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PRESENCE OF LEAF RUST (Puccinia triticina Eriks.) IN SOUTHERN SONORA, MEXICO, DURING THE CROP SEASON 2021-2022

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ABSTRACT

The state of Sonora in Mexico generates 52% of the wheat production in the country. Leaf rust (LR) is an endemic disease in the southern part of the state where it has caused epiphytotics. The objective of this work was to analyze the presence and development of this disease in the Yaqui and Mayo Valleys and in Huatabampo, during the crop season fall-winter 2021-2022. Data were collected from the automated weather station network in the state and from the weekly bulletins published by the local Plant Health Councils (LHPC). The crop season began abnormally warm, December had a historical average maximum temperature (30.6°C); then, the moderate to low temperatures prevailing from the second fortnight of January on, were conducive for accumulation of cold units which favored the development of the wheat crop. LR was detected in Huatabampo on January 21, a region characterized by high humidity where the first two weeks of the year 2022 had over 76% RH; the disease also increased rapidly due to the susceptibility of durum cultivar CIRNO C2008 sown in over 201,000 ha. The timely intervention of the LPHC´s with farmers and the low temperatures that prevailed from the second fortnight of January to March induced proper control of the disease and a good grain yield in the region. The percentage of wheat fields monitored that had LR were 100% in Huatabampo, 70.52% and 68.69% in the Yaqui and Mayo Valleys, respectively.

Keywords: Puccinia triticina, Leaf rust, Triticum durum, Durum wheat.

1. INTRODUCTION

Wheat is one of the most important cereals for human consumption, it occupies the second place in worldwide production (FAOSTAT, 2021). In Mexico, wheat production is carried out in 543,258.64 ha in 22 states, but it is concentrated in Sonora (52.70%), Guanajuato (10.81%), Baja California (9.59%), Michoacán (7.52%), Sinaloa (7.29%), Jalisco (4.38%), and Chihuahua (2.88%) with a national grain production of 3,266,511.53 t in the year 2021 (SIAP, 2022). The most important climatic factors that influence development of many diseases of plants are the temperature, relative humidity and rainfall, which interact and may cause considerable damage (Coscollá, 1980). Several studies carried out using data from weather stations (Grageda Grageda *et al*., 2014; Morales-Coronado *et al*., 2019), have demonstrated that the fluctuation of temperature and the relative humidity in different zones in the Yaqui and Mayo Valleys, cause differences in yield of various crops, and also influence the presence and incidence of pests and diseases in different sectors of the valleys. Plants show distinctive elements by the climatic effect either beneficial or damaging to their growth and development, as well as their exposure or protection from the various climatic factors. Leaf or brown rust of wheat caused by the fungus *Puccinia triticina* Eriks. is an important disease worldwide. This fungus grows wherever wheat

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is cultivated, and it may cause infections when dew is present on leaves and temperatures are around 20°C; as the dew period extends, more infections will take place. Losses are generally low (< 10%), but sometimes can be greater than 30% (Roelfs *et al*., 1992). The areas in Mexico prone to leaf rust development are located in the eastern low-lands which include those across the Texas border in the states of Coahuila, Tamaulipas, and San Luis Potosi; the Highland Plateau in Chihuahua, Jalisco, Mexico, Tlaxcala, Guanajuato, and Michoacan; and in the Pacific region in Sinaloa and southern Sonora (Singh, 1991). Leaf rust is endemic in southern Sonora and has caused economically important epiphytotics during the crop seasons 1976-1977 and 2000-2001 (Dubin and Torres, 1981; Figueroa-López *et al*., 2001). The best control measures are breeding for genetic resistance and the application of foliar fungicides (Roelfs *et al*., 1992; Singh *et al*., 2005). Research done in southern Sonora has demonstrated that the presence of pests and diseases of wheat has been more severe in different zones of the region as a consequence of climatic factors that have been favorable for such phytopathogens. Therefore, the objective of this work was to analyze the presence and development of leaf rust in the Yaqui and Mayo Valleys and in Huatabampo, Sonora, during the crop season fall-winter 2021-2022.

2. MATERIALS AND METHODS

Data were collected from 34 stations from the automated weather station network in the state of Sonora, Mexico (REMAS, 2022) that comprise the Yaqui and Mayo Valleys, as well as the Huatabampo region (Figure 1). The variables taken into consideration for this work were temperature and the relative humidity, since they have an important effect on the adequate development of the wheat crop (Harel *et al*., 2014), pests and diseases (Coscollá, 1980). A database from SIMROYA (Wheat Rust Monitoring System) was generated and digitalized, and from the weekly bulletins from the local Plant Health Councils (LPHC) in the Yaqui and Mayo Valleys and Huatabampo, Sonora. The number of hours with prevailing temperatures between 18 and 22°C were calculated, since this range of temperature is favorable for leaf rust development on the wheat leaf (Roelfs *et al*., 1992).

3. RESULTS AND DISCUSSION

The initiation of the crop season fall-winter 2021-2022 was abnormally warm with an average maximum temperature for the second fortnight of November of 35.3°C, while December had an average maximum temperature of 30.6; the moderate to low temperatures that predominated from the second fortnight of January, with average of 15.7, 14.6, 16.4, 21.1, and 23.8°C for the months of January, February, March, April, and May, respectively, contributed for the accumulation of cold units (625 for the Yaqui Valley and 679 for the Mayo Valley and Huatabampo) which favored the development of the wheat crop. However, leaf rust was detected on January 21, 2022, in the Huatabampo region, which is characterized by a more humid climate (Torres-Cruz *et al*., 2021), in addition to the number of hours with temperatures ranging from 18 to 22°C (30 for each of the first two weeks of 2022, 23 for the third week and 33 for the fourth week). It should be pointed out also, the formation of dew on plants, which is a common and frequent phenomenon in southern Sonora.

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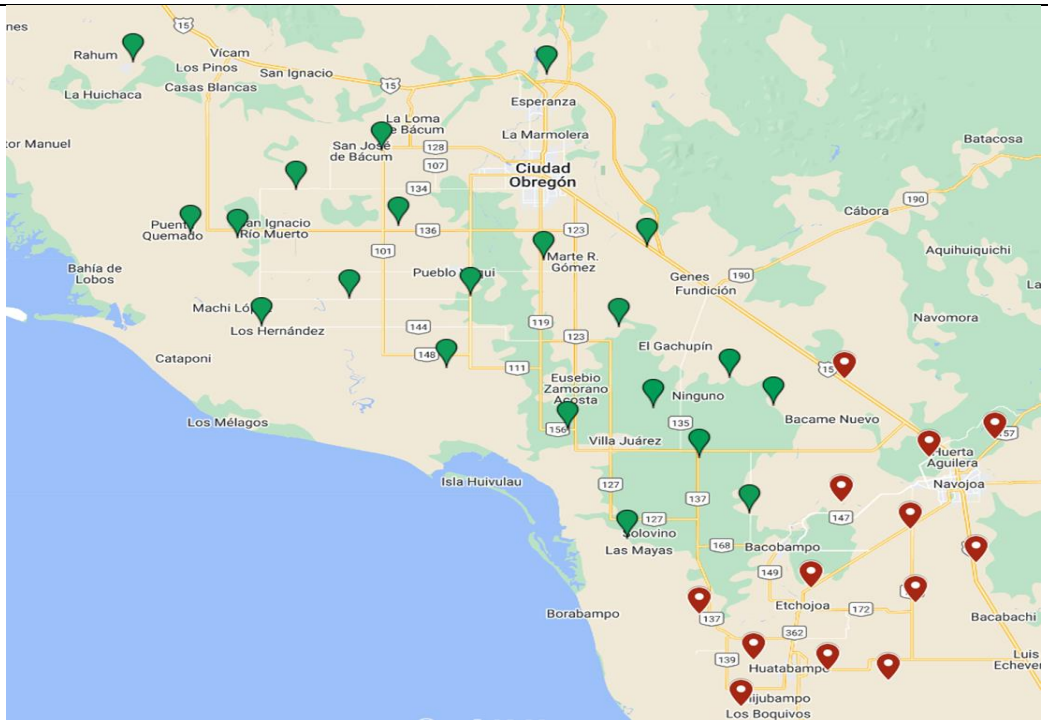

Figure 1. Geographical location of the weather stations in the Yaqui Valley (green) and in the Mayo Valley and Huatabampo (red).

The origin of the primary inoculum is not known in southern Sonora, but Hassan *et al*. (1986) reported that urediniospores of *P. recondita* f. sp. *tritici* (synonym of *Puccinia triticina*), can survive on volunteer wheat plants during the summer, and serve as primary inoculum for wheat sown during the fall. They reported that germinating wheat seedlings trapped urediniospores from the soil or the host plant debris. They also reported that soil-borne spores survived simulated summer temperatures of 34/22°C day/night for up to 22 days on moist soil, 13 d on dry soil, and 4-7 d when covered with a 5 mm layer of soil; trapped spores survived 8 d on dry leaves at 34/22°C; spores in pustules on excised leaves placed on soil at 30-33°C survived up to 15 d, while spores on flood waters were able to infect partially submerged host leaves. An important finding was that dormant mycelium survived all conditions that host tissue was capable of surviving. As to the alternate hosts, Roelfs *et al*. (1992) mentioned that *Anchusa italic*a Retz., *Clematis mandshurica* Rupr., *Isopyrum fumarioides* L., *Thalictrum flavum* L., *Th. foetidum* L., *Th. japonicum* Thunb., and *Th. speciosissimum* Loefl, have a role in the development of leaf rust of wheat; however, those plant species are not included in the flora of the state of Sonora, Mexico (Van Devender *et al*., 2009), or anywhere else in the country (Wiersema and León, 1999). Saari *et al*. (1968) indicated that alternate hosts rarely, if ever, function in North America, South America, and Australia. In the case of inoculum coming from the other regions of the country or abroad, Roelfs *et al*. (1992) reported that the likelihood that exogenous inoculum could constitute a major source of inoculum would be difficult to prove, since several criteria must be met in order to confirm the long-distance movement of spores, like crop phenology in the source area as well as rust phenology and weather conditions, air

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trajectories from the source to the target area, spore content of the air between the source and the target area, spore trapping data in the target area as well as weather conditions, crop phenology and rust phenology in the target area, and matching of phenotypes in the source and the target areas; however, circumstantial evidence has suggested long-distance transport of spores in Australia, China, Egypt, India, North America, and New Zealand. Relative humidity is a key factor in the development of leaf rust, as it was found by Torres-Cruz *et al*. (2022) when they surveyed wheat fields during the crop seasons 2017-2018 to 2019-2020, in southern Sonora. The average relative humidity of the groups of fields with and without the disease showed statistical significance difference in each crop season, while the average and minimum temperature showed difference only during 2017-2018, and the maximum temperature only during 2019-2020. Considering the data in 2021-2022 from the three weather stations in the Huatabampo region {La Regla, Huatabampo, and Navobaxia(Las Piochas)} where the disease was first detected, the average RH during the weeks of January 2022 were 78.51, 76.95, 73.78, and 77.08%, while in late January-February-beginning of March 73.60, 74.26, 71.76, 72.56, and 70.43% (Figure 2). The highest RH weekly in the same order were: 93.52, 90.39, 88.76, 90.37, 89.69, 89.29, 89.30, 90.08, and 90.13%. Also, the number of hours with RH higher than 80% weekly and in the same order were: 108, 93, 89, 101, 89, 99, 92, 88, and 84. The first two weeks of January also recorded 17 and 7 hours with RH higher than 90%. This climatic condition along with the number of hours with temperatures between 18 and 22°C must have favored the germination of fungal spores and the development of leaf rust in the Huatabampo region. During the first four weeks of 2022, the number of hours with that range of temperature were 30, 30, 23, and 33, then, it was reduced to 25, 21, 17, 23, 18, 25, 15, 14 and 11 for the 13th week.

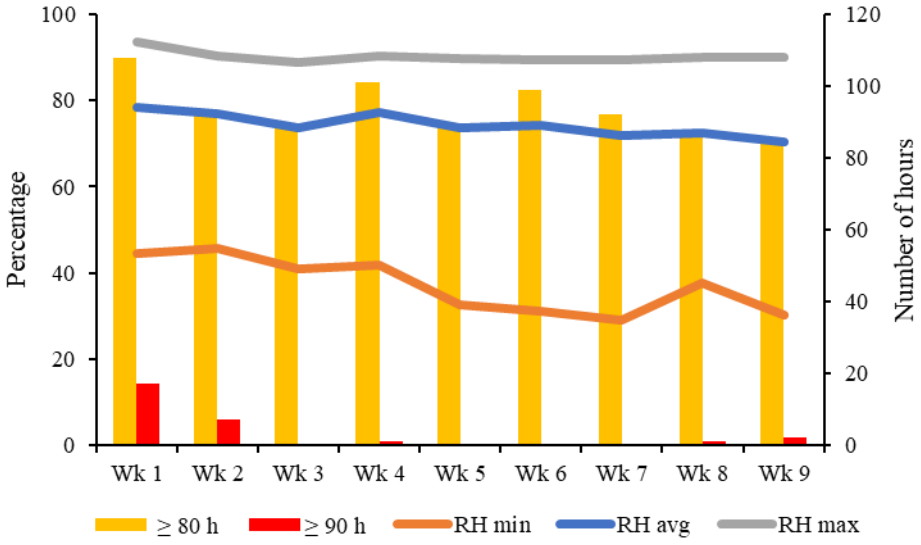

Figure 2. Minimum, average, and maximum relative humidity, and the number of hours with RH greater than 80% during the first 9 weeks of 2022, as well as RH greater than 90% in the first 2 weeks, in the Huatabampo region where leaf rust was first detected.

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It is possible that temperature, high relative humidity and the high susceptibility of durum wheat commercial cultivar CIRNO C2008, which covered more than 201,000 ha in southern Sonora during crop season 201-2022 (CESAVESON, 2022) influenced the occurrence of the disease outbreak, which increased rapidly, but it leveled off by the middle of March (Figure 3). This cultivar released in 2008 for commercial cultivation (Figueroa-López *et al.*, 2010b) has been fundamental for a historic wheat production in southern Sonora, particularly during the crop season fall-winter 2011-2012 for a grain yield average of 7.02 t ha^{-1} (Ochoa Neira, 2012); also in validations with cooperating farmers, this cultivar has produced grain yields greater than 9.0 t ha^{-1}. It has been the dominant cultivar in southern Sonora, 67% out of 258,597.05 ha sown with durum wheat corresponded to CIRNO C2008 during the crop season 2018-2019, in 2019-2020, 55% out of 231,473.84 ha corresponded to the same cultivar; and in 2020-2021 wheat had 283,155.27 ha with an increase of 23% for CIRNO C2008 (CESAVESON, 2019). The gene LrCamayo in chromosome 6BL conferred resistance to leaf rust (Herrera-Foessel *et al.*, 2014), but during the crop season 2016-2017, a new race described as BBG/BP_CIRNO overcame the genetic resistance of this cultivar (Pérez-Lopez *et al.*, 2017); although in greenhouse tests, this new race did not affect some cultivars released previously like Samayoa C2004, Patronato Oro C2008, CEVY Oro C2008, Sawali Oro C2008, Movas C2009, CONASIST C2015, Barobampo C2015, and Norteño C2016 (Huerta-Espino *et al.*, 2017).

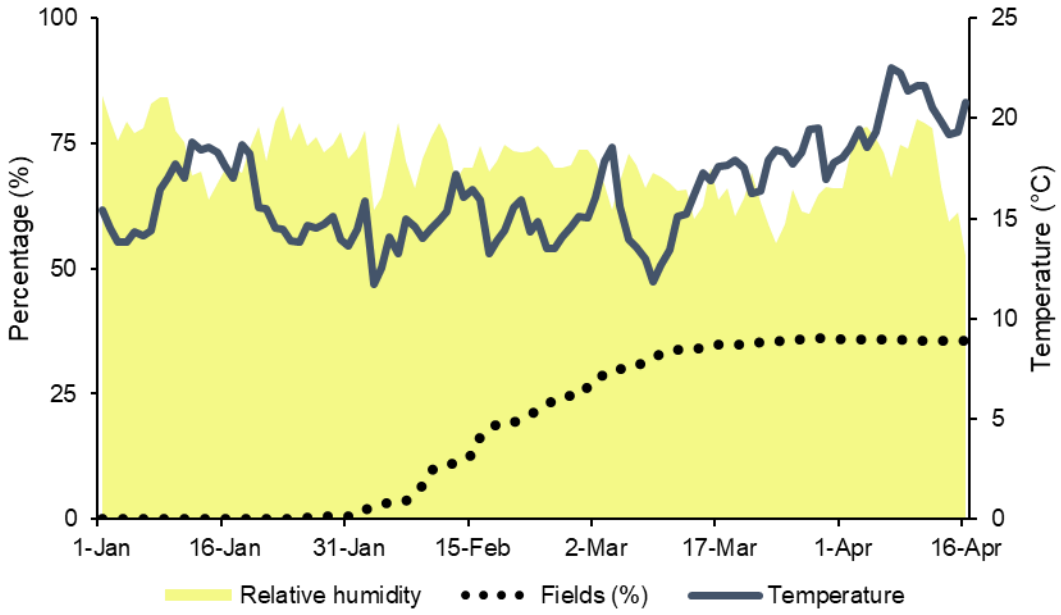

Figure 3. Leaf rust development from January to April in the Yaqui and Mayo Valleys, and in Huatabampo, during the crop season fall-winter 2021-2022.

Given the abrupt increment at the end of January and during the beginning of February, month in which in general, the crop was at the tillering stage (6%), stem elongation (34%), boot (34%), and heading (26%), meetings by the Local Plant Health Councils were inititated with the farmers

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in each region, and in particular in Huatabampo where 100% of the wheat fields monitored showed leaf rust infection, in order to analyze the situation and to recommend frequent monitoring of the crop, and if necessary, the application of fungicides to control the disease. There is a variety of commercial fungicides recommended for rust control (Figueroa-López and Cantúa-Ayala, 2006; Figueroa-López *et al*., 2010a; Martinez-Espinoza *et al*., 2022; French, 2016), primarily from the triazol and strobilurin groups, either singly or in mixtures. Members of the triazol group affect the biosynthesis of ergosterol, which is an important component of the fungal cell plasma membrane (Pérez-García *et al*., 2005; Ribas e Ribas *et al*., 2016); this group of fungicides has also had the best control of Karnal Bunt (KB) of wheat caused by the fungus *Tilletia indica* Mitra (Smilanick *et al*., 1987; Salazar-Huerta *et al*., 1997; Fuentes-Dávila *et al*., 2018, 2022), a disease that has to be considered along with leaf and stripe rust (*Puccinia striiformis* Westend. f. sp. *tritici* Eriks.) of wheat, since KB is endemic in southern Sonora and applications are recommended to the farmers, to be carried out during flowering in order to reduce the incidence of KB and to control rust and spot blotch caused by *Bipolaris sorokiniana* (Sacc.) Shoemaker which is more prevalent in the Huatabampo region, as described by Torres-Cruz *et al*. (2021). The strobilurin group or QoI (quinone outside inhibitor) is used to control a variety of plant diseases caused by different groups of fungi like water molds, powdery mildews, rusts, downy mildews, and fruit rotters on many plant species of economic importance (Vincelli, 2012). This group of fungicides inhibit fungal respiration at the Qo site in mitochondria and block the energy supply (Selim and Khalil, 2021). Genetic resistance is the most economic, safe, and friendly control measure to the environment (Ma *et al*., 1997), but it is required that farmers adopt the wheat cultivars with new resistance genes, that are being generated for northwest Mexico and other wheat-producing regions in the country, by the collaborative program between the National Institute for Forestry, Agriculture, and Livestock Research and the International Maize and Wheat Improvement Center.

4. CONCLUSIONS

The presence of leaf rust in southern Sonora, Mexico, was detected on January 21 in the Huatabampo region, where the first two weeks of the year 2022 had over 76% relative humidity with a maximum of 93.52 and 90.39%, respectively, and with 30 hours each of both weeks of temperature ranging from 18 to 22°C which is favorable for the causal agent. The percentage of pilot commercial wheat fields monitored by the Local Plant Health Councils which had leaf rust infection were 100% for Huatabampo, 70.52% for the Yaqui Valley, and 68.69% for the Mayo Valley. The timely application of fungicides and the climate that prevailed from the second fortnight of January to March contributed to control the disease as well as in the general good grain yield obtained in southern Sonora.

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