INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 5, p. 64-76, 2024

RESEARCH PAPER OPEN ACCESS

Effect of new tomato varieties and fungicides on late blight (*Phytophthora infestans*) disease severity, growth parameters and yield in western highlands of Cameroon

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Key words: Tomato varieties, Disease severity, Late blight, Fungicides, Growth, Yield

http://dx.doi.org/10.12692/ijb/25.5.64-76 Article published on November 06, 2024

Abstract

Late blight is among the major constraints that limit tomato production in most tomato growing regions. Field experiment was conducted in Western Cameroon in 2020 raining season with objectives: to investigate the effect of new varieties and fungicide spray on late blight disease development and tomato fruit yield. The treatments consisted of seven tomato varieties (AVTO1219, AVTO1311, CLN1462A, CLN1464A, CLN1464B, RIO GRANDE 2 and RIO GRANDE +) and three chemical fungicides, one with double action systemic and contact: Bonsoin (Chlorothalonil 30% and Cymoxanil 6%) and two contact: Mancostar (Mancozeb 80 WP) and Plantineb (Maneb 80 WP), was used as a foliar spray including the control. The experiment was laid out in a split plot design with three replications. Results indicated that new tomatoes varieties and fungicide spray significantly reduced late blight disease development and maximizes tomato fruit yield. AVTO1219 and AVTO1311 varieties are found better with lowest disease severity 6.6 % and 7.3 % respectively when sprayed with Chlorothalonil and Cymoxanil. The highest disease severity (95.1 %), were obtained from untreated RIO GRANDE 2 variety. The lowest total fruit yield 3.92 and 3.97 t. ha^{-1} was harvested from none sprayed RIO GRANDE + and RIO GRANDE 2 varieties respectively. Highest marketable yield (53.99 t. ha^{-1}) and highest total fruit yield (59.27 t. ha^{-1}) was obtained on CLN1462A variety treated with double action fungicide. Thus it is recommended to spraying new tomato variety CLN1462A with the fungicide Chlorothalonil and Cymoxanil in the study area to increase tomato yield. However, other management practices should be employed to this variety to confirm its less sensitive ability and to maximize its fruit yield in the presence of the disease in raining season.

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Introduction

Belongs Solanaceae family, tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown around the world and is the second next to potato (Amin *et al.,* 2013; Abdelhak *et al.,* 2016; Tabe-Ojong *et al.,* 2020). It originated from tropical Mexico to Peru (FAO, 2014). Economically, tomato is the most widely cultivated and lucrative vegetable and it is the fourth most important crop after rice, wheat, and soybean (Farheen *et al.,* 2018; Hagos 2020). It is a source of minerals, vitamins, lycopene and health benefits in reduce cancer and heart disease (MINADER, 2012; Tabe-Ojong *et al.,* 2020). It is produced both during the rainy and dry seasons under supplemental irrigation (Meseret *et al.,* 2012; Asela and Yitagesu 2023). The crop is grown between 0 and 2000 meters above sea level, with about 700 to 1400 mm annual rainfall, in different areas and seasons, in different soils, under different weather conditions Birhanu and Ketema (2010).

According to FAOSTAT (2018), 134 000 000 tons of tomato were produced worldwide in 2018, with Asia accounting for 72,224,900 tons, the Americas 24 105 791 tons, Europe 21 499 029 tons, Africa 16 039 847 tons and Oceania 4 921 264 tons. Tomato is one of the world's most widely grown vegetables and the most widely cultivated fruit vegetable in Cameroon (Tabe-Ojong *et al.,* 2020). The cultivation is mainly practiced by small-scale farmers with about 83% of the production intended for sale (MINADER, 2012; FAO, 2018) and approximately 1% exported to neighboring nations such as Equatorial Guinea, Nigeria, and Gabon (Tarla *et al.,* 2015). Tomato cultivation employs approximately 329,000 people in Cameroon and is practiced in all agro-ecological zones of the country, both in rural and urban areas and in all seasons (FAO, 2018).

Despite of its importance, its production and productivity is affected by different biotic and abiotic factors, such as pests and disease, lack of improved and adapted varieties, harsh environmental conditions, inadequate knowledge of production and management (AVRDC, 2009; Minja *et al.,* 2011; Mohammed *et al.,* 2013). Among the biotic problems, tomato late blight caused by *Phytophthora infestans* (Mont.) de Bary, is the major problem to most tomato growing areas and it is the most devastating foliar and fruit diseases in the highlands of Cameroon (AVRDC, 2009; Ojiewo and Kwazi 2011). 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% (Nowicki, 2013; Meya *et al.,* 2014) and fruit losses up to 60% (AVRDC, 2009; Maerere *et al.,* 2010).

However, growers in the study area use whatever fungicide available alone frequently up to harvesting with unknown dose, application time and application frequencies for all tomato varieties. It has reported by Maerere *et al.* (2010) that, currently farmers in Morogoro use high frequency, weekly fungicide applications or up to 12 sprays per tomato crop to control diseases. In Indonesia, shorter spray intervals of 4 days were reported to be effective in controlling late blight disease of tomato although disease incidence was reported to be still high (Fontem *et al.,* 2003). In Cameroon, it was reported that, tomato growers usually apply 2-3 fungicidal sprays per week to limit late blight infections during the wet season, when plants were most susceptible to the diseases (Fontem *et al.,* 2004). In turn, these applications increase both production cost and the potential for human health and environmental risks associated with pesticides.

Therefore, it is in the best interest of the producer and consumer to develop late blight management strategies by using less sensitive tomato varieties that reduce fungicide applications. The current research was carried out with the objective to evaluate the effect of new tomato varieties and fungicide spray on late blight disease development in rainy seasons.

Materials and methods

Description of the study area

Experiment was conducted during rainy season in the Western Cameroon, in the Ndé Division, precisely in the Bangangté Sub-division. This region is one of the main tomato production basin Aghofack-Nguemezi, 2015; Braogue, 2020) 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 14°C and 28°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).

Experimental materials

Seven tomato varieties AVTO1219, AVTO1311, CLN1462A, CLN1464A and CLN1464B (exotic) and RIO GRANDE + and RIO GRANDE 2 (local) was obtained from World Vegetable Center of Yaoundé were used as experimental test crop. The Three chemical fungicides, one with double action systemic and contact: Bonsoin (Chlorothalonil 30% and Cymoxanil 6%) and Two contacts: Mancostar (Mancozeb 80 WP) and Plantineb (Maneb 80 WP), was used as a foliar spray at the manufacturer's label dose of 2.5 kg ha^{-1}. These fungicides were purchased from a phyto-sanitory center in the town of Bangangté.

Experimental design and treatment

The standard method of seedling (Birhanu and Ketema, 2010; Jiregna *et al.,* 2014; Getechew *et al.,* 2014) was used and seedlings of 12 to 15 cm in height, previously produced in the nursery was transplanted in to the experimental field 28 DAS inside pits with a spacing of 50 cm and 50 cm between rows and plants. Each pit containing 100 g of fowl droppings as a background fertilizer (Fondio *et al.,* 2013) and 30 g Carbofuran 5% (nematicide) (Aghofack-Nguemezi, 2015). Treatments was arranged in Split plot design and replicated thrice with plot size of 50 m^2. Seven days after transplanting (DAT), recommended standard fertilizer rate of 240 kg ha^{-1} of NPK (12-11-18) and 100 kg ha^{-1} of urea (46% N) was applied in rounds of each plant as starter fertilizer. At 37 DAT, NPK (12-11-18) and potassium sulphate (50% K20 - 12% S) were applied at a concentration of 240 kg ha-1 (Fondio *et al.,* 2013; Mekonen and Tadesse, 2018). Staking of the plants was done at 40 DAT using bamboos before fruiting.

Plant maintenance was carried out whenever necessary through weeding, hoeing and ridging.

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. Fungicide application was started 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^{-1}) to control Late Blight (Keskse *et al.,* 2019). The experiment relied entirely on natural infection because the site was hot spot area for late blight disease during the rainy season. All agronomic practices such as weeding, cultivation were kept uniform for all treatments in each plot.

Data collection

Disease severity

Disease severity was assessed on the central two rows. Ten plants were selected randomly from each experimental plot, and then 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.

Disease severity (DS) was calculated by the following formula: 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 plants scored

Z = Highest disease score on scale, 5

Determination of plant growth and development parameters

Plant height and diameter was assessed at the 9th week after seedling transplantation. The measurement of the height was done from the base to the terminal bud of ten plants selected randomly with a graduated ruler. The plant diameter was determined on the same plants using a Vernier caliper. The number of grapes and the number of flowers per plant was determined from ten plants selected randomly at flowering phase. Days to 50% flowering was recorded as the number of days from transplanting until 50% of plants have at least one open flower. The number of fruits per plant was counted and recorded in the middle plants of each plots at fruiting stage. The weight of fruits was measured from ten marketable fruits selected randomly after each harvest with an electronic balance. Marketable and Total fruit yield (t/ha) was measured at each harvesting and converted in to hectare.

Statistical analysis

Data on late blight disease severity and various agronomic data collected were subjected to analysis of variance (ANOVA) using Gen Stat-16 statistical software programs and the Fisher's protected Least Significant Difference (LSD) was used to separate means at 5% probability level when the ANOVA test showed significant probability ($p < 0.05$) of difference between means. Pearson correlation coefficient analysis was performed between disease development and yield parameters in order to evaluate the influence of the disease on tomato yield and related parameters of the crop.

Results

Disease development: Late blight disease severity

Table 1 shows the mean values of final disease severity (in %) according to the sprayed fungicide and the tomato variety. The interaction effect of tomato varieties and sprayed fungicide showed highly significant ($p < 0.001$) difference on the percent disease severity. Plants sprayed with fungicides showed the lowest severity with all varieties while the highest severity was obtained with control plants. AVTO1219 and AVTO1311 varieties showed the lowest severity whatever the treatment. With the fungicide Chlorothalonil + Cymoxanil, the CLN1462A (15.9 %), CLN1464A (14.0 %), CLN1464B (15.1 %), RIO GRANDE + (21.0 %) and RIO GRANDE 2 (19.3 %) varieties had significantly similar and higher severities than the AVTO1219 (6.6 %) and AVTO1311 (7.3 %) varieties. These severities ranged from 6.6 % to 21.0 %. The control plants showed that the ROI GRANDE + (94.5%), RIO GRANDE 2 (95.1%), CLN1464A (88.7 %) and CLN1464B (87.6 %) varieties had the highest severities and the AVTO1219 (14.1 %) and AVTO1311 (12.9 %) varieties the lowest.

Table 1. Effect of tomato varieties and treatments on disease severity of late blight of tomato under natural condition during rainy season

Varieties	Treatments			
	Chlorothalonil + Cymoxanil	Mancozeb	Maneb	Control
AVTO1219	6.6±2.9^{l}	10.4±2.6^{kl}	11.17±4.4^{jkl}	14.1±1.7^{ijkl}
AVTO1311	7.3±1.1^{l}	9.6±3.9^{kl}	9.4±3.7^{kl}	12.9±1.4^{ijkl}
CLN1462A	15.9±3.9^{hijkl}	25.4±4.9^{efgh}	22.4±3.2^{efghi}	75.9±5.1^{b}
CLN1464A	14.0±1.2^{ijkl}	29.4±1.9^{defg}	31.9±4.7^{cde}	88.9±2.2^{a}
CLN1464B	15.1±1.1^{ijkl}	29.5±3.6^{defg}	29.8±8.6^{cdef}	87.6±4.5^{a}
RIO GRANDE 2	19.3±0.7^{ghijk}	32.6±3.3^{cd}	33.5±5.3^{cd}	95.1±3.3^{a}
RIO GRANDE +	21.0±1.9^{fghij}	36.9±2.9^{c}	36.0±2.9^{c}	94.5±2.8^{a}

Mean values of disease severity in varieties within treatments, followed by different letters are significantly different

Tomato plant growth parameters

The analysis of variance showed that, the plant heights and stem diameters of the tomato plant were significantly influenced by variety and fungicides applied (Table 2). Plants sprayed with fungicides showed the highest plant height with all varieties while the lowest plant height was obtained with control plants. The control plants showed that the ROI GRANDE + (41.94 cm), RIO GRANDE 2 (40.98 cm), CLN1464A (43.51), CLN1462A (45.39 cm) and CLN1464B (48.73 cm) varieties had the lowest plant height and the AVTO1219 (61.88 cm) and AVTO1311 (73.40 cm) varieties the higher. AVTO1219 and AVTO1311 varieties showed the highest plants without the treatment. With the fungicide Chlorothalonil + Cymoxanil, plant height ranged from 90.68 cm to 99.75 cm the CLN1462A (99.32 cm) varieties had higher plant height than the AVTO1219 (90.75 cm) and RIO GRANDE + (90.68 cm) varieties. With the fungicide Mancozeb, plant height ranged from 86.23 cm to 101.74 cm, the CLN1464B (101.74 cm) varieties had highest plant height than the AVTO1219 (86.23 cm) and AVTO1311 (89.31 cm) varieties. Diameters of plants treated by Chlorothalonil + Cymoxanil, Mancozeb and Maneb were higher than unsprayed plants. No difference could be observed between the plant diameter of CLN1464B treated with Mancostar and Maneb. All plants that received Chlorothalonil + Cymoxanil had higher diameters than plants treated by Mancostar, Maneb and control plants. Diameter of control plants was smaller and similar to that of Maneb plants except CLN1464A, CLN1464B and CLN1462A varieties. The smaller plant diameter was obtaining which RIO GRANDE 2 in control (Table 2).

Table 2. Growth parameters of tomato plants as related to the variety and fungicides applied

Treatments	Varieties	Growth parameters	
		Plant height	Stem diameter
Chlorothalonil + Cymoxanil	AVTO1219	90,75±2,24^{cdef}	0,79±0,06^{defg}
	AVTO1311	95,1±4,44^{abcd}	0,79±0,03^{efg}
	CLN1462A	99,32±2,14^{abcd}	1,12±0,12^{ab}
	CLN1464A	98,63±3,43^{abcd}	1,28±0,1^{a}
	CLN1464B	97,09±3,11^{abcd}	0,99±0,07^{bc}
	RIO GRANDE 2	92,8±2,88^{bcde}	0,8±0,08^{defg}
	RIOGRANDE+	90,68±2,5^{defg}	0,74±0,03^{fg}
Mancozeb	AVTO1219	86,23±2,45gh	0,67±0,05^{ghi}
	AVTO1311	89,31±4,43fgh	0,73±0,03^{fgh}
	CLN1462A	99,77±1,55ab	0,97±0,07^{bcd}
	CLN1464A	99,35±2,99abc	1,11±0,12^{ab}
	CLN1464B	101,74±5,33a	1,03±0,11^{bc}
	RIO GRANDE 2	90,03±3,21efg	0,73±0,08^{fg}
	RIOGRANDE+	92,86±2,76bcde	0,75±0,02^{fg}
Maneb	AVTO1219	76,23±4,75^{i}	0,67±0,03^{ghi}
	AVTO1311	81,23±2,81^{hi}	0,75±0,05^{fg}
	CLN1462A	93,11±2,4^{bcde}	0,97±0,1^{bcde}
	CLN1464A	95,55±4,44^{bcdef}	0,88±0,07^{cdef}
	CLN1464B	94,35±2,3^{bcdef}	1,03±0,06^{bc}
	RIO GRANDE 2	86,28±3,79^{gh}	0,75±0,04^{fg}
	RIOGRANDE+	90,08±2,17^{efg}	0,74±0,05^{fg}
Control	AVTO1219	61,88±3,74^{j}	0,67±0,4^{ghi}
	AVTO1311	73,4±1,25^{i}	0,65±0,04^{ghi}
	CLN1462A	45,39±1,14^{k}	0,65±0,03^{ghi}
	CLN1464A	43,51±2,29^{k}	0,54±0,04^{hi}
	CLN1464B	48,73±2,82^{k}	0,67±0,03^{ghi}
	RIO GRANDE 2	41,94±1,62^{k}	0,53±0,04^{i}
	RIO GRANDE +	40,98±2,18^{k}	0,55±0,02^{hi}

Mean values of growth parameters in column followed by different letters are significantly different.

Tomato plant development parameters

Table 3 shows variations of tomato plant development parameters of different treatments. There was no difference between the number of clusters produced by sprayed plants and control plants. However, highest number of clusters produced per plant was found from sprayed plants and the lowest from control plants. High differences ($p \leq 0.005$) were observed between the number of flower in control plants and the number of flower in plants that received treatments. Chlorothalonil + Cymoxanil, Mancozeb and Maneb plants having had higher number of flower than control plants. Unit fruit weight were highly ($p \le 0.005$) affected by main effect of variety and fungicide in the field. Whatever the treatment applied, the highest fruit weight per plant were found from AVTO1311 variety and lowest in RIO GRANDE 2 variety.

Main treatment effect (varieties and spray fungicide) exhibited no significant difference among varieties and fungicide spray with regard to days to 50% flowering. AVTO1311, CLN1462A and CLN1464B varieties took extended time (40 DAT) to reach 50% flowering, whereas, RIO GRNADE + and RIO GRANDE 2 varieties attained early (37 DAT) (Table 3).

Table 3. Development parameters of tomato plants as related to the variety and fungicides applied

Treatments	Varieties	Development parameters				
		Cluster	Number of flower per plant	Days to 50% flowering	Unit fruit weight	Number of fruit per plant
Chlorothalonil + Cymoxanil	AVTO1219	7,24±0,52^{a}	51,92±2,27^{ab}	39±0,52^{a}	66,98±4,11^{ghi}	39,67±1,09^{cd}
	AVTO1311	6,56±0,35^{a}	35,57±2,24^{defgh}	39,5±0,92^{a}	98,19±3,87^{abc}	39,83±0,91^{cd}
	CLN1462A	7,18±0,51^{a}	56,31±2,31^{a}	38,33±1,15^{a}	86,9±4,3^{cde}	38,5±0,72^{cde}
	CLN1464A	7,26±0,88^{a}	56,96±5,75^{a}	39,33±1,09^{a}	82,36±3,95^{de}	41,17±0,6^{ab}
	CLN1464B	7,79±0,16^{a}	47,55±1,24^{bc}	39,5±0,56^{a}	86,5±4,57^{cde}	38,83±0,48^{cde}
	RIO GRANDE 2	7,7±0,7^{a}	34,92±4,17^{fgh}	40,17±0,65^{a}	55,31±2,21^{ijk}	37,83±0,75^{de}
	RIOGRANDE+	8,43±0,77^{a}	43,51±4,92^{c}	38,67±1,12^{a}	65,95±2,56^{ghij}	39,17±1,11^{cd}
Mancozeb	AVTO1219	7,19±0,52^{a}	41,88±2,15^{cdefg}	39±0,86^{a}	65,48±5,14^{ghij}	37,33±1,08^{defgh}
	AVTO1311	7,38±0,46^{a}	35,33±2,04^{efgh}	40±0,73^{a}	103,57±2,12^{a}	36,43±1,44^{fgh}
	CLN1462A	7,98±0,53^{a}	44,71±1,88^{bc}	40±0,89^{a}	87,04±4,73^{cde}	42,52±1,51^{a}
	CLN1464A	6,85±0,33^{a}	41,78±2,09^{cdefg}	38,33±0,76^{a}	92,31±5,44^{abcd}	41,69±0,94^{ab}
	CLN1464B	7,23±0,14^{a}	43,01±0,83^{cde}	39,33±0,76^{a}	88,84±6,21^{bcde}	40,56±1,24^{bcd}
	RIO GRANDE 2	6,69±0,46^{a}	30,32±3,12^{h}	38,5±0,85^{a}	54,49±3,33^{ijk}	35,79±2,59^{fgh}
	RIOGRANDE+	8,27±0,4^{a}	41,97±1,07^{cdefg}	39,17±0,17^{a}	63,65±4,77^{hij}	38,28±0,6^{cdefg}
Maneb	AVTO1219	6,67±0,43^{a}	34,78±2,4^{gh}	39,17±0,31^{a}	65,58±4,1^{hij}	33,23±2,28^{h}
	AVTO1311	6,37±0,31^{a}	35,39±1,58^{efgh}	40,17±0,48^{a}	103,59±1,68^{a}	33,19±1,3^{h}
	CLN1462A	6,56±0,38^{a}	42,54±1,88^{cdef}	38,5±0,43^{a}	85,4±1,92^{de}	36,72±2,2^{fgh}
	CLN1464A	7,29±0,41^{a}	46,34±0,88^{bc}	37,67±0,8^{a}	90,33±3,29^{bcde}	39,43±1,05^{cdefg}
	CLN1464B	7,05±0,33^{a}	46,3±1,89^{bc}	38,67±0,84^{a}	83,43±3,87^{de}	38,58±1,35^{cdefg}
	RIO GRANDE 2	6,43±0,36^{a}	35,24±4,59^{fgh}	39±0,52^{a}	54,04±2,69^{jk}	35,39±1,97^{gh}
	RIOGRANDE+	7,71±0,58^{a}	43,23±2,69^{cd}	37,33±1,05^{a}	64,2±4,55^{hij}	37,09±1,78^{efgh}
Control	AVTO1219	3,59±0,17^{a}	16,68±0,99^{j}	39,67±1,09^{a}	68,12±2,97^{fgh}	15,63±1,26^{i}
	AVTO1311	3,97±0,55^{a}	18,56±3,23^{j}	39,83±0,91^{a}	100,11±2,81^{ab}	11,68±1,51^{ij}
	CLN1462A	3,51±0,14^{a}	22,31±1,19^{ij}	38,5±0,72^{a}	78,89±5,36^{ef}	10,93±0,75^{ijk}
	CLN1464A	3,39±0,32^{a}	21,78±2,52^{ij}	41,17±0,6^{a}	83,42±4,09^{de}	12,27±1,43^{ij}
	CLN1464B	4,99±0,4^{a}	28±1,81^{hi}	38,83±0,48^{a}	77,65±5,44^{efg}	10,17±1^{jk}
	RIO GRANDE 2	5,27±1,11^{a}	21,1±4,44^{ij}	37,83±0,75^{a}	36,65±5,17^{l}	6,22±0,91^{k}
	RIOGRANDE+	4,03±0,66^{a}	20,17±3,3^{j}	39,17±1,11^{a}	51,36±5,76^{k}	9,09±0,78^{jk}

Mean values of development parameters in column followed by different letters are significantly different.

Number of fruit per plant were significantly ($p \le 0.001$) affected by main effect of variety and fungicide sprayed. However, fruit number per plant significant ($p \le 0.05$) influenced by interaction effect main treatments. Concerning control, the highest number of fruit per plant were found from AVTO1219 (15,63) variety and lowest in RIO GRANDE 2 (6,22) variety. Concerning spray plants, the lowest and highest numbers of fruit per plant were obtained from Maneb plots and Mancozeb and chlorothalonil + cymoxanil plots, respectively (Table 3).

Yield and components

However, the interaction effect treatments revealed significant ($p < 0.05$) difference on marketable and total fruit yields (Table 4). The lowest marketable and total fruit yield was recorded on unsprayed RIO GRANDDE + whereas, highest from CLN1462A variety treated with double action systemic and contact fungicide (Chlorothalonil + cymoxanil).

Table 4. Effect of varieties and fungicide spray on tomato yield parameters

Treatments	Varieties	Yield	
		Total fruit yield	Marketable fruit yield
Chlorothalonil + Cymoxanil	AVTO1219	41,91^{ef}	40,57^{ef}
	AVTO1311	39,56^{fg}	35,9^{fg}
	CLN1462A	59,2^{a}	53,99^{a}
	CLN1464A	52,8^{b}	50,65^{ab}
	CLN1464B	41,4^{fg}	35,8^{fg}
	RIO GRANDE 2	36,06^{h}	35,7^{fg}
	RIO GRANDE +	35,59^{h}	34,96^{fg}
Mancozeb	AVTO1219	40,87^{fg}	37,9^{f}
	AVTO1311	40,6^{fg}	39,6^{ef}
	CLN1462A	49,64^{bc}	47,99^{bc}
	CLN1464A	44,5^{de}	43,37^{de}
	CLN1464B	45,47^{cd}	38,26^{ef}
	RIO GRANDE 2	31,21^{hi}	30,56^{g}
	RIO GRANDE +	36,46^{h}	35,99^{fg}
Maneb	AVTO1219	36,58^{h}	25,67^{hi}
	AVTO1311	31,64^{i}	23,59^{i}
	CLN1462A	43,35^{de}	37,26^{f}
	CLN1464A	46,63^{cd}	45,33^{cd}
	CLN1464B	39,15^{gh}	29,37^{gh}
	RIO GRANDE 2	27,78^{i}	27,57^{gh}
	RIO GRANDE +	36,52^{hi}	35,76^{fg}
Control	AVTO1219	18,97^{j}	17,29^{j}
	AVTO1311	15,2^{j}	11,33^{j}
	CLN1462A	6,11^{k}	2,37^{k}
	CLN1464A	6,5^{k}	3,27^{k}
	CLN1464B	6,11^{k}	1,87^{k}
	RIO GRANDE 2	3,97^{k}	2,66^{k}
	RIO GRANDE +	3,92^{k}	1,83^{k}

Mean values of yield parameters in column followed by different letters are significantly different.

Table 5. Correlation analysis of late blight disease and fruit yield of tomato under raining season

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Total fruit yield (1)										
Marketable fruit yield (2)	0,99	*								
Disease severity (3)	-0,71	-0,70	*							
Plant height (4)	0,58	0,55	-0,38	*						
Stem diameters (5)	0,79	0,81	-0,42	0,57	*					
Number of cluster (6)	0,91	0,92	-0,70	0,49	0,83	*				
Number of flower (7)	0,66	0,68	-0,42	0,43	0,79	0,75	*			
Days to 50% flowering (8)	0,62	0,62	-0,56	0,35	0,46	0,57	0,39	*		
Number of fruits per plant (9)	0,85	0,84	-0,72	0,55	0,66	0,86	0,68	0,51	*	
Unit weight (10)	0,15	0,14	-0,12	0,24	0,15	0,26	0,33	0,15	0,34	*

Correlation between late blight disease and yield parameters

The association between disease and yield parameters was examined using simple correlation analysis (Table 5). Determined Pearson correlation coefficients were used as indices for strength of the association. Tomato fruit yield (Total and marketable), plant height, stem diameter, number of fruit, number of flowers, number of clusters and unit weight were found strong and negatively correlated with disease severity of late blight. Likewise, total and marketable fruit yields were positively correlated with all growth and development parameters of tomato.

Discussion

The field experiment results indicated that varieties AVTO1219 and AVTO1311 was not highly affected by tomato late blight compared to RIO GRANDE 2 and RIO GRANDE + varieties. Late blight caused by *Phytophthora infestans*, is a major constraint to tomato production. The severity of Late blight varied according to the chemical fungicide applied and tomato varieties. All fungicide spray gave appreciable reduction of disease severity when compared to control. The varieties AVTO1219 and AVTO1311 reduced disease severity in control plot. These results could be due to the fact that the fungicides used were contain of active substances and varieties used have technological components in new tomato production package 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) and Keskse *et al.* (2019), who showed that some fungicides such as Metalaxy, Mancozeb, chlorotholomil + cympoxanil, and Manneb have an inhibitory effect on the development of *P. infestans* in Solanaceae crops. 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 severity was showed from the unsprayed control of susceptible potato variety. Of all the fungicides, Chlorothalonil + Cymoxanil 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, Chlorothalonil + Cymoxanil could contain an active substance to which *P. infestans* would have be more sensitive to, compared to the other fungicides Ashenafi *et al.* (2017). The highest 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. Severity of late blight varied according to the tomato variety. Varieties AVTO1219 and AVTO1311 showed the lowest 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 severities observed in these two tomato varieties AVTO1219 and AVTO1311. While variety RIO GRANDE + were more sensitive to the disease and had the highest severity. 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 tomato 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 number of fruit cluster per plant is range between 6 and 8 in sprayed plot. This result is in line which the finding of many authors (Abrar *et al.,* 2011 and Turhan *et al.,* 2011) who reported that the mean number fruit cluster per plant is range between 4 and 16. The highest fruit numbers per plant of sprayed plot were recorded from Mancozeb plots of CLN1462A and CLN1464A. Similarly, the least fruit number per plant was found from control plots of RIO GRANDE 2 variety. This result is in line with the finding of Shushay *et al.* (2014) who reported that some varieties of tomato showed higher fruit number and fruit cluster per plant in spray plot. The mean number of fruits per plant could vary between 6.22 and 42.52 as reported by Eshteshabul *et al.* (2010). The present study was agreed with results of Chernet *et al.* (2013) and Emami *et al.* (2013) who reported wide range of differences such as (4-97) and (33-79) in number of fruits per plant among the tested tomato varieties respectively. Main treatment effect (varieties and fungicides) exhibited no significant difference among varieties and fungicide spray with regard to days to 50% flowering.

CLN1464A variety took extended time to reach 50% flowering, whereas, RIO GRANDE 2 variety attained early in control plot. The result is in line with Fekede (2011); Desta and Yesuf (2015) who reported variations in days to flowering among tomato varieties.

The negative correlation between the disease severity and yield (the marketable fruit yield and the total fruit yield) of tomatoes varieties indicates that the percentage of disease severity was low in tomatoes varieties which produced more fruit. Marketable fruit yield in control plot was higher in AVTO1219 and AVTO1311 and increased with fungicides. Marketable fruit yield in spray plots was higher in CLN1462A and CLN1464A spray with Chlorothalonil and Cymoxanil and decreased with other fungicides. In general, higher total fruit yield is influenced by a combined varieties and fungicide effect and many other growth and yield attributes (Mononon *et al.,* 2018; Hagos *et al.,* 2020). Higher marketable fruit yield found in high CLN1462A may be due to combination of new tomato variety and double action (contact and systemic) of Chlorothalonil and Cymoxanil. It has been reported that potato and tomato production is better in high elevation environments where optimum conditions such as low temperature can be achieved (Derbew *et al.,* 2012; Ashenafi *et al.,* 2017). According to Getachew *et al.* (2018), Keskse *et al.* (2019), late blight is the most important disease affecting potato and tomato growth and yield. Higher disease severity may inhibit yield by reducing growth and development parameters during vegetative phase. This result is in agreement with Hagos *et al.* (2020), who stated fungicide applications reduces disease severity, at the same time maximizes tomato fruit yields. Studies reported that fungicides significantly reduced disease severity and gave increased yield over the control (Binyam, 2014). Many tomato researchers (Meseret, 2012) ranged total fruit yield between 6.46 and 82.50 t ha^{-1}.

Conclusion

Tomato Late blight (*Phytophthora infestans*) is one of the limiting biological factors for its production in humid areas in the world and in Cameroun. Integrated management of late blight disease with new tomato varieties and fungicide (Chlorothalonil and Cymoxanil, Mancozeb and Maneb) spray seems to have affected the disease development and maximizes fruit yield of tomato. The result of the study shows that, even under the pressing problem of the disease in the rainy season, a less sensitive tomato variety like AVTO1219, AVTO1311 and CLN1462A combined with fungicide Chlorothalonil and Cymoxanil spray and RIO GRANDE 2 and RIO GRANDE + tomato varieties sprayed with Chlorothalonil and Cymoxanil significantly manage late blight disease and gave the highest yield as compared to the other treatments and the control. In general, during heavy rainy seasons, it is difficult to manage the disease completely, but it could be suppressed through integration of new tomato varieties with foliar fungicide applications. The overall study result showed that production of tomato even in main cropping season under high disease severity is possible if growers integrate new tomato varieties with application of recommended fungicides. AVTO1219, AVTO1311 and CLN1462A varieties appeared relatively less sensitive to late blight with Chlorothalonil and Cymoxanil application and is the promising varieties as it managed the disease, gave maximum total yield and marketable yield than the remaining combinations. Therefore, all tomato growers such as farmers, private investors and state enterprises must adopt new tomato varieties to restrict the development of late blight and for sustainable tomato production in the study area and in similar agro-ecologies. However, further in-depth studies are needed to arrive at the possibility of producing rainy-season tomatoes without fungicide sprays in the face of the disease challenge.

Acknowledgements

The authors would like to thank the World Vegetable Center, Yaoundé for providing us the tomato seed varieties needed for this work. The staff of the Research Unit and Applied Botany of the University of Dschang for their accompaniment in the realization of this work.

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