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Controlling Foliar Blight of Wheat in South Asia: A Holistic Approach

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Abstract: Foliar blight is a major biotic constraint to wheat in the Gangetic plains of south Asia, particularly in the rice-wheat system. The disease occurs as a complex of spot blotch and tan spot caused by *C. sativus* and *P. tritici-repentis*, respectively. Yield losses reach on average 15% but are variable depending on sowing time, years, locations and stress conditions. Resistance breeding has been the cornerstone of the control strategy. Through international agricultural research efforts in collaboration with National Agricultural Research Systems (NARS), resistance sources from China, Zambia and Brazil were identified and novel germplasm such as synthetic hexaploid wheats derived from crosses with *Aegilops tauschii* and tetraploid wheat were generated. Materials resulting from these pre-breeding activities are now combined to adapted spring wheat to produce new high yielding genotypes showing a lower disease progress. On-going regional efforts include several wheat nurseries jointly organized by CIMMYT and NARS and specially targeted for warmer wheat growing areas. The stability of resistant genetic stocks remains essential considering that *C. sativus* is non-specific and forms a continuum of strains that may change rapidly. Although high moisture and temperature are known to favor the disease, little information is available on the exact role of climatic factors on symptom development. Stress factors appear to influence to a great extent disease progress and epidemics, suggesting that crop management practices are a critical component of an integrated disease control. Thus, understanding their role on foliar blight seems imperative when the increasing adoption of zero tillage in rice-wheat may affect inoculum survival and when genotypes more adapted to new tillage practices will be required. The role of alternate hosts and the source of primary inoculum in rice-wheat systems are still not well documented but indications suggest that seed may play an important role in disease transmission. Seed treatment may prove useful as a part of an integrated disease management approach based on improved resistance and good agronomy.

Key Words: Breeding zero tillage, Foliar blight, Resistance breeding, Wheat

Introduction

In south Asia, spring wheat (*Triticum aestivum* L.) is grown during winter from November-December to March-April. After the impressive progress in controlling leaf and stem rusts in modern varieties during and after the green revolution, foliar blight has recently emerged as the most important biotic constraint of second-generation wheat genotypes in warmer areas, in particular in the intensive rice-wheat system which covers 13 millions hectares in the subcontinent. The disease often occurs as a complex of spot blotch and tan spot caused by *Cochliobolus sativus* (Ito & Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana*) and *Pyrenophora tritici-repentis* (Died.) Drechsler (anamorph *Drechslera tritici-repentis*), respectively. In breeding programs where the fungi old names are still widely used (Maraite, 1998), it is commonly referred to this disease complex as helminthosporium leaf blight (HLB). In field conditions of south Asia, the anamorph stage of both pathogens is found. In the case of spot blotch, the teleomorph stage has only been reported to occur in Zambia. The tan spot pathogen teleomorph stage is found in cropping systems where the stubbles decompose slowly and remain on the soil during the next crop or

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season, a situation that is not occurring in rice-wheat system since paddy fields are flooded. In south Asia, the foliar blight becomes more evident in mid-February as a result of rising temperatures and heavy dew that may remain in the crop canopy for several hours on foggy winter days.

Yield losses on average up to 15% vary depending on sowing time, years, locations, and stress conditions (Duveiller and Dubin, 2002). Late wheat sowing reduces yield because flowering coincides with the hot winds or high temperatures that occur at the end of the following *rabi* (winter) season. When the crop is sown after optimum planting time (end of November-early December) or if the soil fertility is low, the effect of disease on grain-yield increases dramatically and may cause up to 34% losses (Sharma and Duveiller, 2003a).

Management of HLB has received more attention in recent years because of the urgent need to increase crop productivity and ensure food security in the warmer wheat growing areas of the Indian Subcontinent (Duveiller et al., 1998; Duveiller, 2002). Moreover, concerns have emerged regarding the sustainability of the rice-wheat system in south Asia, its decreasing total factor productivity (Hobbs and Morris, 1996), the role of foliar blight and the need to adopt new tillage technologies to produce rice and wheat at a lower cost. This paper summarizes the strategy used in south Asia toward a better control of foliar blight of wheat.

Materials and Methods

Field surveys are conducted on regular basis in Bangladesh, India and Nepal to assess the incidence of both pathogens. In Nepal, detailed epidemiological studies were conducted for two years (2001-2002 and 2002-2003) at Rampur (228-masl, 27º 40' longitude and 84º 19' latitude) to evaluate the possible inoculum source of both pathogens, to observe the symptom initiation and production of *B. sorokiniana* and *D. tritici-repentis* spores throughout the wheat season in six genotypes that differed in the level of resistance to HLB. In this study, the amount of air-borne conidia was monitored on a weekly basis during 17 weeks from plant emergence using a Rotorod™ Model 20 sampler (Multidata LLC, St Louis, USA) installed in the research plots to investigate the correlation with conidia formation on wheat leaves.

Since the disease severity increases very fast in the field and small differences indicating partial resistance need to be observed, disease evaluation is usually based on the area under disease progress curve (AUDPC) calculated from minimum three field observations. For each disease rating, the percent diseased leaf area (%DLA) can be assessed on the flag (F) or penultimate leaf (F-1) but this method is time consuming. Alternatively, HLB severity can be visually scored for each plot at weekly intervals 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). The first digit (D_1) indicates the disease progress in height and the second digit (D_2) refers to severity measured as the diseased leaf area. For each score, %DLA was estimated based on the following formula:

$$\% \, DLA = ((D_1/9) \times (D_2/9) \times 100)$$

Individual scores are recorded over a three-week period. The AUDPC is calculated using the percent severity estimates corresponding to the three to four ratings as outlined by Das et al. (1992) and shown below:

$$AUDPC = \sum_{i=1}^{n-1} \left[(X_i + X_{i+1}) / 2 \right] (t_{i+1} - t_i),$$

where, x_i = disease severity on the *i*th date, t_i = *i*th day, and n = number of scoring dates. The AUDPC measures the amount of disease as well as the rate of progress, and has no units.

Because the sustainability of the rice wheat system is questioned, foliar blight severity was also assessed in a long term trial where different level of fertilizers have been used in Bhairahawa (Nepal). Similarly, because sowing time can be advanced by up to 15 days when a resource conserving technique such as zero tillage is used, the effect of sowing time on yield and disease is analyzed to assess the potential impact of changing cropping practices. In a study conducted in two locations in Nepal to assess the effect of stress on disease development, disease severity was compared under optimum and low fertility (Sharma and Duveiller, 2003a).

Pre-breeding efforts are conducted at selected hot spot locations in Nepal and Bangladesh. This includes the evaluation of local and exotic sources of resistance to foliar blight in unreplicated trials to assess genetic stocks. Recent introductions include double haploids, exotic materials from warmer areas (China, Zambia, and Brazil) and wide crosses derivatives. After validation of resistance, the materials are made available to cooperators as parental lines for new crosses and are included in CIMMYT's germplasm bank. Another aspect of the pre-breeding effort is the HMN (Helminthosporium Monitoring Nursery), which is proposed on regional basis to evaluate the resistance stability (genotype x environment). The nursery includes parental materials from different geographical and genetic origins that may not have the proper agronomic type for the region, synthetic hexaploids resulting from crossing tetraploid wheat with *Aegilops squarrosa* (syn. *T. tauschii*) and a few advanced lines produced by breeders in south Asia. A core of entries remains the same over years to assess any change in resistance but several lines are changed every year.

Due to the need of increasing wheat production in marginal areas where the yield gap between farmers' fields and experiment stations is still very high, a new regional breeding effort was initiated to specifically promote materials targeted towards warmer areas. The Eastern Gangetic Plain Screening Nursery (EGPSN), organized in 1997, includes a set of 150 entries proposed by national programs breeders who share their best advanced lines for testing across hot spot locations. Data are summarized by CIMMYT's regional office and returned to cooperators (Ortiz-Ferrara et al., 2003). After evaluation, the best entries are recycled in the national breeding programs or become part of the 'Eastern Gangetic Plain Yield Trial' (EGPYT) before being proposed for release or evaluated directly by farmers through participatory varietal selection (PVS) at the village level. This method is particularly effective as small farmers are able to give their input and choose themselves among a set of advanced materials before new varieties are released, thus increasing the chance of adoption of improved genotypes (Ortiz-Ferrara et al., 2001). Lastly, although fungicide treatments are not a viable option we also assess the benefits of seed treatments on plant establishment by comparing several chemicals available on the local market.

Results and Discussion

Field surveys conducted over several years showed that tan spot is largely overlooked. This reality was particularly well documented in Nepal where *P. tritici-repentis* was isolated easily during four years from samples collected not only in mid-hills where the climate is cooler but also in the warmer lowland areas (Sharma et al. 2003b). *Bipolaris sorokiniana* isolates, unlike rusts, do not show clear virulence patterns and consist of a continuum of strains differing in aggressiveness (Maraite et al., 1998). The epidemiological study conducted at Rampur, showed that *B. sorokiniana* could be isolated from plant tissues sampled as early as the seedling stage whereas *P. tritici-repentis* was isolated on lesions observed at near-booting stage, 10 weeks after sowing. This observation suggests that seed or soil is probably an initial source of inoculum for *B. sorokiniana* whereas the infection by *P. tritici-repentis* might result primarily from air-borne spores possibly coming from alternate hosts (Sharma et al., 2003a). Later in the season, air-borne conidia on the spore trap are predominantly *B. sorokiniana* due to the profuse multiplication of this fungus during secondary infection cycles.

In south Asia it is crucial to favor resource conserving technologies allowing farmers to sow wheat early to avoid post-anthesis heat stress and drastic yield reductions. As indicated, early wheat sowing can be promoted by a range of options such as zero tillage or reduced tillage. Zero-tillage facilitates early wheat sowing by up to 15 days which on average translates to improved yields to the extent of 10-25% over conventional practices. However, early wheat sowing appears characterized by higher HLB severity probably due to the high relative humidity and residual soil moisture that prevails at the beginning of the wheat season. In 2002, we observed that AUDPC could increase by as much as 30% in some varieties sown 15 days earlier. Thus, even though yield increases with early sowing when adopting resource conserving technologies, there might be trade-offs due to lack of resistance to HLB. The effect of seeding date was significant ($P<0.01$) and AUDPC was lower in late planting (Sharma et al., 2003a).

Recent studies of a long-term trial in Nepal showed the important role of potash in reducing foliar blight severity. The AUDPC decreased by 50% when 40 kg of K_2O was applied in a deficient soil (Regmi et al., 2002). Potassium prolongs the canopy's stay-green character.

Many locations in south Asia present potassium deficiencies, and yet most farmers do not apply this nutrient for several socio-economical reasons. Similarly, when farm-yard manure (FYM) is applied (10 t/ha), the AUDPC drops by 30%, suggesting not only that FYM contains a significant amount of potassium, but that copious levels of organic matter are beneficial and reduce disease severity. The study conducted at two locations in Nepal in 2002 (Table 1) showed that foliar blight severity (AUDPC) and yield losses (grain yield and thousand kernel weight) are higher when soil fertility is low, confirming that non-specific pathogens causing foliar blight are favored when the crop is under stress.

Genetic stocks are currently tested at specific hot spot sites like Rampur and Bhairahawa to confirm the resistance of parental lines. Some of the best entries are given in Table 2. Sources of resistance include wheat materials from China, Zambia and Brazil and novel

Table 1. Mean AUDPC and reduction in grain yield and thousand kernel weight due to foliar blight under optimum and low soil fertility: averaged over three genotypes at two sites (Rampur and Manara) in 2001-2002 in Nepal (** = P<0.01).

Applied Fertilizer (Kg/ha)A $N:P_2O_5:K_2O$	AUDPC	Reduction due to foliar blight					
		Grain yield (Kg/ha)			Thousand kernel weight (g)		
		Non-sprayed	Sprayed	Loss (%)	Non-sprayed	Sprayed	Loss (%)
120-60-40	414	2583	3144	17.8**	35.0	42.3	17.4**
0-0-0	544	1050	1602	34.5**	30.4	41.0	25.9**
Loss (%)		59.3**	49.0**		13.2**	3.2	

Table 2. Wheat genotypes among genetic stocks observed in Rampur (Nepal) in 2002-2003 with a particularly low HLB level ranging from 51 to 62 (00-99 double digit scale).

Parentage	Heading Date	Diseases March 10 2003 HLB	Leaf rust
(205)/5/BR/2*3/4/IAS55*4/CI14/23/3/IAS55*4/EG.AUS//IAS55*4/ALD	20-Feb	51	0
CHIRYA-7	22-Feb	51	0
MILAN/SHA7	21-Feb	52	0
SERI82//VEE"S"/SNB"S" LAJ3302/TURACO//TURACO	25-Feb	52	0
NL838 = ATTILA	27-Feb	52	0
PBW 343	26-Feb	52	0
SW89-3064	28-Feb	52	0
Mayoor//TK SN1081/Ae.squarrosa(222)/3/FCT	25-Feb	52	0
SW89-3060	3-Mar	52	0
Mayoor//TK SN1081/Ae.squarrosa(222)/3/FCT	23-Feb	52	0
GAN/AE.SQUARROSA(236)//CETA/AE.SQUARROSA (895)/3/MAIZ/4/INQALAB91	23-Feb	53	0
BL 2637=YAV 3/SCO//JO96/CRA/3/YAV 79/4/AE.SQ(498)/5/W 174.6.SC2.1	24-Feb	53	0
Mayoor//TK SN1081/Ae.Squarrosa(222)/3/FCT	24-Feb	53	0
DOY1/Ae.squarrosa (447)//CETA/Ae.squarrosa (895)/3/MAIZ/4/Inqalab91	25-Feb	53	0
BL2499=CBRD/CHIR3	19-Feb	60	0
NL 750=CIGM87B1.116B	20-Feb	62	0
BL 1905=ZSH12/HLB19//NL297	20-Feb	62	0
BL 1970=NL297*2/DANIAL88//HLB18	20-Feb	62	14
CHIRYA- 3	22-Feb	62	0
SW89-5422/NL251	12-Feb	62	10
RR21 (check)	11-Feb	85	0

germplasm such as synthetic hexaploid wheats derived from crosses with *Aegilops tauschii* and tetraploid wheat. In China, genotypes from Heilongjiang, Sichuan and the Yang Tze River valley are characterized by a very short and efficient grain filling period resulting from the warmer conditions occurring at the end of the growing season in these areas, a trait that may explain a better resistance to foliar blight and again underlines that resilience to stress conditions is important to limit the disease.

An analysis of the performance of 17 common genotypes included in the HMN in three cropping seasons (2000-2002) is presented in Figure 1 showing a biplot based on decreasing average resistance (higher AUDPC) comparing to an ideal genotype average computed from field observations (Yan and Kang, 2002). Results confirmed the superiority of entries from China and novel sources of resistance such as derivatives from synthetic hexaploid wheats and *Ae. squarrosa* crossed to Chinese or CIMMYT materials. It also indicates the degree of similarity between testing locations which in turn can help scientists to decide on the relevance or not of testing materials at each of the sites and reduce unnecessary research costs.

Interestingly, the best grain yield performance is not necessarily obtained by entries scoring a low AUDPC as shown in recent results from the EGPSN (Ortiz-Ferrara et al., 2003). This observation underlines the importance of general adaptation to the environment, particularly to abiotic stresses such as heat. It also confirms that resistance to foliar blight is still moderate and needs further improvement. No source of resistance gives high resistance in early maturing genotypes, although there are several materials combining high yield and low disease infection (Table 3). Better resistance levels in adapted genetic backgrounds may be obtained through the use of careful crossing and selection methods (Sharma and Duveiller, 2003b).

Since the primary source of foliar blight inoculum is not exactly known, appropriate management practices that enhance crop establishment and plant health at an early stage are critical. Options for controlling tan spot and spot blotch include sowing disease-free seed. Preliminary results using fungicide seed treatments indicate that the effect of these seed treatments on the number of infected seedlings per m^2 was not significant. However, there was an effect ($P<0.01$) on plant establishment and tillering vigor suggesting that these options should be considered. But due to the overwhelming importance of airborne inoculum of this polycylic disease, this effect does not translate in a significant increase in grain yield (Table 4).

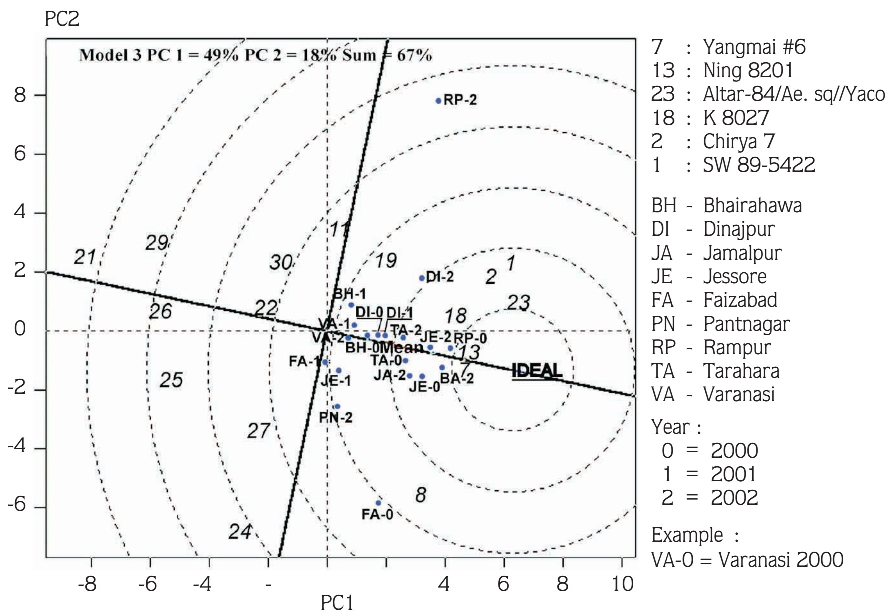

Figure 1. Biplot comparing 17 genotypes to an ideal cultivar based on decreasing resistance to foliar blight (AUDPC) in 19 environments of south Asia.

Table 3. Top 20 entries for higher grain yield (GYP, gram/plot) in the 5th EGPSN at 13 locations in the Eastern Gangetic Plains (2001-2002): days to heading (DH), thousand kernel weight (TKW), highest disease score (% diseased leaf area), AUDPC and ranking out of 150 lines.

Genotype	GYP	Rank	TKW	Rank	DH	Rank	HDS%	Rank	AUDPC	Rank
Shatabdi (=MRNG/BVC//BLO/PVN/3/PNB 81)	413	1	41	21	76	101	65	40	320	46
CHIRYA-3 (HLB Resistant Check)	411	2	36	109	77	110	65	4	293	28
NL 724/NL 750	398	3	38	61	78	114	71	21	292	27
DANIAL88/CHILERO//BHRIKUTI	397	4	36	109	70	25	62	78	394	90
90B57/4/R37/GHL121//KAL/BB/3/JUP/MUS/5/SW 90.1057	386	5	36	109	78	116	72	57	319	44
HPO/TAN//VEE/3/2*PGO/4/CROC-1/AE.SQ (213)//PGO	385	6	40	36	74	86	58	51	283	25
PBW 475	384	7	38	61	83	148	68	2	195	1
HW 90.1057/3/HE 1/3*CNO 79//2*SERI	383	8	36	109	80	129	75	13	253	10
BL 1048*/BB/TOB//CNO 67/3/HUAC/4/TIRESEL/4/BB/PL*/5/SX	379	9	41	21	69	21	49	123	503	138
HUW 542	378	10	35	132	82	144	77	39	262	13
PBW 343/CHIR 3	376	11	40	36	78	115	65	29	317	42
PBW 343 (Improved Check from India)	376	11	37	84	81	139	70	7	214	5
CATBIRD	375	13	36	109	83	146	67	45	308	36
DL 784-3/VEE#7//PRL/UP 262/3/CHIRYA -7	372	14	42	10	77	102	67	61	372	78
NAC/VEE'S'//ATTILA	372	14	40	36	72	50	54	42	351	67
PEWIT 3	370	16	39	47	78	119	70	70	415	99
RAYON F 89	369	17	38	61	77	108	60	34	311	39
KANCHAN (Improved Check from Bangladesh)	368	18	41	21	72	54	59	133	443	120
LOCAL CHECK	367	19	38	61	71	45	56	60	379	80
BCN*2/4/SHA7//PRL/VEE#6/3/FASAN	366	20	35	132	77	111	65	28	273	19

Table 4. Effect of seed treatment observed in susceptible genotype Sonalika in Rampur, Nepal, during 2002 and 2003 wheat seasons.

Treatment	Emergence/m^2				Infected Seedlings/m^2		Number of tiller per 2m row		Grain yield (Ton/ha)	
	2002	+%	2003	+%	2002	2003	2002	2003	2002	2003
Vitavax-200	50.7	43.2	60.5	30.6	2.6	2.5	72.9	154	2.63	2.82
Check (untreated)	35.4		42.0		2.1	3.3	59.9	146	2.44	2.78
	P<0.01		P<0.01		NS	p=0.04	P<0.01	NS	NS	NS

Conclusions

As presented in this paper, controlling foliar blight in south Asia follows an approach combining epidemiology, pre-breeding efforts, breeding and crop management. Further epidemiological studies are needed to understand the factors promoting disease outbreaks and the causes of its increasing severity in the rice-wheat system of south Asia. Recent studies suggest that the incidence of tan spot is overlooked and not negligible. Germplasm is paramount. Since the disease is rather new, the genetic basis of host resistance to HLB is relatively narrow and presently limited to Chinese materials and derivatives of wide crosses combined to CIMMYT materials. There is a need to broaden the sources of variability and research is needed to identify new resistant materials. Very little is known on the inheritance of resistance genes effective against spot blotch and tan spot and field genetic studies are highly needed. The task is complicated by the similarity of symptoms induced by two pathogens, most probably triggering different resistance genes, and the limited areas where these studies can be conducted on one disease (tan spot or spot blotch) at a time. The role of crop rotation and fertilization seems equally important, but the long-term effects of using new resource conserving cultural practices will need to be monitored. In summary, controlling foliar blight in wheat is complex and requires a holistic approach. It is part of technological packages that make small-scale wheat production more cost-effective and sustainable, particularly in warmer areas. Farmers are increasingly involved in this research process, and the whole production system must be considered. More than ever, controlling foliar blights requires a multidisciplinary team effort.

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