskse *et al.* (2019), who showed that as soon as blight appeared in the first tomato plants, the disease spread through contamination of the other plants. Incidence and severity of Late blight varied according to the tomato variety. Varieties AVTO1219 and AVTO1311 showed the lowest incidences and severities. While RIO GRANDE+ and RIO GRANDE 2 had the highest. These results could be related to the fact that the varieties AVTO1219 and AVTO131 are less sensitive to Late Blight, caused by *P. infestans*. Hence, the low incidences and severities observed in these two tomato varieties AVTO1219 and AVTO1311. While local variety RIO GRANDE+ were more sensitive to the disease and had the highest incidence and severity in the fruiting phase. This difference of results could be explained by the fact that the AVTO1219 and AVTO1311 varieties have a genetic material that permits them to be less sensitive to the disease. This would not be the case for the RIO GRANDE+ (local variety). Ghislain *et al.* (2018), showed that Late blight was strongly present on all the local tomato varieties they grew. This difference in results could be explained by the fact that none of the potato varieties used were less sensitive to *P. infestans*. However, some of the tomato varieties used in this study were reported to be less sensitive to *P. infestans*. According to Forbes *et al.* (2014) and Nowakowska *et al.* (2014), there are tomato varieties that are genetically resistant to *P. infestans*, causal agent of Late Blight in Solanaceae.

The result of AUDPC showed that, the chemical fungicide Bonsoin considerably reduced the AUDPC of all the varieties studied. This would be due to the dual contact and systemic action of this fungicide which would have inhibited the development of *P. infestans*. These results coroborate with those of Getachew (2017), Daniel *et al.* (2019) and Arafa, *et al.* (2022) working on tomato and potato and reported that, low AUDPC value was obtained from protected tomatoes varieties with four times sprayed Mancozed and high value from unprotected plot of tomatoes varieties.

The yields obtained with the plants treated with the different fungicides were higher than those of the control plants. This could be explained by the fact that the fungicides applied to the plants of the different tomato varieties would have significantly reduced the incidence of fungal diseases. Hence the high yields obtained. These results corroborate with de Getachew (2017) and Daniel *et al.* (2019) who reported that fungicide-treated tomato plants produced higher yields than the control plants. The varieties AVTO1219 and AVTO1113, even without receiving fungicide treatments, showed higher yields compared to the other control varieties. These results would be due to the fact that these two tomato varieties are less susceptible to Late Blight. This is because they showed the lowest prevalence's and severities, compared to the other varieties where these two parameters were high. As a result, the disease

caused less damage to them; hence the high yields they produced. The results are similar to those of Forbes *et al.* (2014) and Nowakowska *et al.* (2014), who showed that Late Blight-resistant tomato varieties produced higher yields than those not resistant to the disease.

Conclusion

This study showed that some chemical fungicides such as Bonsoin and tomato varieties AVTO1219 and AVTO1311 could be used to manage the Late Blight of tomato cause by *Phytophthora infestans.* However, RIO GRANDE 2 and RIO GRANDE+, were highly attacked by the disease. Infact when these two tomato varieties were treated with the chemical fungicide, these chemical fungicides help to reduce the incidence and severity of the Late Blight.

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