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RESEARCH ARTICLE

Pathotype surveillance and pre-emptive breeding against black and brown rusts of wheat in Nilgiri hills

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ABSTRACT: Surveillance in Nilgiri hills was conducted from September 2010 to November 2012. There were dominance of pathotypes (pts) 77-5 (121R63-1), 77-7 (121R127) and 77-8 (253R31) of brown rust, and 40A (62G29) and 40-1(62G29-1) of black rust in Nilgiri hills. Majority of resistant genes in cultivars released for peninsular and central zones are susceptible to pts occurring in Nilgiri hills except *Lr* 24 for brown rust and *Sr*31 for black rust. Black rust resistant gene, *Sr*31, confers immunity in India. It is susceptible to race Ug99, hence protection due to this gene is at risk due to identification of matching virulences in other countries. Cultivars in peninsular and central India need to be fortified with additional resistant genes for achieving longer protection against wheat rusts. Several useful resistant genetic stocks pyramided with number of rust resistant genes have been developed at IARI Regional Station, Wellington and can be utilised in breeding durable resistant wheat varieties. All these stocks have been listed and can be procured on demand.

Key words: Wheat, black rust, brown rust, Nilgiri hills, central India, peninsular India, durable resistance

Wheat (*Triticum aestivum* L.) is major cereal grown in the Indian subcontinent with an annual production of around 94 million tonnes. All the three rusts, viz. black rust (*Puccinia graminis* Pers. f. sp. *tritici* Ericks and Henn), brown rust (*P. recondita* Rob. ex. Desm. f.sp. *tritici*), and yellow rust (*P. striiformis* Westend) pose serious challenge to wheat production under favourable conditions. Losses due to three rusts though under check largely due to systemic and pre-emptive breeding, still pose a great threat as proved by incidence of yellow rust in North West plain zone. Significant losses by rusts have been reported (Asthana, 1948; Barclay, 1890; Joshi *et al.,* 1975; Mehta, 1940; Prasada, 1960; Gupta and Singh, 1981; Sharma *et al*., 2011) from time to time. Black rust is of greater concern in the warmer central and peninsular India, yellow rust in cooler northern parts and Southern hills and brown rust being adapted to wider range of temperature affects wheat yield in all the zones. Deployment of effective and durable resistant genes along "*Puccinia* path" is the most successful strategy of wheat rust management in Indian sub-continent. Rust incidence in central and peninsular India is effectively managed by regular monitoring of rust pathotypes (pts) in Nilgiri hills and subsequent deployment of effective resistant genes. Therefore, racial structure of rust population prevailing during 2010-12 in Wellington and other valleys of Nilgiri hills along with resistance status of wheat cultivars released for target areas are discussed. The role of new genetic stocks developed as a result of pre-emptive breeding for keeping black and brown rusts at bay even in the future in these zones is also discussed.

MATERIALS AND METHODS

Rusted leaf samples were collected randomly from experimental farm of IARI Regional Station, Wellington. Uredospores were collected from sporulating pustules on rusted leaves with the help of lancet needle. The uredospores were inoculated on 7-day-old seedlings of Agra Local with a lancet needle. Inoculated pots were kept under high humidity for establishing proper infection. Subsequently, pots were transferred in separate glasshouses at 20°C for brown rust and 25°C for black rust along with light regime of 16:8 hours (light:dark). After sufficient sporulation, uredospores were collected on butter paper and 7-day-old seedlings of differential sets 0, A and B proposed by Nagarajan *et al.* (1983), Bahadur *et al*. (1985) and Bhardwaj (2012) were inoculated with collected uredospores. The methods used for rust establishment and subsequent development have already been described. Host-pathogen interactions were recorded by following standard international procedures of Mains and Jackson (1926) for brown rust and Stakman and Levine (1922a,b) for black rust. Binomial system of nomenclature described by Nagarajan *et al.* (1983) was used to designate the pts.

Designated pts were counted for clusters of three months beginning from September 2010 to November 2012. Percentage of pts monitored was calculated in total number of isolates analysed in a given cluster of months. Percent values of pts obtained for nine clusters of three months each between September 2010 and November 2012 were subjected to analysis of standard deviation about mean.

Status of resistance in wheat varieties was determined by reaction of resistant genes carried by varieties as corresponding to avirulence/virulence formulae (Table 1) of pts monitored in Nilgiris during the period under surveillance. Genetic stocks developed through repeated backcrossing in genetic background

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Table 1. Avirulence/virulence formulae of black and brown rust pathotypes prevalent in Nilgiri hills

Pathotype		Avirulence	Virulence
Old name	New name		
Brown rust			
77-5	121R63-1	*Lr* 9,18,19,24,28	*Lr*1,2a,2c,3,10,13,14a,17,15,20,23,26
77-7	121R127	*Lr* 18,19,24,28	*Lr*1,2a,2c,3,9,10,13,14a,15,17,20,26
77-8	253R31	*Lr* 9,14a,24,26,28	*Lr*1,2a,2c,3,10,13,15,17,18,19,20
Black rust			
40A	62G29	*Sr* 7a,13,14,21,24,30,37	*Sr*5,7b,8b,9b,9e,11,28
40-1	62G29-1	*Sr* 7a,13,14,21,30,37	*Sr*5,7b,8b,9b,9e,11,24,28

Table 2. Comparative prevalence of black and brown rust pathotypes in Nilgiris/Himalayas (inoculum source areas) and states of Karnataka, Maharashtra and Madhya Pradesh (inoculum target areas)

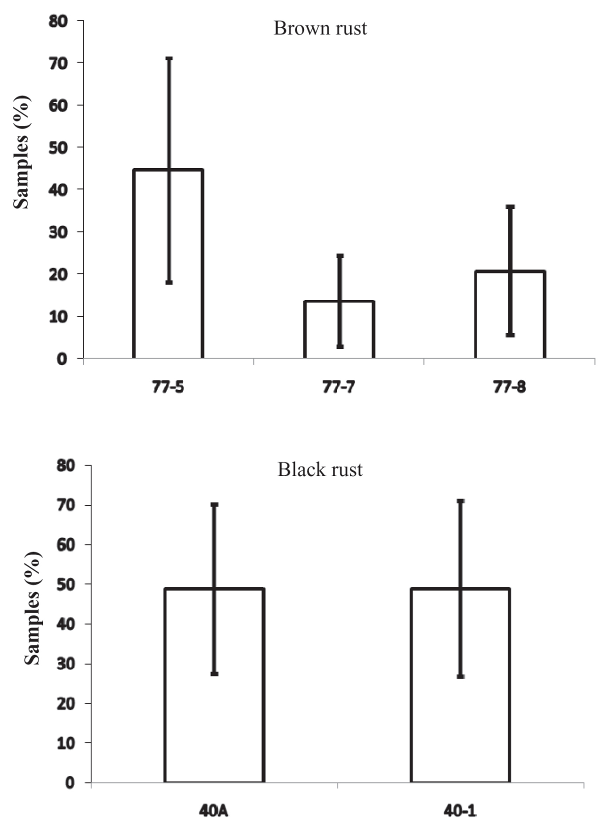
Year	Dominating pts * prevalent at source				Dominating pts monitored at target					
	Nilgiris		Himalayas (H.P., J&K and Nepal)**		Karnataka**		Maharashtra**		Madhya Pradesh**	
	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust	Leaf rust	Stem rust
2010	77-5,77-7, 77-8	40A, 40-1	77-5,104-2, 162-2	34-1	77-5	-	77-5	40A, 40-1	77-5	40A
2011	77-5,77-7, 77-8	40A, 40-1	77-5,104-2, 104-4	34-1	77-5	-	77-5, 104-2	40A	77-5, 104-2	-
2012	77-5,77-7, 77-8	40A, 40-1	77-5,77-2, 77-10	34-1	-	-	-	-	-	-

*new names in bracket: 77-5(121R63-1), 77-7(121R127), 77-8 (253R31), 40A (62G29), 40-1(62G29-1), **2010 (Anonymous, 2010), **2011 (Anonymous, 2011), **2012 (Anonymous, 2012)

of already released varieties were evaluated for rust severity on modified Cobb scale (Peterson *et al*., 1948) at Zadoks growth stage 87 (Zadoks *et al*., 1974).

RESULTS AND DISCUSSION

The pattern of leaf and stem rust pts prevalence in Nilgiri hills during 2010-12 is presented in fig. 1. For leaf rust, pt 77-5 was found to be the most predominating followed by pts 77-7 and 77-8. For stem rust, only two pts, *viz*. 40A and 40-1, occurred with equal frequencies. The results of survey conducted during 2010, 2011 and 2012 corroborate the hypothesis that Nilgiri hills are likely to act as source of initial inoculum for central and peninsular India covering Karnataka, Maharashtra and Madhya Pradesh as most of the pts prevailing in source and target areas are similar (Table 2). The Himalayan region, other source of initial inoculum for both the rusts carries the races of brown rust, which are not present in central and peninsular India except pt 77-5 and therefore can be safely ruled out as the source of inoculum for these regions. On the basis of host - pathogen interaction studies of prevailing pts and resistance base in released wheat cultivars for central and peninsular India (Table 3), disease scenario is reviewed here. It is alarming to note that majority of released varieties are susceptible to one or other races of leaf rust surviving in Nilgiris. Matching virulent races against *Lr* genes, *viz*. *Lr*10, *Lr*13, *Lr*23, *Lr*26 commonly used in released varieties are available in Nilgiri hills. The *Lr*24 effective against all prevailing races, hold promise against brown rust,



[a]Per cent frequencies of samples is mean of 9 trimesters from September 2010 to November 2012
Vertical bars represent standard deviation about mean

Fig. 1. Per cent frequency of various races of black and brown rusts monitored during 2010-2012 in Nilgiris[a]

Table 3. Status of resistance to Nilgiri races of black and brown rusts* in wheat varieties released for central and peninsular India

Variety	Resistance gene/s present		Whether Effective (E)/Non-effective (NE) resistance	
	Black rust (*Sr*)	Brown rust (*Lr*)	Black rust	Brown rust
Central Zone			**(IT's)**	**(IT's)**
HI 8381	*Sr*2+9e	-	E	NE
DL803	*Sr*31	*Lr*23+26+	E	NE
HW 2004	*Sr*24	*Lr*24+ 34+	NE	E
Dl 788-2	*Sr*2+5+24	*Lr*24	E	E
GW 273	*Sr*9b+11	*Lr*13+10	NE	NE
HI8498	*Sr*2+11	-	E	NE
HD4672	*Sr*11+	-	NE	NE
GW322	*Sr*2+11	*Lr*13	E	NE
MP4010	*Sr*24	*Lr*24	NE	E
HI1500	*Sr*24	*Lr*24	NE	E
HD2864	*Sr*11+	-	NE	NE
HI8627	-	-	NE	NE
HI1531	*Sr*2+24	*Lr*24	E	E
GW366	*Sr*2+	-	E	NE
HI1544	*Sr*24+	*Lr*24	NE	E
HD2932	-	*Lr*13+	NE	NE
MP1203	*Sr*31	*Lr* 1+23+26	E	NE
MPO1215	-	-	NE	NE
Peninsular Zone				
MACS 2846	*Sr*2+9e	*Lr*23+	E	NE
DDK1009	-	-	NE	NE
K9644	*Sr*2	*Lr*13	E	NE
GW322	*Sr*2+11+	*Lr*13+	E	NE
HD2781	*Sr*2+	-	E	NE
RAJ 4037	*Sr*2+24+	*Lr*24	E	E
NIAW917	*Sr*2+31+	*Lr*1+26+	E	NE
HD2833	*Sr*11+24	*Lr*24+	NE	E
PBW 533	*Sr*31	*Lr*23+26+	E	NE
RAJ4083	-	-	NE	NE
AKDW2997-16	*Sr*2+7b	-	E	NE
DDK1029	*Sr*11+	-	NE	NE
HI8663	*Sr*9e	*Lr*23+	NE	NE
HD2932	-	*Lr*13+	NE	NE
UAS415	*Sr*9e	*Lr*23+	NE	NE
MACS2971	-	-	NE	NE
PBW596	*Sr*31	*Lr23*+26+	E	NE
MACS6222	-	-	NE	NE
AKAW 4027	*Sr*24	*Lr*24	NE	E
South Hill Zone				
HW 1085	*Sr*8b+9b+11+24+31	Lr24+	E	E
HW 3094	*Sr* 24+31+	*Lr*24+26+	E	E

*Black rust: 40A (62G29), 40-1(62G29-1); brown rust: 77-5(121R63-1), 77-7(121R127), 77-8 (253R31)

however, deployment of single gene with major effect over large area is prone to breakdown due to evolution of matching virulence. Pyramiding of *Lr*24 with other major or minor genes may pre-empt such threat. Linkage of *Lr*24 with *Sr*24 and availability of matching virulence against *Sr*24 in black rust pt 40-1 existing in Nilgiris calls for pyramiding of additional *Sr* genes in such cultivars, if envisaged for cultivation in central and peninsular parts of India. Presence of pt 77-7 and its increasing trend in the recent years renders other highly effective gene *Lr*9 useless, if used alone in central and peninsular India.

The ability of two pts 40A and 40-1 of black rust prevailing in Nilgiris infect varieties of central and peninsular India having genes *Sr*7b, *Sr*9b, *Sr*9e, *Sr*11, *Sr*24 etc. renders deployment of these genes alone or in combination useless. However, use of *Sr*2 in combination of two or more of these genes is able to provide complete

Table 4. Genetic stocks generated through backcrossing and their host response at seedling and adult plant stages to Nilgiri flora of black and brown rusts

Name	Pedigree	Rust reaction-adult plant response races		Seedling resistance test Brown rust races					Black rust	
		Black	Brown	17	77A	77-5	77-7	77-8	40A	40-1
*Lr*24+*Sr*24+*Sr*27										
HW 2091	C 306*3//TR 380-14 *7/3Ag# 14/KS [*Sr*27]	TR	10MS	;1	;2	;	;1	2	2+	2
HW 2093	C 306*3//CS 2A/2M 4/2/KS [*Sr*27]	TR	10MS	;1	;2	;	0	;2	2	3
*Lr*28+*Sr*26										
HW 2096	Lok-1*3//CS 2A/2M 4/2/Kite	TS	TR	;1	;1	1	0	2	2	2+
HW 2099	WH-147*3//CS 2A/2M 4/2/Kite	TS	TR	;2	1	1	1	1	;1	;
*Lr*37+*Sr*38+*Yr*17										
HW4022	HD 2285*5/RL 6081	5MR	5MS	;1	;	;	;1	1	;1	2
HW4023	HD 2329*5/RL 6081	10MS	5MS	0	;	;	;1	0	1	2
HW4024	HUW234*5/RL 6081	TR	5MS	1	1	0	;1	1	;2	1
HW4025	Kalyansona*5/RL 6081	5MS	5MS	0	;1	0;	;1	;	;1	2
HW 4026	Lok-1*5/RL 6081	TS	5MS	;1	;2	;	0;	;	;	;2
HW4028	PBW 226*5/RL 6081	TS	5MS	;1	;1	;2	;1	1	2	2
HW 4029	Sonalika*5/RL 6081	TS	5MS	;	;1	;1	0;	2	2	;2
HW 4030	WH 147*5/RL 6081	R	5MS	;	2+	2+	2+	2	;2	2
HW 4031	WH 542*5/RL 6081	TS	5MS	;1	;1	;2	;1	;2	1	;2
*Sr*31+*Lr*26+*Yr*9+ *Lr*28 (additive effect for yield increase observed)										
HW 4041	C 306 *2//WH 542/CS 2A/2M 4/2	10MS	10MR	;2	;2	;2	0;	0;	1	2
HW 4042	HD 2329*2//WH 542/CS 2A/2M 4/2	10MR	10MR	;1	;1	;1	;2	;	;2	;2
HW 4043	HUW 234*2//WH 542/CS 2A/2M 4/2	10MR	10MR	;2	0;	;1	2+	2+	;2	2+
*Sr*31+*Lr*26+*Yr*9+*Lr*32 (additive effect for yield increase observed)										
HW 4049	HD2285*2//WH542/C86-8/ Kalyansona F4	TR	10MR	;	;2	;	;2	1	2	;2
HW 4050	HD 2329*2//WH 542 /C 86-8/ Kalyansona F4	TR	10MR	;1	2	;1	;	0;	1	;2
HW 4052	Kalyansona*2//WH 542 /C 86-8/ Kalyansona F4	TR	10MR	;2	;1	;1	;	0;	1	2
HW 4053	Lok-1*2//WH 542/C 86-8/ Kalyansona F4	TR	10MR	;2	;2	;1	;1	;	;1	;2
HW 4055	PBW 226*2//WH 542 /C 86-8/ Kalyan sona F4	TR	10MR	1	;2	;2	0;	;1	;1	;2
HW 4056	Sonalika*2//WH 542 /C 86-8/ Kalyansona F4	TR	10MR	0;	;1	;1	;	;1	;2	;2
HW 4057	WH147*2//WH542/C 86-8/ Kalyansona F4	TR	10MR	;1	;1	;1	;1	;2	;2	;2
*Sr*31+*Lr*26+*Yr*9 +*Lr*19+*Sr*25 (additive effect for yield increase observed)										
HW 4059	HD 2009*2//WH 542 / Sunstar*6/ C 80-1	10MR	TS	;1	;2	;1	1	;1	;2	;2
HW 4059-1	HD 2009*2//WH 542 / Sunstar*6/ C 80-1	10MR	TS	;	;2	;2	1	;2	2+	2
HW 4060	HD 2329*2//WH 542 / Sunstar*6/ C 80-1	10MR	TS	0;	;	;1	1	;	;2	2
HW 4061	HI 1077*2//WH 542/Sunstar*6/ C 80-1	10MR	TS	0;	;1	;1	;	;1	;2	;2
HW 4061-A	HI 1077*2//WH 542/ Sunstar*6/ C 80-1	10MR	TS	;1	;2	;1	;2	;1	;2	;1
HW 4062	J 24*2//WH 542/ Sunstar*6/ C 80-1	10MR	TS	;2	;	;1	;2	;	;2	;

HW 4063	Kalyansona*2// WH 542/Sunstar*6/ C80-1	10MR	TS	;1	;1	;	;2	;	;1	;2
HW 4064	Lok-1*2//WH 542/ Sunstar*6/C 80-1	10MR	TS	;1	;1	;2	0;	;	2	2
HW 4065	NI 5439*2//WH 542/ Sunstar*6/ C 80-1	10MR	TS	;1	;1	;1	;1	;1	;2	2+
HW 4065-A	NI 5439*2//WH 542/ Sunstar*6/ C 80-1	10MR	TS	;	;1	;1	0;	;	;1	0
HW 4066	WH 147*2//WH 542/ Sunstar*6/ C 80-1	10MR	TS	;	;1	;2	;	;1	;2	;2
*Lr*19+*Sr*25, *Sr*36+*Pm*6 (resistant to leaf, stem, yellow rusts and powdery mildew)										
HW 4202	HD 2009*3//COOK*6/C80-1	TS	10MR	;2	;2	;	;	0;	;1	;
HW 4203	HD 2285*3//COOK*6/C80-1	TS	TS	;2	;	;1	;1	;2	;2	1
HW 4204	HD 2329*3//COOK*6/C80-1	TS	TS	;2	;1	;1	;2	;2	1	0
HW 4205	HD 2402*3//COOK*6/C80-1	TS	TS	;1	;	;1	;2	;1	0	;1
HW 4206	HD 2687*3//COOK*6/C80-1	TS	10MR	;	0	0;	;1	0	;	;1
HW 4207	HS 240*3//COOK*6/C80-1	TS	10MR	;1	;1	;	1	;	0	0
HW 4208	J 24*3//COOK*6/C80-1	TS	TS	;1	;1	;2	0;	;1	;	;1
HW 4209	Kalyansona*3//COOK*6/C80-1	TS	TS	2	2	2	2	2	;2	;2
HW 4210	Lok-1*3//COOK*6/C80-1	TS	TS	;2	;1	0;	;1	;2	0	;
HW 4211	MACS 2496*3//COOK*6/C80-1	TS	10MR	;	;2	;2	;	0;	;1	;1

R = Resistant, TS = Trace susceptibility, MR = Moderately resistant, MS = Moderately susceptible, TR = trace

protection from both the pts. Presence of *Sr*2 in combination with other major genes in majority of varieties of peninsular zone and central India (Table 3) has ensured no yield losses due to black rust in these zones since last 4-5 decades. *Sr*2 complex comprising 4-5 minor linked genes and derived from cultivar Hope has also been effective since late 60s in southern America too (Rajaram *et al*., 1988). The world over effectiveness of this gene and extensive deployment by CIMMYT in its germplasm make this complex indispensable.

Some of the varieties in both central and peninsular India (Table 3) possess gene *Sr*31 which is resistant to both the races monitored in Nilgiris. Such varieties hold promise for future but for race Ug99 and its variants. Ug99, though not reported from India yet, its continued spread since its emergence has now been recognised as a major threat to wheat production as current cultivars are susceptible to it (Singh *et al*., 2006). Cultivars, HI 1531 and DL 788-2, carry both *Sr*2 and *Sr*24 and therefore are able to provide complete protection against available black rust flora in the country (Table 3). The identification and release of new varieties like HW 3094 in southern hill zone (Table 3), which is an inoculum source area, with pyramid of *Lr*24 and *Lr*26 and other genes, may delay the emergence of matching virulent races against genes like *Lr*24. Most of these stocks exhibited adult plant resistance continuously for five years to black and brown rusts under natural epiphytotics at Wellington (Table 4). These lines can be either directly released in the area of their adaptation through limited testing and or can be used as genetic base for further improvement by various active ongoing breeding programmes throughout India.

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