THE USE OF THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) TO ASSESS THE EPIDEMICS OF SEPTORIA TRITICI IN WINTER WHEAT

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Abstract:*Septoria tritici blotch (STB) caused by the ascomycete fungus Mycosphaerella graminicola (anamorph S. tritici) is currently one of the most serious foliar disease of wheat in Europe and other world regions characterized by temperate and wet environment during growing season. Twenty-five wheat genotypes with different resistance levels were evaluated in natural conditions for their reaction to S. tritici attack during 2009-2010 year. The experimental design was a randomized block design with three replications. Disease rating was visually recorded by using the double-digit scale (00-99) in two different times and crop stages (Z53-1/4 head out and Z70-milk development). There were also calculated the Septoria Progress Coefficient (SPC) and Area under Disease Progress Curve (AUDPC) for each wheat genotype evaluated. SPC was low for the higher genotypes comparatively with the shortest ones leading to the conclusion that disease progress is higher as plant height is low (r=-0,8584***). The same aspect was also emphasized by the negative correlation between plants height and disease progress height (r=-0,7241**).The shortest genotypes showed higher necrosis percentage and AUDPC values. There was also a correspondence between genotype susceptibility and AUDPC showing that the most susceptible wheat cultivars recorded higher AUDPC values. Thus, Renan (295), Esential (231), Renesansa (234), Autan (186) recorded the highest AUDPC values while Aztec (45), Meunier (41) and Capo (20) had the best resistance reaction to S. tritici attack. Comparatively with the control Briana cultivar (AUDPC = 153), created to ARDS Simnic, the differences recorded by Renan, Renesansa Esential, Ciprian, Exotic, Cezanne, Aztec, Capo and Meunier were statistically significant. There was also a negative correlation between AUDPC and yield (r=-0,5140). The Area under the Disease Progress Curve (AUDPC) can be an efficient instrument to evaluate the epidemic development of foliar pathogen S. tritici considering each genotype susceptibility and specific architecture.*

Key words: *AUDPC, disease, SPC, S.tritici blotch, wheat*

INTRODUCTION

Septoria tritici blotch (STB) caused by ascomycete fungus *Mycosphaerella graminicola* is currently one of the most important foliar disease of wheat (*Triticum aestivum* L.) in Europe (Poley and Thomas 1991; Eyal 1999) and is among the top two of three most economically damaging diseases of this crop in the United States (Ponomarenko et al., 2011). Yield losses attributed to heavy incidences of disease range from 31% to 53% depending on cultivars, infection stage and disease severity (Eyal, 1981; Kia et al., 2006a,b). The disease occurs particularly in temperate, high-rainfall environments (Van Ginkel and Rajaram, 1993) and the symptoms are characterized by necrotic blotches on wheat leaves that contain asexual and sexual fructifications (Shaw and Royle 1989; Eyal 1999; Hunter et al. 1999). The telemorph is considered to be largely responsible for the over-summering of the disease and the anamorph mainly contributes to disease development during the growing season, showing that M. graminicola is able to complete several generations of ascospores after the establishment of the disease in autumn, a finding of considerable epidemiological importance (Shaw and Royle, 1989, 1993). Because extensive application of fungicides increase worldwide the economic costs attributed to STB many previous researches were focused on cultural management as well as genetic resistance of cultivars. Also an important attention was done to wheat canopy architecture as escape mechanism (Rosielle 1972; Parleviliet 1977; Jlibene et al. 1992; Simon et al. 2005) knowing that rainfall splash plays an important role in pathogen spreading (Scharen 1999; Chung et al. 2000). The study of Septoria tritici evolution within wheat mixtures has been studied also by previous authors, but the pathogen evolution and the impact of disease progression in the field were not well understood in pathosystems that vary quantitatively for resistance and pathogenicity (Browning and Frey 1969; Jeger et al. 1981; Wolfe 1985; Manthey and Fehrmann 1993; Garret and Mundt 1999; Finckh et al. 2000; Cowger and Mundt 2002). Wheat mixtures are predicted to be less effective in suppressing disease when initial inoculum is abundant and well distributed (Mundt et al. 1995; Abbott et al. 2000). Thus, using Area under Disease Progress Curve (AUDPC) it was assessed disease severity in the field plots in order to help evaluate the utility of cultivar mixtures for managing Septoria tritici disease.

MATERIAL AND METHODS

Field plots of winter wheat were established during 2009-2010 growing season at the Agriculture Research and Development Station Simnic-Craiova in the Breeding and Plant Protection Laboratory on brown reddish soil (pH 5,6; humus 1,8%). Twenty-five winter wheat cultivars with different origin and resistance levels were evaluated in natural conditions for their response to *Mycosphaerella graminicola (*anamorph *S. tritici)* attack. Plants received a balanced starter fertilization preplanting with 40 kg N/ha and 40 kg P_2O_5 kg/ha basal applied and top-dressed with 60 kg N/ha on early spring (March). Seedling was done on the 15th of October 2009 using a seed rate of 550 grains/m^2. The experimental design was a randomized complete block design with three replications. Disease rating was visually recorded as soon as the first symptoms appearance on the lowest leaves two times with 10 days interval using the double-digit scale (00-99) developed as a modification of Saari and Prescott`s severity scale to assess wheat foliar diseases (Saari and Prescott 1975; Eyal et al. 1987) in two different crop stages (Z53-1/4 head out and Z70-milk development). The first digit (D_1) indicated vertical disease progress on the plant and the second digit (D_2) refers to severity measured as diseased leaf area. For each score, disease severity percentage was calculated based on the following formula (Sharma and Duveiller 2007):

$$\% \text{ severity} = (D_1/9)\ (D_2/9)\ 100$$

Growth stages of plants were recorded according to the Zadoks scale (Zadoks et al. 1974) modified by Tottman and Makepeace (Tottman and Makepeace 1979). Area under the Disease Progress Curve (AUDPC) was calculated for all varieties according with the following function (Shaner and Finney 1977):

$$\text{A.U.D.P.C.} = \sum_{i}^{n-1}\left[\left\{\frac{Yi + Y(i+1)}{2}\right\} x(t(i+1) - ti)\right]$$

in which *Yi* = disease severity on the *i*th date; *ti* = *i*th day; *n* = number of dates on which Septoria Tritici Blotch was recorded. To evaluate disease progress considering wheat plants stature was used Septoria Progress Coefficient (SPC) following the formula (Eyal and Ziv, 1974):

$$\text{SPC} = \text{disease height (cm)/Plant height (cm)}$$

in which Disease height (cm) = the maximum height (cm) above ground level at which the picnidia of S. tritici could be found on green plant tissue. This coefficient allows the comparison of infected placement on cultivars with different plant stature. The correlation coefficient (r) was also calculated according with the following formula (Pearson and Hartley, 1970):

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

The control was Briana, a Romanian wheat variety created to ARDS Simnic-Craiova. Means for the yield were separated using least significance differences (LSD) at the 1% to 5% level of probability. Statistical analysis involved analysis of variance procedure (Saulescu, 1967).

RESULTS AND DISCUSSION

The results of the experiment suggested that STB severity depends mainly on climatic conditions and resistance level of studied varieties. Humidity played an important role in all stages of the infection cycle of the pathogen, pycnodiospores having the most importance as secondary inoculums and disseminated mainly by rain splashing (Scharen, 1999; Chung et al., 2001). Gene rotation, cultivar mixtures and other resistance deployment strategies might be useful to sustain the stability of resistance to Septoria tritici blotch (Ahmed et al., 1996). Cultivar mixtures influenced *Mycosphaerella graminicola (*anamorph *S. tritici)* severity differently. Resistant varieties were more stable across environments then susceptible varieties.

The varieties which recorded higher AUDPC values showed severe necrotic blotches of the foliage that were filled with the asexual and sexual fructifications according with those previously mentioned by other authors (Shaw and Royle, 1989; Eyal, 1999; Hunter et al., 1999). Performances in mixtures in suppressing STB varied among tested wheat varieties. Thus, comparatively with the control the most stable varieties were Meunier, Aztec,Exotic,Capo,Cezanne and Ciprian while the most sensitive were Renan, Renesansa and Esential, aspect emphasized also by AUDPC values (Table 1). It was also observed that the AUDPC of the control exceeded the average value of the experiment, leading to the conclusion that also Briana is a wheat variety susceptible to Septoria tritici blotch. The results suggested that in this pathosystem climatically conditions may be an important determinant of infection levels in a given mixture tend more toward those of the resistant or the susceptible component. Whatever, previous findings (Cowger and Mundt, 2002) showed that the interactions of resistance components with environment would be required to alter the effects of host diversity on disease progression qualitatively from year to year (Cowger and Mundt, 2002). The different levels of pathogen aggressiveness on susceptible cultivars as compared with less susceptible ones can be explained by differences in variances in aggressiveness when the pathogen is on different host genotypes.

Ahmed and coworkers (1996) showed also that cultivar mixture beside gene rotation and other resistance deployment strategies might be useful to obtain stability of resistance to Septoria tritici blotch. Previous findings showed also that escape mechanisms, like plant height and heading date, reduce the chance of contact between pathogen and host (Parleviliet 1977; Jlibene et al., 1992; Simón et al., 2004, 2005), so these mechanisms should be taken into account. Reduced plant height was usually associated with more necrosis due to the highest necrosis percentage of the shortest lines. The greater plant height was strongly associated with reduced AUDPC values in the tested wheat mixture leading to the conclusion that vertical progress of Septoria tritici from lower to upper leaves is affected by the distance between consecutive leaves („the ladder effect”). Thus, for tall cultivars the Septoria progress was lower comparatively with dwarf and semidwarf cultivars (Fig.1).

Table 1

Area under Disease Progress Curve (AUDPC) and Septoria Progress Coefficient (SPC) recorded in the mixtures of winter wheat naturally infected with *Mycosphaerella graminicola* (anamorph *S. tritici*) in 2009-2010

No.	Variety	AUDPC	± Signif.	Plant height (cm)	STB height (cm)	SPC*
15	Renan	295	142**	67	56	0,83
18	Renesansa	234	81*	68	47	0,69
8	Esential	231	78*	75	42	0,56
20	Autan	186	33	60	48	0,80
11	GK David	165	12	63	48	0,76
12	Fridoline	161	8	73	50	0,68
1	Briana	153	Control	74	41	0,55
14	Apache	143	-10	68	44	0,64
23	Martina	140	-13	64	51	0,79
25	Bercy	138	-15	75	38	0,51
4	Boema	113	-40	82	22	0,27
13	Josef	110	-43	72	42	0,58
7	Moldova 83	102	-51	85	23	0,27
3	Dropia	96	-57	71	29	0,41
24	Pobeda	89	-64	67	44	0,65
9	Magistral	88	-65	71	43	0,60
5	Flamura 85	82	-71	69	40	0,58
2	Glosa	79	-74	89	30	0,33
10	Karligash	70	-83	92	32	0,34
6	Ciprian	67	-86^{o}	82	42	0,51
17	Exotic	53	-100^{o}	65	50	0,77
22	Cezanne	52	-101^{o}	73	33	0,45
21	Aztec	45	-108^{oo}	76	34	0,45
16	Meunier	41	-112^{oo}	72	39	0,54
19	Capo	20	-133^{oo}	76	29	0,38
	Average AUDPC	118				

LSD 5%=71; 1%=123; 0,1%=245

*SPC = Septoria Progress Coefficient

The lower distance between consecutive leaves facilitated the contact between newly emerging leaves and splashed pycnidiospores leading to an earlier occurrence of pycnidia on upper parts of dwarf cultivars. SPC was lower for the higher genotypes comparatively with the shortest ones leading to the conclusion that disease progress is higher as plant height is lower (r=-0,8584***) (Fig.2). The same aspect was also emphasized by the negative correlation between plants height and disease progress height (r=-0,7241**) (Fig.3). There were also cultivars for which the pathogen progressed only to basal or middle level and the AUDPC values were not necessarily low. However, previous findings showed that under severe epidemics the difference in plant architecture and stature of susceptible cultivars are no important for pathogen (Eyal et al. 1987).

Most yield loss studies on STB showed relationships between disease severity on the upper one and three leaves and yield (King et al., 1983 a, b). The greatest risk to a crop is the occurrence of conditions that favor spore dispersal during and shortly after flag leaf emergence. James (1974) showed that crop loss is related to total leaf area infected including necrotic lesions and chlorotic flakes. Also, previous findings showed that necrosis were high correlated with reduction of kernel weight (TKW) (Forrer and Zadoks, 1983).

In the present study the severity of the pathogen attack on the flag leaf was generally low, explained also by the negative but not significant correlation between AUDPC and yield (r=-0,5150) (Fig.4).

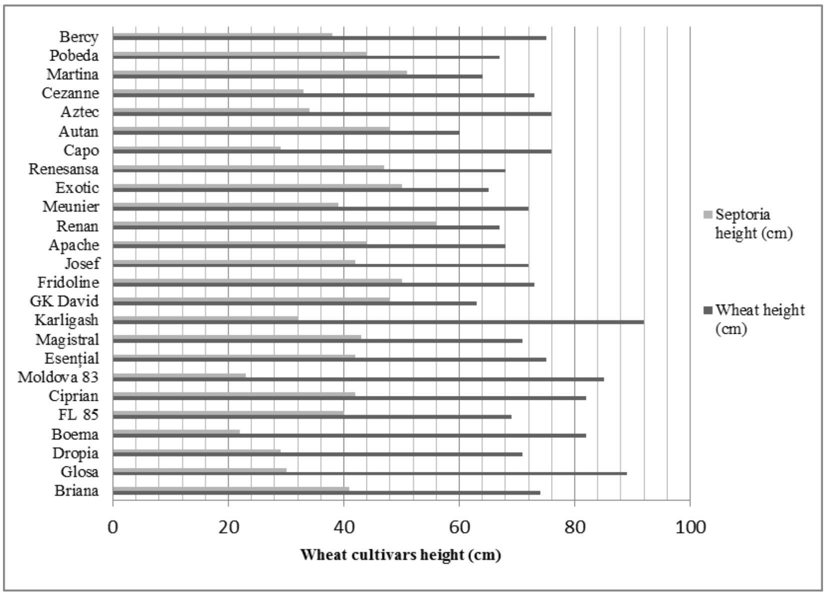

Fig. 1. The progress of *Mycosphaerella graminicola* (anamorph *S. tritici*) on different wheat cultivars in ARDS Simnic in 2009-2010

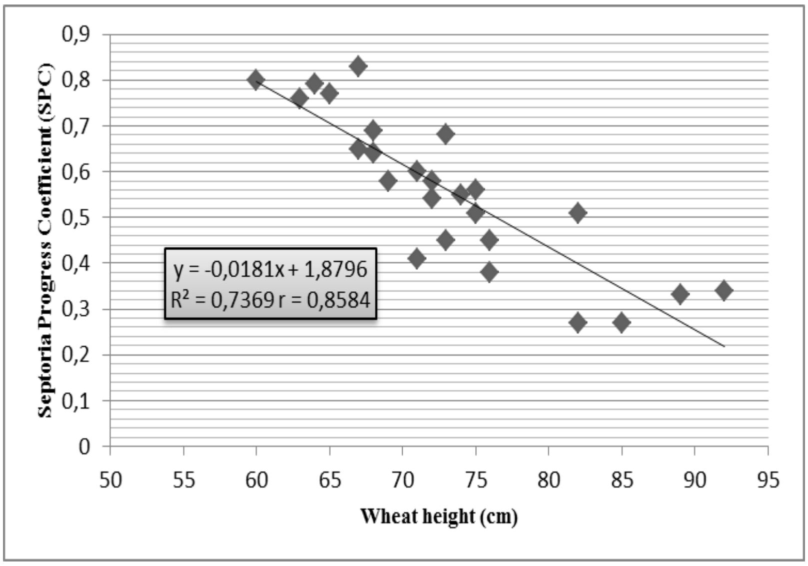

Fig. 2. Relationship between wheat height and *Septoria* Progress Coefficient in ARDS Simnic in the conditions of 2009-2010

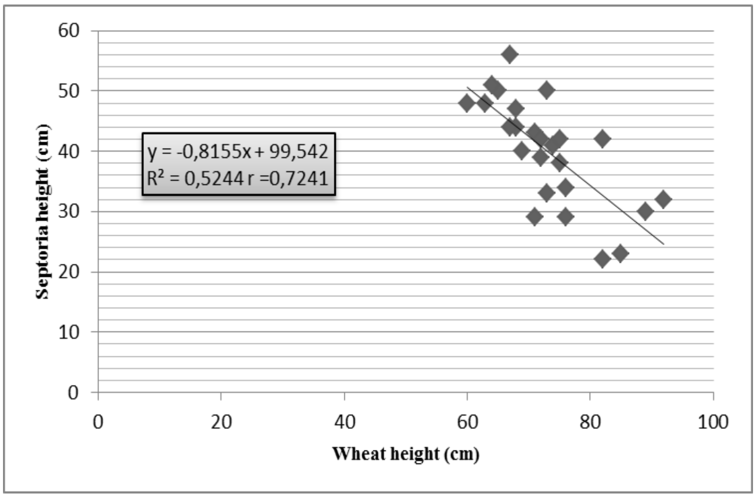

Fig.3. Relationship between wheat height and *Septoria* Height in ARDS Simnic in the conditions of 2009-2010

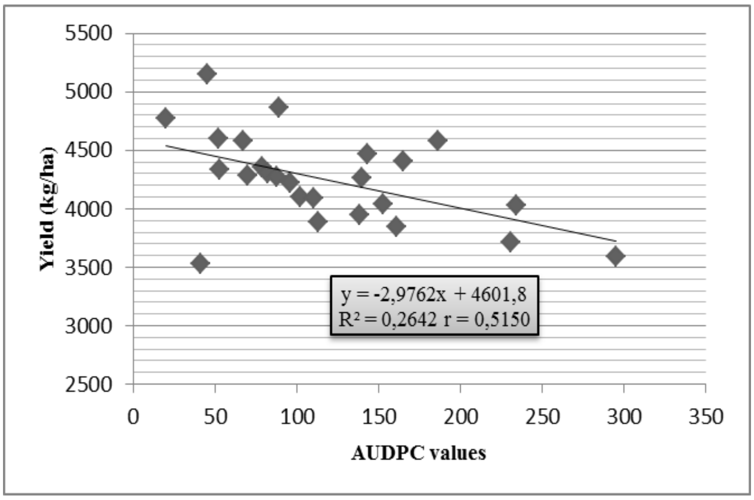

Fig.4. Relationship between AUDPC values and cultivars yield in ARDS Simnic in the conditions of 2009-2010

CONCLUSIONS

The mixture effect on *M. graminicola* (anamorph *S. tritici*) appears variable and environmentally influenced. The relationship between wheat plant height and mixture resistance indicates that management of wheat cultivars should be optimized to reduce the STB severity. Thus, the greater plant height was strongly associated with lower AUDPC values reducing the chance of contact between pathogen and host. Shortest genotypes showed higher necrosis percentage and AUDPC values. There was also a correspondence between genotypes susceptibility and AUDPC showing that the most susceptible wheat cultivars recorded high AUDPC values. The most susceptible wheat cultivars were Renan, Esential, Renesansa and Autan while Aztec, Meunier and Capo had a better resistance reaction to S. tritici attack.

The Area under the Disease Progress Curve (AUDPC) can be an efficient instrument to evaluate the epidemic development of foliar pathogen *S. tritici* considering each genotype susceptibility and specific architecture.

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