Response of native roselle varieties (*Hibiscus sabdariffa* L.) to infection by *Phytophthora parasitica* Dastur in Mexico

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**ABSTRACT**

Diseases that affect roselle (*Hibiscus sabdariffa* L.) reduce significantly its yield. In order to evaluate the resistance of roselle to *Phytophthora parasitica* Dastur, a set of 51 landraces were studied. The evaluation was carried out under both field conditions under high natural incidence of the pathogen and greenhouse conditions artificially inoculated at seedling stage. In both conditions, incidence of *P. parasitica* was evaluated. Measurements of the disease severity were recorded, while the area under the curve that describes the disease progression was calculated. Additionally, the severity distribution was recorded and the index of damage calculated. In field conditions, Criolla Super Precoz was the most resistant with the lowest sensitivity index and severity value, while in the greenhouse, UAN 8 and UAN 25 were the most resistant with lowest area under disease progress curve (AUDPC), damage and a severity distribution with 97% of plants in level 1 (healthy plant, no damage).

**Keywords:** Genetic resistance, susceptibility, incidence, severity.

**INTRODUCTION**

Roselle (*Hibiscus sabdariffa*) is an annual shrub and self-pollinated plant (Vaidya, 2000). According to Murdock (1959), it is a native from East Africa, which came to the American Continent during the slave trade. Roselle is a crop of economic and commercial importance and source of income for small farmers, normally planted in intercrop (El-Naim and Ahemd, 2010). The dehydrated sepal is used in production of drinks, jellies, wine and marmalades due to its high content of anthocyanin and organic acids (Abou El-Nasr et al., 2014). The main producing countries are China, India, Sudan, Uganda, Indonesia, Malaysia and Mexico (Correa et al., 2011). In the latter, the main producing states are Guerrero (Gro.), Oaxaca (Oax.), Michoacan (Mich.), Puebla (Pue.) and Nayarit (Nay.) with 98% of the national production of the country. In Mexico, this crop was planted in 19, 315 ha producing a total of 6,726 t. Guerrero is the main producing state planting an area of 14, 274 ha with an average yield of 320 kg ha and a total production of 4,634 t, followed by the states of Oaxaca, Michoacan, Puebla and Nayarit with productions ranging from 756, 800, 216 and 181 t, respectively (SIAP-SAGARPA, 2014).

The main problems limiting production and expansion of the roselle crop are the rain patterns, very limited crop practices and problems at harvest time (El-Awad, 2001). In addition to these problems, there are other biotic factors, including diseases, among which the most important are foliar diseases, caused by *Corynespora cassicola*, *Cercospora hibisci*, *Rhizoctonia solani* and root rots by *Phytophthora parasitica* and *Fusarium oxysporum* (Amusa et al., 2005; Ortega-Acosta et al., 2015). In Mexico, reports indicating up to 50% losses in production are due to the
disease known by farmers as “black foot”, caused by *P. parasitica* in adult plants of local cultivars in the states of Guerrero, Tabasco, Michoacan, Oaxaca and Colima (Hernández and Romero, 1990; Hernández-Morales et al., 2009). Typical symptoms of the disease in adult plants are yellowing, necrosis at the basis of the stem, foliar wilt and death (Escalante et al., 2001).

To control the disease, several chemical control methods were implemented, but they have not been adopted due to the high cost involved and residues left on the calices (Tripathi and Dubey, 2004). In some genetic improvement programs, genetically resistant genotypes to the disease were selected and used as commercial varieties or resistant progenitors to transfer genes for resistance to commercially susceptible genotypes (Anaya-López et al., 2011) and to decrease yield losses and costs of production.

Several studies related to yield, anthocyanin content, earliness, size of calices, etc have been published (Ruelas-Hernández et al., 2008; Ibrahim et al., 2013); however, not much has been done in relation to genetic resistance to diseases. Genetic resistance to *P. parasitica* is a viable alternative of control due to the diversity of available genotypes (Torres-Morán et al., 2011). In Ivory Coast, Bocca and Pellegrin (1976) evaluated six roselle varieties and pointed out the usefulness of the infection rate in the selection of resistant genotypes concluding a response of horizontal resistance with polygenic action. In Mexico, there is no research related to resistance to *P. parasitica* in roselle varieties.

The objective of this research was to evaluate the level of resistance to *P. parasitica* in roselle varieties from the states of Guerrero, Nayarit, Puebla and Colima.

**MATERIALS AND METHODS**

**Plant material**

A total of 51 native roselle varieties from the states of Nayarit, Guerrero, Colima, and Puebla were evaluated for their resistance to *P. parasitica*. These were selected for yield, earliness, anthocyanin content and acidity in the calices (Table 1). Seed of these varieties were donated by the “Unidad Académica de Agricultura” from the Autonomous University of Nayarit.

**Evaluation of resistance in field conditions**

In the cropping cycle of spring-winter 2012 the 51 varieties were planted in Tecoanapa, Guerrero (16°59′15″N, 99°15′33″W, altitude 437 m), under rainy conditions, using a completely randomized experimental design with two replications with 18 plants in each experimental unit. When plants were at flowering stage, the first data on disease incidence and severity were collected and a second data collected when plants were at the end of the flowering stage. Measurements were recorded using an arbitrary scale with five levels: 1) healthy plant; 2) necrosis <10 cm at the basis of the stem; 3) necrosis of 10 to 20 cm in main stem and branches, leaf chlorosis and leaf-wilting; 4) defoliated plant, and necrosis >20 cm and 5) dead plants.

With the data of the second evaluation of severity, the damage index (DI), which describes the sanity of plants according to the weighted mean of each variety was calculated using the scale 1 to 5, where 1 corresponded to healthy plant and 5 to dead plant. DI was calculated as the weighted mean of the number of plants in each infection level divided by the total of plants (36 plants) as follows:

\[
DI = \frac{\sum(n \times b)}{N}
\]

Where: DI = Damage index; n= Plants in each severity level; b= Severity level and N= Total plants evaluated.

**Evaluation of resistance in greenhouse conditions**

Genetic resistance to *P. parasitica* was evaluated in seedling stage in the Plant Pathology greenhouse at the Colegio de Postgraduados, Montecillo, Mex. (19°34′46″N, 98°42′29″W) in 2013. Seeds were planted in previously steam sterilized soil. Pots utilized had a capacity of approximately 250 ml, where one seed per pot and 30 plants per variety were planted.

Inoculum of *P. parasitica* was obtained from stems of plants with symptoms of the disease in Tecoanapa, Guerrero. These were taken to the laboratory, cut in pieces of 1 cm and disinfected by immersion in a 1.5% sodium hypochlorite solution for 3 min, followed by 2 rinses of sterile double distilled water, placed in Petri dishes with potato-dextrose-agar (PDA) medium and incubated for one week at 26°C. The isolates were purified following the hypha tips technique. Six isolates identified morphologically following the taxonomic keys of Erwin and Ribeiro (1996) were selected. Previously, evaluation of genetic resistance in greenhouse and a test of pathogenicity of the selected isolates was done by inoculating 8 weeks-old roselle seedlings of varieties identified as susceptible in field conditions and placing discs of each culture at the basis of the seedling, while selecting the most virulent isolate producing necrosis, wilting and death of the plant in the shortest time. The most virulent isolate was increased in Petri dishes with V8® medium for 10 days at 28°C. When the colony of the
pathogen covered the Petri dish, discs of the medium with approximately 15 mm in diameter were placed in dishes with sterile double distilled water and incubated at 28°C to induce sporangial formation.

**Determination of inoculum concentration**

The correct amount of inoculum to be used in evaluating resistance of the roselle varieties in greenhouse was determined by evaluating six different concentrations, including 50, 100, 150, 375 and 500 × 10^3 zoospores plant⁻¹, respectively. Twenty seedlings, 35 day old of each of the six varieties grew in 250 ml pots with sterile soil inoculated with each concentration. In 2012, entries were selected as susceptible in field conditions in Tecoanapa, Gro. Evaluation of infection of inoculum concentrations was done 12 days after inoculation.

**Seedling inoculation to evaluate resistance**

One week before inoculation, pots with seedlings at two-thirds level were submerged in water tanks with controlled temperature at 25 ± 2°C. A total of 30 seedlings of each variety were inoculated 35 days after planting by injecting 5 ml of a zoospore suspension with inoculum concentration of 375 × 10³ zoospores, when they were 20 cm high in the crown of the seedlings using an automatic syringe injection of inoculum. To avoid escapes, a second inoculation was done 12 days later using a similar method and inoculum concentration. To maintain a constant temperature of 24°C in water and soil, thermostats were placed in the water and kept under continuous movement in the water tub following the technique described by Walker (1957). Temperature in the greenhouse was kept at 20 to 25°C.

**Area under disease progress curve (AUDPC)**

Eight days after inoculation, severity of damage in each individual plant in every 72 h were done seven times, using an arbitrary 5 level scale, where: 1) healthy plant with turgent leaves, green color; 2) necrosis <2 cm at the basis of the stem, some leaves with chlorosis; 3) necrosis of 2 to 3 cm at the basis of the stem and leaves with necrosis; 4) necrosis >3 cm at the basis of the stem, plant curved, lower leaves with chlorosis, wilted or defoliated and 5) dead plant. Using the severity data and the periods of time when recorded, the AUDPC per replication of each variety were calculated following the trapezoidal integration method (Campbell and Madden, 1990).

**Severity frequency (SF)**

This was determined in each variety by counting the total number of plants in each of the infection levels.

**Damage index of seedling infection**

This was calculated as previously described in the field evaluation. Due to severity variables (field) and AUDPC (greenhouse) did not fit the normal distribution for analysis of variance; these values were transformed using the natural logarithm scale. Each replication had 10 seedlings. Data was analyzed using the SAS GLIMMIX 9.3 version (SAS Institute, 2012). Means separation was done using the instruction means with options adjust= Tukey (α= 0.05) and lines.

**RESULTS AND DISCUSSION**

**Response to *P. parasitica* infection in field**

Under field conditions, the variety Criolla Super Precoz, collected in Colima, showed the lowest severity (0.34) and it is considered the most resistant (Table 2). However, this variety only showed significant differences in severity against 11 varieties with values of 1.43 to 1.55 which did not reach flowering stage due to damage by the pathogen.

According to the mean comparison test the 39 varieties with severity ranging from 0.69 to 1.38, were located

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**Table 1**: Native varieties evaluated for genetic resistance in field and greenhouse conditions.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guerrero</td>
<td>Q-12 cr., 2MQ2, 3Q3, 4Q4, 6Q6, 7Q7, 9 Cruza Negra, 10 y 11 Coneja.</td>
</tr>
<tr>
<td>Colima</td>
<td>Colima, Criolla Morada, Criolla Super Precoz, Tempranilla Negra, Tempranilla Roja y Tempranilla tipo flor.</td>
</tr>
<tr>
<td>Puebla</td>
<td>Criolla Precoz, Criolla Roja, Criolla Roja Violeta y Jersey Acriollada.</td>
</tr>
</tbody>
</table>
between Criolla Super Precoz and the 11 most susceptible, even though they did not show significant differences in severity, plants of these varieties reached the flowering and fruiting stages and could be considered as varieties with intermediate resistance or disease tolerance (Schafer, 1971).

The small statistical differences in disease severity of the disease in the roselle varieties evaluated could be due to the reduced genetic variability between them, due to the fact that this crop was introduced to Mexico and increase if it is considered that most of the varieties used in this research came from only the state of Nayarit representing 1.7% of the total area planted to this crop in Mexico (SIAP-SAGARPA, 2014).

Since there were only two evaluations of severity of the disease in field conditions, it was not possible to determine the time when most differences of the disease between varieties could be observed, resulting in small differences between genotypes. This coincides with results of Bocca and Pellegrin (1976) that found small differences between roselle varieties evaluated against *P. parasitica* in Ivory Coast, suggesting average values of severity to differentiate varieties. In spite of using the average severity value, it was not possible to obtain contrasting differences between varieties.

**Damage index (DI)**

Regarding to DI of the varieties, Table 2 shows that there is a direct relationship between values of severity and Damage Index, Criolla Super Precoz with 1.0 and severity (0.34) had the lowest. The five varieties with the highest severity values also showed the highest damage indexes.
Exceptions to this relationships between severity and DI is shown with varieties such as UAN 25, with a severity level lower than the most susceptible varieties where all plants died (DI=5), suggesting that there are highly susceptible varieties which died with lower severity value. Results were opposite with varieties 7Q7, Criolla Roja Violeta, 6Q6, UAN 12 and UAN 25-1, with the highest severity values while the DI shows that, as an average, plants did not die, indicating high levels of tolerance to P. parasitica.

Results indicate that there were varieties moderately resistant but with a DI in 4 or 5, as in varieties UAN 6 (Novillero), UAN 20, UAN 25 and UAN 6-1 with severity values near 1.0. These varieties, with two thirds of the maximum severity value (1.55) had a DI near 5. These varieties with lower severity values soon reached a DI of 5, in contrast with the most susceptible varieties, UAN 21 and UAN 21-1 which reached a severity value of 1.55 and a DI of 5.0.

Since the field activities were under natural inoculum soil, the severity response and DI could be influenced by heterogeneous native inoculum distribution resulting in plants escaping infection. Another possible cause was the presence of more than one race of the pathogen with different pathogenic variability, as mentioned by Escalante et al. (2001), that reported virulence differences in 30 cultures isolated from 3 roselle producing areas where the most virulent cultures produced initial necrosis 11 days after inoculation as compared with 22 days required by the less virulent cultures, while Jaarsveld et al. (2003), when evaluating resistance to P. nicotianae remark the genetic variability in inoculated tobacco plants and the importance of isolates in selection of moderately resistant varieties.

Response to infection to P. parasitica in greenhouse

In the evaluation for resistance in greenhouse conditions, the analysis of variance and mean comparison showed that out of 51 varieties evaluated UAN 8 and UAN 25 had the lowest AUDPC and were significantly different when compared with the 11 most susceptible varieties. Table 3 shows the 51 varieties showed differences in DI to infection by P. parasitica in seedling stage.

Determination of inoculum concentration

The concentration of 375 000 zoospores plant⁻¹ allowed differentiation of varieties according to their resistance 9 days after inoculation. With lower concentration, there was no symptom development, probably due to the lower inoculum concentration or to a larger latent period. With 500,000 zoospores plant⁻¹ dead plants were induced five days after inoculation making it possible to detect differences in resistance between varieties.

Area under disease progress curve (AUPC)

The 51 roselle varieties in greenhouse conditions showed diseased symptoms six days after inoculation with AUDPC values at the end of the evaluation of -1.07 to 2.36 (Table 3). According to the means comparison, UAN 25 and UAN 8 with values of -0.15 and -1.07 had the lowest AUDPC values and statistically different (0.05%) with 20 varieties, which AUDPC were ≤ 1.1. Varieties, Tempranilla Negra, Tempranilla Roja and UAN 6 (Novillero) had higher AUDPC and could be considered as susceptible checks in future works on genetic resistance (Table 3).

The small statistical differences in their AUDPC between varieties coincide with results from Boccas and Pellegrin (1976), when evaluating varieties indicating there is need to include more variables such as severity incidences, days for symptoms appearance and length of necrosis in the stem to calculate differences between varieties.

Distribution of severity

All roselle varieties evaluated were heterogeneous in their response to P. parasitica as all plants showed values between 1 and 5. This could be due to the fact that all roselle varieties include a mixture of lines with variable levels of resistance to P. parasitica. The most resistance varieties, such as UAN 8 and UAN 25 had 97% of plants in level 1, coinciding as the varieties with the lowest AUDPC, while the most susceptible includes Tempranilla Negra, Tempranilla Roja, UAN 6 (Novillero), UAN 23-1 and 3Q3, had almost 60% of plants in level 5 (Table 3).

In some varieties, such as UAN 24, Criolla Super Precoc, UAN 25 and UAN 8, the disease severity is high in level 1 (> 28 plants), allowing for selection of resistant plants within the varieties and obtain homogenous lines with genetic resistance which could be used either as varieties per se by farmers or in genetic improvement programs.

Non specific resistance (horizontal type) to P. parasitica was reported in this crop (Boccas and Pellegrin, 1976), however, in this research the fact that most of the varieties had plants distributed in all categories, including healthy plant in level 1, dead in level 5 and intermediate severity levels of 2 to 4, suggest that most roselle varieties had both specific (presence of healthy plants) and non specific resistances (plants with different degrees of severity), similar to reports in resistance against Phytophthora infestans in potato varieties (Mosquera et al., 2008).

Damage index (DI) in seedlings

This variable had values from 1.03 to 4.1 and its value is
Table 3: Response to Phytophthora parasitica in seedlings of 51 roselle varieties in greenhouse. Montecillo, Mexico, 2014.

<table>
<thead>
<tr>
<th>Variety</th>
<th>AUDPC</th>
<th>Severity distribution</th>
<th>Damage index</th>
<th>Variety</th>
<th>AUDPC</th>
<th>Severity distribution</th>
<th>Damage index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempranilla Negra</td>
<td>2.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9 1 2 3 4 5 21</td>
<td>3.80 UAN 17</td>
<td>1.36&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>20 3 2 2 3 1.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tempranilla Roja</td>
<td>2.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8 1 2 19 19</td>
<td>3.77 Criolla Precoz</td>
<td>1.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18 2 2 1 7 2.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN 6 (Novillero)</td>
<td>2.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5 1 2 22 22</td>
<td>4.10 UAN 26</td>
<td>1.27&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>22 1 7 2 0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN 23-1</td>
<td>2.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8 1 1 20 20</td>
<td>3.77 UAN 31</td>
<td>1.26&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>25 5 1 6 1.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3Q3</td>
<td>2.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10 1 3 16 16</td>
<td>3.50 UAN 22</td>
<td>1.10&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>19 1 2 8 2.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN 20</td>
<td>2.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16 1 13 13</td>
<td>2.83 UAN 11</td>
<td>1.05&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>26 4 1 6 1.53</td>
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<tr>
<td>UAN 6-1</td>
<td>2.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17 2 11 11</td>
<td>2.60 Colima</td>
<td>0.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21 2 6 2 0.03</td>
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<tr>
<td>Criolla Morada</td>
<td>2.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10 1 19 19</td>
<td>3.56 UAN 12</td>
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<td>23 1 6 1 1.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN 30</td>
<td>2.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18 1 11 11</td>
<td>2.53 Negra UAN</td>
<td>0.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21 2 7 2 0.07</td>
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<td></td>
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<tr>
<td>Negra Quiviquinta</td>
<td>1.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14 1 14 14</td>
<td>3.03 UAN 16-1</td>
<td>0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22 1 7 1 1.97</td>
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<tr>
<td>11 Coneja</td>
<td>1.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15 4 1 10 10</td>
<td>2.70 Jersey Acriollada</td>
<td>0.93&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>27 3 1 1 1.40</td>
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<tr>
<td>Criolla Puebla Precoz</td>
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<td>18 2 1 9 9</td>
<td>2.33 Q12 cr.</td>
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<td>25 1 1 1 1.43</td>
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<td></td>
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<tr>
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<td>1.82&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>12 1 2 15 15</td>
<td>3.27 UAN 15</td>
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<td>23 2 5 1 1.87</td>
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<tr>
<td>2MQ2</td>
<td>1.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>26 1 3 3</td>
<td>1.47 Criolla Roja Violeta</td>
<td>0.84&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>24 1 2 1 1 1.53</td>
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<td></td>
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<tr>
<td>UAN 12-1</td>
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<td>24 1 5 5</td>
<td>1.73 UAN 7</td>
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<td>27 3 1 1 1.40</td>
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<tr>
<td>4Q4</td>
<td>1.60&lt;sup&gt;ab&lt;/sup&gt;</td>
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<td>2.43 UAN 24</td>
<td>0.48&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>28 1 1 1 1.17</td>
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<tr>
<td>UAN 6 (Puga)</td>
<td>1.56&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>25 1 1 3 3</td>
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<td>25 1 4 1 1.60</td>
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<td>UAN 9</td>
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<td>24 1 2 1 1 1.53</td>
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<tr>
<td>UAN 21-1</td>
<td>1.54&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>20 1 10 10</td>
<td>2.33 6Q6</td>
<td>0.14&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>25 1 3 1 1.50</td>
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<tr>
<td>UAN 25-1</td>
<td>1.51&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>16 1 3 10 10</td>
<td>2.67 UAN 10-2</td>
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<td>26 1 1 2 1.43</td>
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<tr>
<td>UAN 10-1</td>
<td>1.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>17 3 10 10</td>
<td>2.53 Criolla Super Precoz</td>
<td>0.08&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>28 1 1 1 1.23</td>
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<tr>
<td>UAN 29</td>
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<td>0.06&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>26 3 1 1 1.47</td>
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<td>Tempranilla tipo flor</td>
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<td>7Q7</td>
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<td>UAN 21</td>
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<td>25 1 4 4</td>
<td>1.60 UAN 25</td>
<td>-0.15&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>29 1 1 1 1.13</td>
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<sup>1</sup>Values logarithm transformed. Means followed by same letters are not statistically different (Tukey, p< 0.05). <sup>2</sup>Distribution of plants in each severity level, 1) healthy plant with turgent leaves, green color; 2) necrosis < 2.0 cm at basis of stem, some leaves with chlorosis; 3) necrosis from 2.0 - 3.0 cm at basis of stem, chlorotic leaves; 4) necrosis > 3.0 cm at basis of stem, plant curved lower leaves chlorotic, wilted or defoliated and 5) dead plant. Values of 30 plants.

directly related to the number of dead plants. Varieties with the lowest DI were UAN 8 and UAN 25 with 1.03 and 1.13, respectively, where 29 out of the 30 plants evaluated showed value 1 (healthy plants), while UAN 6 (Novillero) had 22 plants in level 5 (dead plant) with the highest DI value (Table 3).

The DI in UAN 8 indicates that this is among the most resistant varieties both in field and greenhouse could be considered that its resistance is effective in the two stages of plant development. In the adult stage in field conditions, the variety UAN 25 showed a low severity and all plants died having a high DI (5.0), indicating contrasting results in seedling stage in the greenhouse, where it showed a low severity and DI (1.13) with 29 healthy plants, suggesting that resistance in this variety is not effective in the adult stage. These results coincides with those from Ansar et al. (2010), on selections of pea resistant to Fusarium spp. in seedling stage but susceptible near maturity stage indicating that this difference is due to either the action of different genes or difference in infection during plant development.

The variety UAN 6 (Novillero) was highly susceptible to P. parasitica both in field and greenhouse conditions, showing a DI value of 4.0 in field and very similar to greenhouse of 4.1, followed by the varieties Tempranilla Roja, UAN 23-1 and 3Q3, which were highly susceptible in spite of a value of 1.0 in 5 out of 10 seedlings.

The response of the varieties was grouped according to the severity values, DI and DS, the most susceptible varieties grouped according to their AUDPC from 2.26 to 2.36 and DI from 3.5 to 3.8, where most of the plants were in level 5. The varieties statistically similar to the most
resistant (UAN 25 and UAN 8), with AUDPC values between 1.07 and 1.05 was also grouped according to the DS with more than 60% of their plants in level 1.

Responses in field vs. greenhouse

When comparing the response of all varieties in field and greenhouse in the two stages of development in field, the DI of all varieties had the highest value of 2.9, with 34 varieties with values higher than 3.0, while in greenhouse there was an average value of 2.12 with 8 varieties and had a DI > 3.0. This result may be due to greater variability of the pathogen in the field with virulent isolates, the stage of the crop and double evaluation than in seedling greenhouse, indicating that there was a longer period for disease development in field conditions.

Even though there was no artificial inoculation of plants in the field 11 varieties, including UAN 11, Colima, Jersey Acriollada, Q12 cr., UAN 7, UAN 24-1, Criolla Roja, Criolla Super Precoco, UAN 13, UAN 25 and UAN 8, with low severity values <1.0, results coincide with those obtained in greenhouse where the severity values were <1.05 in the same varieties. This trend suggests that resistance in seedling stage is also effective in adult plant stage without discarding the presence of genes that express themselves only in the initial stages of plant development.

It is suggested that further studies be carried out to evaluate roselle varieties genetic resistance to *P. parasitica* and include or discard those moderately resistant such as UAN 24-1, UAN-31, and 2MQ, with outstanding agronomic characters to be incorporated in a breeding improvement program.

Conclusions

All varieties studied showed a variable degree of resistance. In all varieties, there are resistant plants. Under field conditions, the variety, Criolla Super Precoco was highly resistant with the lowest severity and damage index in near maturity stage. Thus, under greenhouse conditions, varieties UAN 8 and UAN 25 showed high level of resistance.

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REFERENCES


Tripathi P, Dubey NK (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and...


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