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Investigation note

Physiological races of *Puccinia triticina* E. identified in the North of Sinaloa and germplasm resistance

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Abstract

Leaf rust caused by *Puccinia triticina* E. is the most important disease in the North and Northwest of Mexico. In the North of Sinaloa, it is widely distributed in the wheat production areas of Valle del Fuerte and Valle del Carrizo; however, it is unknown which races are influencing that region. The objective was to identify the physiological races of leaf rust, which occur in the main producing areas of Northern Sinaloa, and to identify germplasm with resistance. During the autumn-winter 2018-2019 crop cycle, 50 samples of leaf rust were collected from experimental and commercial lots, these samples were transferred to Lanarec. With the monopostular technique, the identification of races was carried out. Subsequently, with the most frequent races, 35 bread wheat genotypes were evaluated under greenhouse conditions and for their resistance in seedlings and adult plants. Seven physiological races of leaf rust were identified (CBJ/QQ, MBT/SP, MCT/SP, MGJ/SP, MBJ/SP, MBJ/QQ, MFJ/SP), of which CBJ/QQ was identified with higher frequency (29%). Of the 35 genotypes evaluated with the CBJ/QQ and MCT/SP races, it was determined that CONATRIGO F2015 and the lines CHEWINK #1/MUTUS//MUTUS∗2/HARIL#1 and MUTUS∗2//ND643/2∗WBLL1/3/BORL14 were resistant in seedling and adult plant to both races, which indicates that it possesses at least one gene for effective resistance to leaf rust. Genetic resistance is one of the most viable sustainable management alternatives for the control of wheat rusts in Mexico.

Keywords: genotypes, resistance, virulence.

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At the global level, bread wheat (*Triticum aestivum* L.) is the most important cereal after corn, its production is mainly for human consumption (FAO, 2020). In Mexico the main wheat-producing regions are located in the Northwest (Sinaloa, Sonora and Baja California), where 64.2% of the national total is produced, said production is carried out under irrigation conditions during the autumn-winter cycle (A-W) (SIAP, 2020).

In Sinaloa, the wheat area includes the municipalities of Guasave, Sinaloa de Leyva, Ahome, Angostura and El Fuerte. The municipality of Ahome concentrates more than 80% of the total production of the state, highlighting the Valle del Carrizo as the main wheat area with 33 350 ha planted in the A-W 2018-2019 cycle (CESAVESIN, 2019).

Wheat production is affected by biotic and abiotic factors. Among biotic factors, diseases such as rusts, caused by different species of the genus *Puccinia*, are the most economically important for wheat cultivation in Mexico. Leaf rust caused by *Puccinia triticina* E. is the most important in the North and Northwest of the country, this disease is the most distributed and occurs in most of the irrigation areas where wheat is sown (Huerta-Espino *et al*., 2011).

Singh *et al*. (2016) indicate that rusts have historically caused large losses in wheat crops and remain economically important despite the widespread use of genetic and chemical control. On the other hand, Rodríguez *et al.* (2010) mention that rusts constantly threaten the production of this cereal in the world, since they can overcome the specific resistance of new varieties due to the evolution towards new biotypes of the pathogen or physiological races with new virulence genes; they also reproduce quickly and can move very long distances. Leaf rust has caused yield losses ranging from 10 to 50% (Huerta-Espino *et al*., 2011).

In leaf rust there is a marked difference between the populations of the pathogen that attack flour wheat (*Triticum aestivum* L.) (Singh, 1991), compared to those that attack durum wheat (*Triticum durum* L.) (Huerta-Espino and Roelfs 1989). In Mexico, Huerta-Espino and Singh (2000) indicated that more than 50 physiological races of leaf rust have been identified in bread wheat, a drastic change in the population of this pathogen occurred in 1994 in the South of Sonora where the race prevailed. MCJ/SP (which eventually became present in the High Valleys) but in 1996, in Oaxaca, the M(B)J/SP, race, a variant of the MCJ/SP race, was detected for the first time. On the other hand, Villaseñor *et al*. (2003) in 2000 in the High Valleys of Mexico identified 13 physiological races that affect bread wheat, MCJ/SP being the most frequent followed by MBD/QM.

Genetic control in rusts is based on using varieties with resistance to various physiological races. For this reason, the aim is to generate varieties that possess durable resistance (polygenic, multigene, horizontal or quantitative) based on genes of slow rusting pathogenesis (Singh *et al.*, 2011). To date, 77 resistance genes have been cataloged for leaf rust (McIntosh *et al.* 2017). Of which, *Lr12*, *Lr13*, *Lr22a*, *Lr22b*, *Lr34*, *Lr35*, *Lr37*, *Lr46*, *Lr48*, *Lr49*, *Lr67*, *Lr68*, *Lr74*, *Lr75* confer resistance in adult plant (RPA) (McIntosh *et al*., 2017).

In the North of Sinaloa, leaf rust is widely distributed in the wheat production areas of Valle del Fuerte and Valle del Carrizo; however, it is unknown which physiological races are influencing this region. The objective of this research was to identify the physiological races of leaf rust, which occurred in the main producing areas of Northern Sinaloa during the autumn-winter 2018-2019 cycle and to identify germplasm with resistance to the most common races and with a greater spectrum of virulence.

During the autumn-winter 2018-2019 cycle, 50 samples of leaves with signs of leaf rust were collected in different farms of the Valle del Carrizo and Valle del Fuerte belonging to the North of Sinaloa, recording the collection data. The samples were transferred to the national laboratory for rusts and other cereal diseases (LANAREC) of INIFAP-CEVAMEX, located in Texcoco, State of Mexico.

Identification of physiological races

Using the monopostular technique and following the methodology described by Huerta-Espino *et al*. (2020) 150 isolates were obtained. For the identification of physiological races, a set of 20 differential lines was used, arranged in five sets of four differentials each. In addition to the 20 differentials, another 31 wheat genotypes were sown that allow corroborating the virulence and avirulence of the fungus in these genes, as well as the differentiation of breeds of bread wheat vs crystal wheat.

At 10 days after inoculation, the reaction of the genotypes was recorded using the 0-4 scale described by Roelfs *et al*. (1992). The nomenclature for the designation of races was based on the one proposed by Long and Kolmer (1989), modified by Singh (1991) and described for Mexico by Huerta-Espino *et al*. (2020).

Evaluation of genotypes in seedling and adult plant

At LANAREC, under greenhouse conditions (T_{max} 24 °C - T_{min} 18 °C), the resistance in seedlings and adult plants of eight control varieties and 27 advanced lines of bread wheat, from the genetic improvement program of INIFAP-CEVAMEX rainfed wheat. For the seedling evaluation, the 35 genotypes were sown in plastic trays, small holes were marked and 8 to 9 seeds were placed per genotype, later 11 days after sowing the seedlings were inoculated with a suspension of urediniospores of the strains of leaf rust called CBJ/QQ and MCT/SP, at a concentration of 1×10^6 urediniospores ml^{-1}.

The urediniospores were suspended in mineral oil (Soltrol® 170; Chevron Phillips Chemical Company) and sprayed with an atomizer connected to a compressor. The inoculated seedlings were placed in a bioclimatic chamber with temperatures of 24 °C for 24 h and sprayed at 100%. Later they were transferred to the greenhouse and after 10 days of inoculation their reaction to leaf rust was recorded using the scale proposed by Roelfs *et al*. (1992), where readings from 0 to 2 are considered resistant and from 3 to 4 susceptible.

On the other hand, for the evaluation for their resistance in adult plant to RH, the 35 genotypes were sown in plastic pots where 3 seeds were placed per pot. At 60 days after sowing, the plants were inoculated with a suspension of the CBJ/QQ and MCT/SP races, at a concentration of 1×10^6 urediniospores ml^{-1}. The inoculated plants were placed in a bioclimatic chamber with temperatures of 24 °C for 24 h and sprayed at 100%.

Subsequently, they were transferred to the greenhouse and after 15 days of inoculation the severity of the disease was recorded, using the modified Cobb scale (Peterson *et al*. 1948) and the host's response to infection was determined according to Roelfs *et al*. (1992). Where: R= resistant, tiny uredinia; MR= moderate resistance, small uredinia; MS= moderate susceptibility, small uredinia of moderate size; and S= susceptible, large uredinia.

Seven physiological races of leaf rust were identified, which occurred in the autumn-winter/2018-2019 cycle in the North of Sinaloa, in Table 1, their virulence/avirulence formula is presented and in this table it can be observed , that the most frequent breed was the CBJ/QQ with 29% frequency, this breed was identified for the first time in 1994 in the High Valleys of central Mexico as mentioned by Huerta-Espino and Singh (1994) and shares a certain similarity with the CBJ/QL and CBJ/QB breed reported by Singh (1991) identified in the state of Tlaxcala.

Table 1. Physiological races of leaf rust identified in the North of Sinaloa (cycle A-W 2018-2019).

No.	Races	Frequency (%)	Virulence/avirulence
1	CBJ/QQ	29	Lr3,3bg,10,11,13,17,19/1,2a,2c,3ka,9,15,16,18,23,24,26,27+3,30
2	MBT/SP	23	Lr1,3,3ka,3bg,10,11,13,15,17,23,27+31,30/2a,2c,9,16,18,19,24,26
3	MCT/SP	18	Lr1,3,3ka,3bg,10,11,13,15,17,23,26,27+31,30,/2a,2c,9,16,18,19,24
4	MGJ/SP	10	Lr1,3,3bg,10,11,13,15,16,17,23,27+31/2a,2c,3ka,9,18,19,24,26,30
5	MBJ/SP	10	Lr1,3,3bg,10,11,13,15,17,23,27+31/2a,2c,3ka,9,16,18,19,24,26,30
6	MBJ/QQ	5	Lr1,3,3bg,10,11,13,17,19/2a,2c,3ka,9,15,16,18,23,24,26,27+31,30
7	MFJ/SP	5	Lr1,3,3bg,10,11,13,15,17,23,24,26,27+31/2a,2c,3ka,9,16,18,19,30

Lr= leaf rust.

On the other hand, the most frequent breed was the MBT/SP with 23%, followed by the MCT/SP (18%), MGJ/SP and MBJ/SP with 10% and with 5% frequency the MBJ/QQ and MFJ/SP. The races with less spectrum of virulence were CBJ/QQ and MBJ/QQ; however, the latter was identified less frequently. On the other hand, the most virulent and frequent races were MCT/SP and MBT/SP. Of the seven identified breeds, a certain similarity was observed with other breeds reported mainly in the United States of America, such is the case of the MBT/SP breed, this breed shares similarity with the MBTSB breed identified since 2005 and reported by Kolmer *et al*. (2011); Kolmer and Hughes (2018).

The MFJ/SP breed was identified similarity with the MFJSB breed reported by Kolmer and Hughes (2018). In general, most of the identified breeds presented a broad spectrum of virulence, which indicates that over time they have evolved in an accelerated manner and have overcome the resistance of most of the major genes available in Mexico.

The most viable strategy to control rusts is through genetic control, which is based on incorporating effective resistance genes into the germplasm of the various wheat breeding programs that exist in Mexico and the world. For which the search for germplasm with resistance to the most frequent races and with a greater spectrum of virulence is a constant work. Of the races identified in the present investigation, the most frequent was CBJ/QQ and one of the most virulent was MCT/SP, for these races genotypes with resistance in seedlings and adult plants to leaf rust were identified.

Table 2 indicates the level of resistance in seedling and adult plant under greenhouse conditions of eight varieties of bread wheat recommended for sowing under irrigation conditions in Northwest Mexico, of which Conatrigo F2015 was resistant in seedling and adult plant to both races, indicating that it possesses at least one gene for effective resistance to leaf rust.

Table 2. Response in seedling and adult plant of bread wheat genotypes that can be used as progenitors, sources of resistance and release of varieties.

No.	Variety/genotype	MCT/SP		CBJ/QQ	
		PLT	PA	PLT	PA
1	Kronstad F2004	3	40MS	1	10MR
2	Roelfs F2007	3	50S	1	1R
3	Villa Juarez F2009	3	20MS	1-	1R
4	Borlaug 100 F2014	3	20MS	;	5MR
5	Bacorehuis F2015	3+	30MS	1-	5MR
6	Conatrigo F2015	1-	1R	1-	5MR
7	Noreste F2018	3	40MS	1-	5MS
8	Hans F2019	3+	70S	1-	5MR
9	BECARD/FRNCLN//BORL14	X	15MR	1-	0
10	CHEWINK #1/MUTUS//MUTUS∗2/HARIL#1	;	0	1	5MR
11	MUTUS∗2//ND643/2∗WBLL1/3/BORL14	;	0	0	0
12	FRET2∗2/KIRITATI//KIRITATI/2∗TRCH/3/…	3	30MS	1-	5MR
13	NS.732/HER/3/PRL/SARA//TSI/VEE#5/4/…	3	30MS	1-	1R
14	WBLL1∗2/BRAMBLING//WBLL1∗2/…	3+	30MS	1-	5MR

R= resistant; MR= moderate resistance.

On the other hand, the Villa Juarez F2009, Borlaug 100 and Bacorehuis F2015 varieties were moderately susceptible to the most virulent race (MCT/SP); however, with a behavior of moderate susceptibility to susceptible were the varieties Kronstad F2004, Roelfs F2007, Noreste F2018 and Hans F2019.

Of the 27 lines evaluated, only six showed a resistance reaction, moderate resistance and moderate susceptibility. Lines 10 (CHEWINK #1/MUTUS//MUTUS∗2/HARIL#1) and 11 (MUTUS∗2//ND643/2∗WBLL1/3/BORL14) were resistant in seedling and adult plant to the two races evaluated as which indicates that they possess at least one effective gene for resistance to leaf rust.

Conclusions

In the Valle del Carrizo and Valle del Fuerte during the autumn-winter cycle, 2018-2019, seven physiological races of leaf rust were identified, of which CBJ/QQ was the most frequent. CONATRIGO F2015 showed resistance in seedlings and adult plants to the CBJ/QQ and MCT/SP races, which indicates that it has a greater gene for resistance to leaf rust. Most of the races identified had a broad spectrum of virulence. Races detected with low frequency may not become dominant in Sinaloa. It is very important to identify lines with genetic resistance to the main physiological races of rusts that occur in the North of Sinaloa, which will allow the generation of varieties that reduce the economic impact caused by leaf rust. Genetic resistance is one of the most viable sustainable management alternatives for the control of wheat rusts in Mexico.

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