

Impact of weather on occurrence of brown rust of wheat in southeast of the Lublin region Poland

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ABSTRACT

Twenty years (1976 to 1995) data on incidence of brown rust disease (*Puccinia recondita*) of winter wheat recorded from different districts of Lublin region, Poland was analysed to find out the effect of weather parameters on disease development and its intensity. Periods were separated based on infection spread over 50% of the crops, and those where infected percentage was less than 30%. The correlation coefficients (r) between the volume of the infected wheat by *Puccinia recondita* and weather parameters during different phases of wheat were calculated. The results indicated a complex influence of weather conditions on the development of *Puccinia recondita*. The most significant effect on the scale of the infection of winter wheat was cloud cover, number of days with dew, amount of rainfall and number of days with precipitation. In the case of more than 50% of the infected plants, the most important parameters were number of days with fog, relative humidity, low humidity and cloud cover.

Keywords: Winter wheat, brown rust, *Puccinia recondita*, growth stages, weather conditions

Weather conditions affect the growth and development of plants significantly. Agrometeorological studies apply methods which define comprehensive influence of meteorological elements on plants using statistical and empirical methods (Górski 1996). The consequence of a significant proportion of cereals in cropping patterns is the intensified appearance of diseases caused by fungi, which can be the reason of the significant crop losses of 20 to 45% (Jończyk 1999). Increase in air and soil temperature, caused by global climate changes, has an influence on soil microbial activity, thus on the occurrence of pathogens (Pregitzer 1993). In higher temperature and higher content of CO₂ in the atmosphere, photosynthesis can be more intensive than it is currently. Therefore the tissue of certain species of plants may be more susceptible to infections (Wong 1990). From an economic point of view, the forecasts produced for effective protection against adverse weather conditions have an important role to play in the agro meteorological research. Most of these studies used a multiple regression technique. The 7 or 14 day observations are used in the prediction models to examine relationships between the development of the disease and biological and weather variables (Kuna-Broniowski 1999, Waggoner et al. 1980). There are also adequate systems that use air temperature and total precipitation data (Murali 1991, Secher 1991). These

systems allow the so-called 'index of the risk of infection' to be determined. The quality of these forecasts is very limited due to the possibility of random phenomena, which often disturb expected developments.

The purpose of this study is to assess the impact of weather conditions on the occurrence of brown rust caused by *Puccinia recondita* in winter wheat fields, in the southeast of the Lublin region.

MATERIALS AND METHODS

The study is based on observations that were conducted for 20 years (1976-1995) in four districts viz. Bigorajski, Hrubieszowski, Tomaszowski and Zamojski (Table 1) of southeast of the Lublin region. The weather elements viz. air temperature (°C), sunlight hours (hr) and cloudiness (a scale of 1 to 10), relative humidity (%), and saturation deficit (hPa), wind speed (ms⁻¹), total precipitation (mm), number of days with the weather events such as rainfall, fog or mist and dew recorded at four stations were used. Ten day means total were calculated.

Disease observations

The observations on wheat infested by pathogens (*Puccinia recondita*) were conducted annually on fifteen research sites, in each of the districts. From 1 ha of wheat

Table 1: The list of weather stations included in the study

Locality	Latitude	Longitude	Altitude(m)	District
Zamoœæ	50°42'	23°15'	212	Zamoœæ
Tomaszów Lubelski	50°27'	23°25'	273	Tomaszów Lubelski
Werbkowice	50°45'	23°46'	204	Hrubieszów
Podhajce	50°32'	23°44'	220	Tomaszów Lubelski
Zwierzyniec	50°42'	23°15'	212	Zamoœæ
Bi³goraj	50°33'	22°43'	190	Bilgoraj

Table 2: Development phases of wheat, dates of disease observations, and the average infestation by *Puccinia recondita* in Lublin region

Year	Period of development phases			Dates of disease observations	Percentage (%) of infestation
	Start of spring vegetation	Stem formation	Heading		
1976	April 1-20	May 1-20	June 1-20	June 16-July 19	49.7
1977	March 11-20	April 21-May 10	June 1-10	June 29-July 25	46.8
1978	April 1-20	May 1-June 10	June 21-30	July 11-21	51.1
1979	March 21-April 20	May 11-20	June 1-10	July 2-16	48.1
1980	April 1-20	May 11-31	June 1-30	July 4-17	29.1
1981	March 21-31	May 1-20	June 1-10	July 8-19	53.9
1982	April 1-10	May 1-20	June 1-20	June 23-July 12	57.0
1983	March 21-31	April 21-30	May 21-31	June 13-July 27	80.1
1984	April 1-10	May 1-10	June 1-10	June 20-July 18	54.6
1985	March 21-April 10	May 1-10	May 21-June 10	June 17-July 16	46.2
1986	March 21-31	April 11-30	May 21-31	June 24-July 11	46.8
1987	April 1-10	May 1-10	June 21-30	June 25-July 15	36.7
1988	April 1-10	May 1-10	June 1-10	June 21-July 14	34.4
1989	March 11-31	April 11-30	May 21-31	June 14-30	44.8
1990	Feb 21-March 20	April 21-30	May 21-31	June 16-25	25.5
1991	March 21-31	May 1-10	June 11-20	June 16-27	8.5
1992	March 21-31	April 21-30	June 1-10	June 10-July 10	8.5
1993	April 1-20	April 21-May 10	May 21-June 10	June 14-July 7	10.6
1994	March 21-April 10	April 21-May 10	June 1-10	June 15-29	4.1
1995	April 1-20	April 21-30	June 1-10	June 19-30	23.6
(x)	Feb 21-April 20	April 21-June 10	May 21-June 30	June 13-July 27	38.0

Table 3: Mean and standard deviation of weather parameters during different phases of wheat

Weather parameters:	Phase I		Phase II		Phase III	
	Mean	SD	Mean	SD	Mean	SD
Tmean (°C)	8.0	0.8	14.5	1.8	16.3	1.2
RHmean (%)	76.3	4.1	76.5	4.1	77.8	4.1
VPD (hPa)	3.9	0.6	5.7	1.3	5.9	1.5
Wind speed (ms ⁻¹)	3.4	0.4	3.0	0.4	3.1	0.5
Average cloudiness (1-10)	5.6	0.8	5.3	1.1	5.5	1.1
Sunlight hours (h day ⁻¹)	4.7	1.5	8.1	2.3	7.6	3.5
Precipitation (mm)	62.7	34.8	69.6	25.5	71.0	33.5
No. of days with precipitation	19.3	6.2	15.2	5.0	13.5	5.1
No. of days with fog	18.0	8.9	10.5	5.3	10.4	6.9
No. of days with dew	13.6	6.6	16.0	8.9	11.4	7.8

Table 4: The correlation coefficient between the total size of winter wheat's infestation by *Puccinia recondite* and the selected meteorological elements or climatological characteristics in the intermediate stages

Infestation	Phenophase	Significant weather element	Correlation coefficient
Overall infestation	Start of spring vegetation- Stem formation	Average cloudiness (1-10)	0.607
		No. of days with dew	-0.625
	Stem formation-Heading of <i>Puccinia recondite</i>	Average cloudiness (1-10)	0.541
		Precipitation (mm)	0.578
Infestation < 30%	Heading-Appearance of <i>Puccinia recondite</i>	No. of days with precipitation	0.548
		Average cloudiness (1-10)	0.818
Infestation > 50%	Stem formation-Heading	Precipitation (mm)	0.754
		No. of days with fog	0.878
	Heading-Appearance of <i>Puccinia recondite</i>	RHmean (%)	-0.945
		VPD (hPa)	0.847
		Average cloudiness (1-10)	-0.921

field five points (situated diagonally) on each of about 1 m² area, were selected, in which 50 plants were examined. The kind of pathogen, the number and percentage of infested plants in relation to all analyzed plants were determined in a laboratory as per guidelines given by Pruszyński (1993) and Węgorek (1976).

Observations of *Puccinia recondite* were conducted every year in June/July which coincides with the flowering to seed milk maturity phase of wheat. Depending on the degree of infestation diseased, plants were divided into three groups viz. weak infestation: up to 10% of the leaf assimilative areas, medium infestation: from 10 to 30%,

and strong infestation: more than 30% of the leaf assimilative area.

The assumption was that the highest percentage of infested wheat plants was recorded in the years with weather conducive to infections and diseases during the growing season, while in the period when weak infestation was observed, weather reduced the course of a disease.

The growing season of winter wheat was divided into three phases viz.

Phase I: start of spring vegetation – stem formation, Phase II: stem formation – heading, and

Table 5: Regression equation for predicting wheat infestation by *Puccinia recondite* using weather parameters in different phenophases.

Infestation	Phenophase	Regression equation
Total	Start of spring vegetation- Stem formation	$Y = -45.91 + 15.03x$ where: x - Average cloudiness
	Stem formation-Heading	$Y = 60.17 - 1.39x$ where: x - No of days with dew
	Heading-Appearance of <i>Puccinia recondite</i>	$Y = -13.21 + 9.37x$ where: x - Average cloudiness $Y = 13.80 + 0.34x$ where: x - Precipitation $Y = 9.34 + 2.13x$ where: x - No. of days with precipitation
<30%	Heading-Appearance of <i>Puccinia recondite</i>	$Y = -20.68 + 7.91x$ where: x - Average cloudiness $Y = 2.76 + 0.28x$ where: x - Precipitation
>50%	Stem formation-Heading	$Y = 32.14 + 2.19x$ where: x - No of days with fog
	Heading-Appearance of <i>Puccinia recondite</i>	$Y = 342.60 - 3.54x$ where: x - RHmean $Y = 14.14 + 8.726x$ where: x - VPD $Y = 143.82 - 13.67x$ where: x - Average cloudiness

Phase III : heading – appearance of *Puccinia recondite*.

Observational materials were subjected to statistical analysis. The correlation coefficients (r) between the size of wheat's infestation caused by *Puccinia recondite* and the mean and sum values of the selected climatological elements and characteristics during different stages of wheat were carried out. In addition to overall analysis correlation and regression were also worked out separately for disease infestation less than 30% and more than 50%. The linear regression of type: $Y = a + bx$ – were developed. Where,

Y – infestation of winter wheat by *Puccinia recondite*. x – value of the selected meteorological elements or climatological characteristics in the following intermediate stages. a – absolute term and b – coefficient of regression equation

RESULTS AND DISCUSSION

It may be noticed that the start of spring vegetation was as early as during 21-28 February in year 1990 and as late as during 11-20 April in different years: similarly the stem formation was observed the 11-20 April to 21-31 May, whereas heading was observed between 21-31 May to 21-30 June (Table 2). At that time, infestation by *Puccinia recondita* in winter wheat fields reached the average value of 38.0% ranging from 4.1% in 1994 to 80.1% in 1983. Such a significant degree of infested plants in various years gives grounds to a supposition, that the weather conditions may affect the degree of infestation. Since the condition of the plants during the growing season depends on their

development, it is advisable to present the course of the particular meteorological elements in the following intermediate stages. The mean value of the analyzed meteorological elements and climatological characteristics in different phases are shown in Table 3.

A comparison of average value of each meteorological element to the size of winter wheat's infestation by *Puccinia recondite* showed a significant correlation ratio between certain variables. From among the studied meteorological elements a substantial impact on winter wheat infestation have cloudiness in the first period $r=607$, the number of days with dew and cloudiness in the second period, precipitation and the number of days with precipitation in the third period i.e. from heading to the emergence of the pathogen (Table 4). These connections are described in Table 5.

Implementing the methodical assumption that the highest percentage of infested wheat plants was recorded in the years with weather conducive to infections and diseases during the growing season, the course of weather in intermediate stages over the years with different degree of infestation was analyzed. With the wheat's infestation which did not exceed 30% of infested plants, significant correlation ratio between the average cloudiness and total precipitation in the period from heading to the appearance of infestation by *Puccinia recondita* took place (Table 4).

In five of the considered twenty years, the infestation of winter wheat was massive and exceeded 50%. During these years, the significant correlation ratio with infestation by *Puccinia recondita* was recorded in the periods from stem formation to heading as well as from heading to the

appearance of the pathogen (Table 4). Equations which describe these correlations are presented in Table 5. In light of these obtained results, the decrease in humidity, thus increase in saturation deficit and little cloudiness in the period between heading and appearance of the pathogen stimulate (over 50%) the significant infestation of winter wheat by *Puccinia recondita*. These results seem to be in contradiction with the results according to which the increase in cloudiness and precipitation during the period from heading to appearance of the pathogen stimulates the size of wheat's infestation (overall degree and infestation < 30% of all plants). The answer to this problem must be sought in weather conditions in earlier periods of wheat growth. This is because weather conditions in intermediate stages viz. start of spring vegetation – stem formation or – stem formation – heading affects the size of wheat's infestation. In interpreting the results it should be noted that such weather conditions as wet beginning of the growing season (lots of cloud), rather the dry period from stem formation to heading (a small number of days with dew) and the wet period from heading to the appearance of the pathogen (lots of clouds, high precipitation and large number of days with rain) are conducive to the infestation of wheat by *Puccinia recondita*. A large number of days with fog or mist, which indicate high humidity in the period between stem formation and heading, and the dry following growing season (low humidity, high saturation deficit, little cloudiness) are conditions prone to the massive occurrence of infestation by brown rust.

CONCLUSIONS

Presented results show the complexity of the issues concerning the relation between weather conditions and the size of winter wheat's infestation by *Puccinia recondite*. The meteorological elements viz. cloudiness, the number of days with dew, total precipitation and the number of days with rain, had the impact on the size of winter wheat's infestation. In a case of the infestation exceeding 50% of all observed plants, the significant elements were the number of days with fog, relative air humidity, saturation deficit and cloudiness. The conducted studies show the need to continue and expand the research using automatic station network. These studies would allow assessing the impact

of daily variations of weather conditions on wheat infection by this pathogen.

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