Status of Wheat Yellow Rust (*Puccinia striiformis*) Races and their Virulences in major Wheat Growing areas of Ethiopia

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Abstract

Yellow rust caused by *Puccinia striiformis* Westend. f.sp. *tritici* is one of the major wheat diseases in the highlands of Ethiopia. Monitoring races and inventory of resistance genes would be very important for the control of the disease. A total of 10 different yellow rust races had been identified from samples collected in the southeastern Ethiopia from 1998 to 2003. Three of these (230E158, 198E158 and 206E158) were detected for the first time in Ethiopia and exhibited virulence for most of the seedling resistance genes except Yr_{CV}, Yr_{SP}, $Yr1$, Yr_4, Yr_5, Yr_{10}, Yr_{15} and Yr_{17}. One of the high yielding bread wheat cultivars, 'Kubsa' and many others succumbed to race 230E158. Based on the results of this study and perusal of past reports, the races so far identified in the country could be grouped into three categories. Races in the first group are assumed to be evolved from the parental race 82E0, and have had virulences for Yr_{SU} (Suwon x Omar*)*, Yr_7, Yr_9 (Fed 4*/KVZ) and Yr_{10} combinations. These races were detected mainly in the central and northwestern Ethiopia where durum wheat used to be dominant. The commonly occurring races in the southeastern Ethiopia have apparently been originated from the third parental race (6E16), that had virulences for Yr_6, Yr_7 and Yr_8 combinations. To contend with the ever evolving yellow rust races and virulence in Ethiopia, the genetic basis of resistance of bread wheat should be broadened and diversified.

Introduction

Yellow rust caused by *Puccinia striiformis* Westend., is one of the major diseases of wheat in temperate regions as well as in the highlands of the tropics and subtropics. It is considered as a 'low temperature' disease and mainly a problem in areas where night temperatures are below 20°C (Röbbelen & Sharp 1978).

The fungus has a hemi-form of life cycle comprising only the uredial and telial states, and so far no alternate host has been found. Allison & Isenbeck (1930) were the first to demonstrate the physiological specialization of yellow rust. According to Little & Manners (1969), new races may develop through mutation or recombination of nuclei *via* a para- sexual process. New races or virulences are often selected within pathogen populations in response to the selection pressure exerted by specific resistance characteristics in upcoming commercial cultivars and breeding lines (McIntosh & Brown 1997).

In Ethiopia, yellow rust has been one of the diseases threatening wheat production since the early 1980s. Most of the commercial bread wheat cultivars have been succumbed to yellow rust in major wheat growing areas in Ethiopia. This could be due to the fast replacement of the local cultivars (often mixtures) with uniform high yielding semi-dwarf bread wheat genotypes (Ayele Badebo *et al.* 1990). Virulence for *Yr9*[+] (cv. Clement), which attacked the VEE'S' and BOW'S' derived bread wheat varieties was first detected in 1986, and then became predominant among race populations in Ethiopia (Ayele Badebo and Stubbs 1995). The yellow rust races from Ethiopia had been monitored from 1977-1992 at Institute of Plant Protection (IPO), Wageningen, The Netherlands in collaboration with CIMMYT (Ayele Badebo *et al.* 1990; Louwers *et al.* 1992). Then, similar activities had been initiated at Kulumsa Research Center, Ethiopia, within the period of 1993-97 (Ayele Badebo *et al.* 1998). Thus, the yellow rust races in Ethiopia have had broad virulence patterns which overcome most of the known resistance genes (*Yr2*[+], *Yr6, Yr 6*[+], *Yr 7, Yr 7*[+], *Yr 8, Yr 9*[+] and *Yr SD*) singly or in many combinations.

Monitoring of virulences and races could serve as one of the preemptive measures to control the disease. Therefore, this study was initiated to identify the prevailing races of yellow rust in major wheat producing regions in Ethiopia and examine their lineage among races detected.

Materials and Methods

About 110 yellow rust infected leaf samples were collected from different wheat varieties and lines both on-farm and research stations in the southeastern Ethiopia (Arsi and Bale zones) from 1998 to 2003. Mono-spore isolates were made and maintained for about 70% of samples on the susceptible bread wheat cultivar, Morocco and on the original wheat cultivars in the greenhouse at Kulumsa Research Center. About ten varieties were used for the preliminary characterization (Table 1). Only isolates that showed differential interaction on selected cultivars were selected for race analysis. Isolates from 1998 and 1999 seasons were analyzed in the Institute of Plant Pathology and Plant Protection, University of Goettingen in 2000. Whereas the race analysis for the rest isolates was carried out at Kulumsa Research Center during 2002 and 2003.

A total of 21 yellow rust standard differential lines obtained from IPO, Wageningen, The Netherlands were used for race analyses (Table 1). The 'world-set' and the 'European set' comprised of eight differential lines each (Stubbs 1985). Moreover, the analysis was carried out by incorporating *Yr15* (Kema and Lange, 1992) and *Yr5* (Wellings & McIntosh, 1990) in the 'world set' of differentials. In addition, Kalyansona (*Yr2*) and Federation *4/Kavkaz (*Yr9*) (Stubbs, 1988) and VPM1 (*Yr17*) (Bariana & McIntosh, 1994) were included as supplemental differential set for yellow rust. In each test a susceptible bread wheat cultivar, 'Morocco' was used as a check.

Twenty bread wheat cultivars obtained from the national breeding program at Kulumsa were exposed to four Ethiopian yellow rust races at seedling stage (Table 2). The experiment was conducted according to the internationally agreed norms and procedures as indicated bellow in Goettingen, in 2000.

About seven seeds from each genotype were sown in 5 x 5 x 5 cm Jiffy pots that contained a mixture of soil, sand, and compost at the ratio of 1:1:1 v/v/v/ in the greenhouse. Seedling tests were conducted according to Stubbs (1985) and Zadoks (1961). When the first leaves fully expanded seedlings were inoculated by spraying a suspension of yellow rust spores in mineral oil (FC-40, 3M Fluorinert Electronic liquid, Saint Paul, USA) onto the leaves. Inoculated seedlings were incubated for 24 hours in plastic cages at 10°C and *ca.*100 % relative humidity. Thereafter, the seedlings were transferred to a growth cabinet to allow symptom development. Inside the cabin, the day/night regime was 16 hr of light (20,000 lx) and 8 hr dark at 18/17°C, and the relative humidity was *ca* 70%. About a week after inoculation the second leaves were cut to minimize shade effects.

Yellow rust assessment was made 16 days after inoculation using a 0-9 disease scoring scale (McNeal *et al.* 1971). Infection types, 0-6 were classified as low or resistant while 7-9 scores were considered as high or susceptible infection types. Based on infection types, the races were designated according to an international system of notation on 18 standard differential lines (Johnson *et al.* 1972). Based on the results of this study and previous reports, we have attempted to establish the evolutionary relationships among races identified so far in Ethiopia.

Table 1. Yellow rust races identified in major wheat producing regions in Ethiopia from 1998 to 2003

Variety	Race code[a]	World set										European set								Supplimental set		
		Chinese 166 –*Yr1*	Lee –*Yr7*+[c]	Heines Kolben-*Yr6*	Vilmorin 23 –*Yr3V*	Moro -*Yr10*+[c]	Strubes Dickkopf-*YrSD*	Suwon/Omar-*YrSU*	Clement *Yr9*+	*Triticum* s. *album*-*Yr6*	*T.dicoccoides*-G25-*Yr15*	Hybrid 46 –*Yr4*+	Reichersberg 42 – *Yr7*+	Heines Peko –*Yr6*+	Nord Desprez –*Yr3N*	Compair-*Yr8*+[c]	Carstens V – *Yr32*	Spaldings Prolific- *YrSP*	Heines VII- *Yr2*+	Kalyansona –*Yr 2*	Federation *4/KVZ-*Yr9*	VPM 1- *Yr17*
HAR1685	230E158	·	S[b]	S	·	·	S	S	S	·	·	·	S	S	S	S	·	·	S	S	S	·
HAR710	230E150	·	S	S	·	·	S	S	S	·	·	·	S	S	·	S	·	·	S	S	S	·
Dashen	166E150	·	S	S	·	·	S	·	S	·	·	·	S	S	·	S	·	·	S	S	S	·
K6295-4A	70E150	·	S	S	·	·	·	S	·	·	·	·	S	S	·	S	·	·	S	S	S	·
HAR1899	6E16	·	S	S	·	·	·	·	·	·	·	·	·	·	·	S	·	·	·	·	·	·
HAR1868	6E6	·	S	S	·	·	·	·	·	·	·	·	S	S	·	·	·	·	·	·	·	·
HAR1899	78E30	·	S	S	S	·	·	S	·	·	·	·	S	S	S	S	·	·	·	·	·	·
HAR1003	78E158	·	S	S	S	·	·	S	·	·	·	·	S	S	S	·	·	·	S	·	·	·
HAR1522	198E158	·	S	S	·	·	·	S	S	·	·	·	S	S	S	S	·	·	S	S	S	·
HAR2508	206E158	·	S	S	S	·	·	S	S	·	·	·	S	S	S	S	·	·	S	S	S	·

[a] Nomenclature according to Johnson *et al.* (1972).
[b] S= Virulence, · = avirulence on differential genotypes
[c] += Additional designated yellow rust resistance genes (*Yr*) were recently reported by Chen (2005).

Results and Discussion

Ten different yellow rust races were identified out of samples collected in the southeastern Ethiopia from 1998 to 2003 (Table 1). Four of the isolates were collected from four commercial bread wheat cultivars; namely, K6295-4A, Dashen, HAR710 and HAR1685. The races identified were 70E150, 166E150, 230E150 and 230E158, respectively. Race 166E150 was first isolated from CIMMYT originated VEE'S' and BOW 'S' bread wheat lines in Arsi and Bale zones during 1986; thereafter, it has been the dominating one among the race population. For example, it occupied more than 50% of the race population in Ethiopia during 1987 to 1989 (Ayele Badebo and Stubbs 1995). Similar findings have been reported from East Africa (Danial, 1994) and the Middle and Near East countries (Hakim & Mamluk 1996). The race 70E150 was detected at a lower frequency and was isolated from relatively old bread wheat cultivars, especially of Kenyan origin. The yellow rust race, 230E150 was identified from samples collected from the bread wheat cultivars HAR710 (MRL'S'/BUC'S') and Dashen (VEE'S') at different locations in Arsi and Bale zones during 1998. A similar race was detected in Kenya in 1988 (Danial & Stubbs 1992). Race 230E158 was isolated from samples collected from HAR1685 (Kubsa) in 1998 and exhibited virulence for all commercial bread wheat cultivars in Ethiopia (Table 2).

The two races, 6E6 and 6E16 were less virulent when compared to the rest and have also been reported in Kenya and Ethiopia (Danial & Stubbs 1992; Ayele Badebo and Stubbs 1995). Races 78E158, 198E158 and 206E158 were detected and reported for the first time in Ethiopia during 2002 and 2003 seasons. Races 78E158 and 206E158 attacked the yellow rust differential Vilmorin-23 (Yr_{3V}) and the former was reported in Kenya (Danial 1994).

The evolution of yellow rust races and virulences in Ethiopia within the period from 1977 to 2003 is shown in Figure 1. Based on the results of this study and previous reports by Ayele Badebo & Stubbs (1995) and Ayele Badebo *et a.l* (1998), three virulence groups were identified. The races in the first group might have been evolved from race 82E0. This race had virulences for Yr_7, Yr_9 (Federation*4/Kavk), Yr_{10} and Yr_{SU}, and it was detected in 1977. The other two races in this group, 82E16 and 86E0 could have been evolved after a one-step mutation for virulence on Yr_8 (Compair) and Yr_6 (Heines Kolben), respectively. In 1988, using Federation*4/Kavkaz, as supplemental differential line, we have identified virulence for Yr_9 at IPO (Ayele Badebo *et al.* 1990). The races in this virulence group were identified mostly from samples collected in central and northwestern Ethiopia where cultivation of durum wheat is commonly practiced. For example, in 1989, races 82E0 and 82E16 were identified from samples collected around, Weliso, Selalle, Degem and Bichena. These races attacked a very resistant durum wheat cultivar, 'Sham 1', in greenhouse tests in Wageningen; however, other isolates which were collected from bread wheat either from Ethiopia or elsewhere were avirulent (Louwers *et al.* 1992). Similar findings obtained on leaf rust (*Puccinia triticina*) by Huerta-Espino (personal communication) of which leaf rust isolated from indigenous durum wheat cultivars from Ethiopia did not attack the globally susceptible bread wheat cultivars. The specialized forms of adaptation of rust pathogens to the indigenous durum wheat cultivars could be due to the co-evolution of the tetraploid hosts and the pathogen since antiquity in Ethiopia.

The races in the second group including race 206E158 evolved from race 6E6 and/or 6E16 through a stepwise mutation as indicated in Figure 1. The races in the third group did presumably evolve from race 6E16. The race was detected in 1977 and had been the dominating one in the early 1980's. All the major yellow rust races including race 166E150 might have been evolved from it through a stepwise mutation.

New races often selected within yellow rust populations in response to the selection pressure exerted by specific resistance characteristics in upcoming commercial cultivars (McIntosh, 1997). For example, prior to the introduction of semi-dwarf bread wheat cultivars to Ethiopia, Kenyan originated bread wheat cultivars, such as Enkoy, K6295-4A, K6290-Bulk, and other awnless 'local' bread wheat cultivars had been predominating. Due to a significant yield advantage over the prevailing ones, most farmers including state farms then adopted a semi-dwarf bread wheat cultivar, which occupied large tracts of land within a short period.

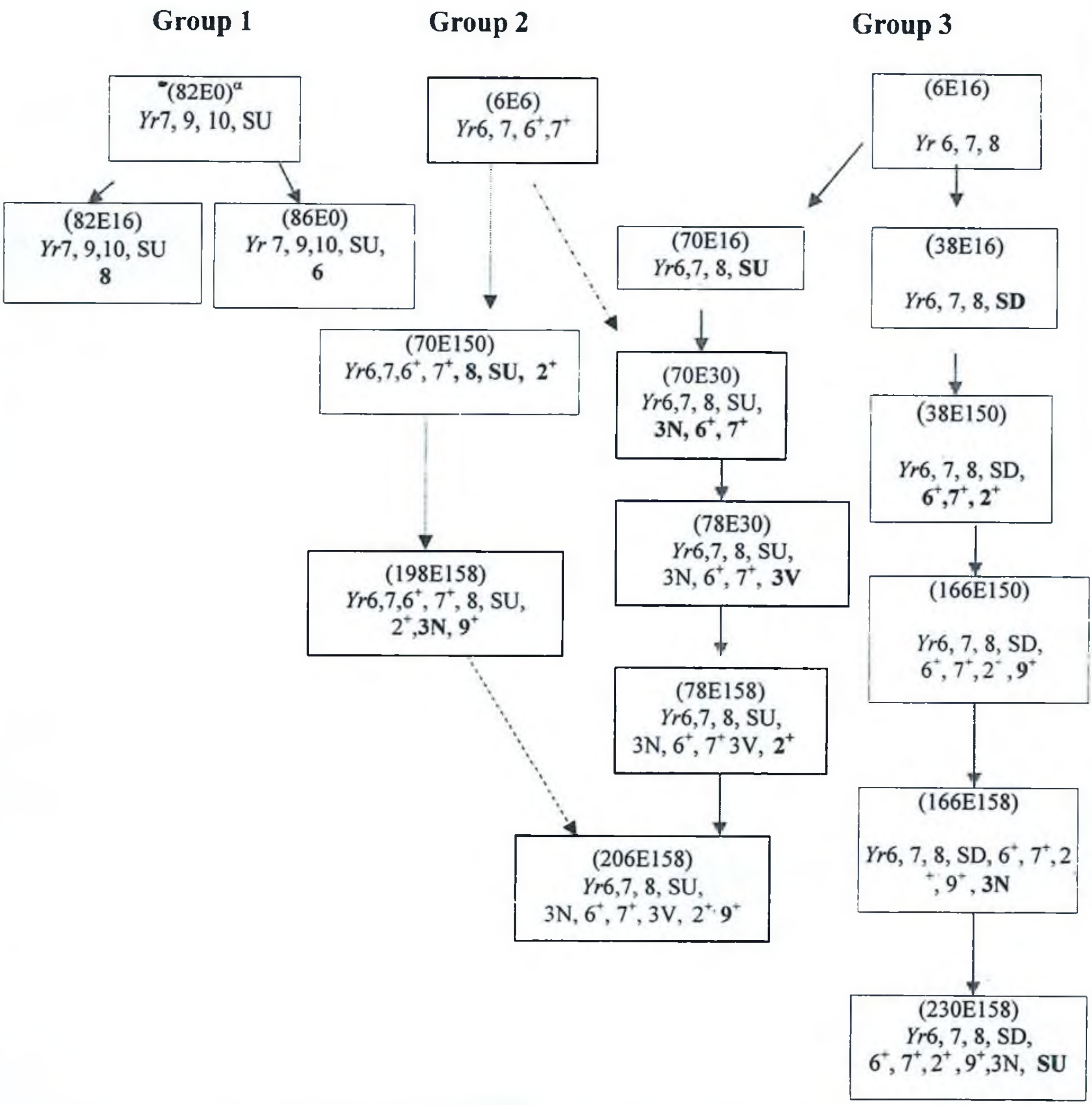

Figure 1. Evolution of yellow rust races and virulence in Ethiopia within the period of 1977 to 2003. ([α] Refers race number according to Johnson *et al.* (1972), and numbers with prefix *Yr* refers virulence to the corresponding resistance genes. Newly added virulences are printed bold-faced.

Table 2. The reaction of commercial bread wheat cultivars to four yellow rust races from Ethiopia at seedling stage

Commercial cultivars	Yellow rust races			
	70E150	166E150	230E150	230E158
HAR1899 (Cook/Vee/Dov/Seri/3/Bjy/Coc	S	S	S	S
HAR1407 (Cook/Vee/Dov/Seri)	·	·	·	S
HAR416 (BOW #28)	·	S	S	S
HAR1775 (ARO Sel 60/89)	S	S	S	S
HAR1522 (BOW'S / BUC'S)	S	·	S	S
HAR1595(F371/TRM//BUC'S'/3/LIRA'S'	·	·	S	S
HAR1868(Gov Az//Mus's'/3/R37/Ghl/2/...	·	S	S	S
HAR710 (MRL'S'/BUC'S')	·	·	S	S
HAR1685 (Attila 'S')	·	·	·	S
HAR604 (4777(2)//FKN/GB/3/PVN'S')	·	S	S	S
HAR1709 (BOW 28 X ROMANY B.C.)	·	S	S	S
BATU (SUN BIRD 4)	·	S	S	S
DASHEN (VEE #17)	·	S	S	S
GARA (BOW'S')	·	S	S	S
HAR407 (VEE #15)	S	S	S	S
K6295-4A(ROMANYX GB-GAMENYA)	S	S	S	S
ET13 A2 (UQ105 Sel. X ENKOY)	S	S	S	S
DERESELIGN (CI81541//2*FR)	S	S	S	S
K6290-B(AF.MAYOXGEM) XROMANY	S	S	S	S
ENKOY (Hebrard Sel./WIS245xSUP51) x $(FR-FN/Y)^2$ .A	S	S	S	S

Note: S= susceptible, and · = resistant reaction

Apparently, the new race 166E150 appeared in 1986 and inflicted heavy damage on VEE'S' and BOW 'S' derived bread wheat cultivars in 1988 (Ayele *et al.* 1990).

In addition, two new bread wheat cultivars, HAR1685 (ATTILA'S') and HAR710 (MRL'S'/BUC'S') released in 1994/1995 covered a large area of land also became vulnerable to the newly evolved races 230E150 and 230E158, respectively in 1998. The later had virulences for Yr_{2+}, Yr_{3N}, Yr_{6}, Yr_{6+}, Yr_{7}, Yr_{7+}, Yr_{8}, Yr_{9+}, Yr_{SU} and Yr_{SD} combinations. Again in 2002 and 2003, three other new races 78E158, 198E158 and 206E158 were detected. Race 206E158 had additional virulence for Yr_{3V} (Vilmorin 23), and it might have been evolved from the third (6E16) or the second group (6E6) after a stepwise mutation. It had virulence for Yr_{2+}, Yr_{3N}, Yr_{3V} Yr_{6}, Yr_{6+}, Yr_{7}, Yr_{7+}, Yr_{8}, Yr_{9+}, *and* Yr_{SU} combinations.

The results indicated that yellow rust races in Ethiopia have had broad virulence spectra and overcome most of the known yellow rust resistance genes singly or in combinations except, Chinese 166 (*Yr1*), Hybrid 46 (*Yr3b+4b+*), *Triticum aestivum* subsp. *spelta* 'Album' (*Yr5*), *Triticum turgidum* var. *dicoccoides* G-25 (*Yr15*), Carstens V (*Yr32*) and Spaldings Prolific (*YrSp*). Monitoring of races and inventory of the main resistance genes deployed in wheat cultivars minimizes the risk of building up of new virulences and promote appropriate gene management strategies for sustainable wheat production.

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References

Allison C., Isenbeck K. 1930. Biologische Specialieserung von *Puccinia glumarum tritici* Eriks. und Henn., *Phytopathologische Zeitschrift* 2: 87-98.

Ayele Badebo and Stubbs RW. 1995. Valuable sources of resistance of wheat to the East African yellow rust isolates. pp. 206-214. In: D.L. Danial (eds.). Breeding for disease resistance with emphasis on durability. Proceedings of a regional workshop for Eastern, Central, and Southern Africa. Njoro, Kenya.

Ayele Badebo, Stubbs RW., van Ginkel M., and Getinet Gebeyehu. 1990. Identification of resistance genes to *Puccinia striiformis* in seedlings of Ethiopian and CIMMYT bread wheat varieties and lines. *Neth. J. Pl. Pathol.*, 96: 199-210.

Ayele Badebo, Temesgen Kebede, Zewdie Alemayehu, and Bedada Girma. 1998. The reaction of bread wheat lines and varieties to stripe rust at seedling and adult plant growth stages. *Pest Management Journal of Ethiopia 2*: 36-42.

Bariana HS. And McIntosh RA. 1994. Characterization and origin of rust and powdery mildew resistance genes in VPM1 wheat. *Euphytica* 76: 53-62.

Chen XM. 2005. Epidemiology and control of stripe rust (*Puccinia striiformis* f. sp. *tritici)* on wheat. *Can. J. Plant Pathol.* 27: 314–337.

Danial DL. 1994. Aspects of durable resistance in wheat to yellow rust. Ph.D. thesis. Wageningen Agricultural University, The Netherlands. 143 pp.

Danial DL and Stubbs RW. 1992. Virulence of yellow rust races and types of resistance in wheat cultivars in Kenya. pp. 165-175. In: Tanner D.G., and W. Mwangi (eds.). Seventh Regional Wheat Workshop for Eastern, Central, and Southern Africa. Nakuru, Kenya: CIMMYT.

Hakim MS and Mamluk OF. 1996. Virulences of wheat yellow rust pathogen in Syria and Lebanon. P. 141. Proceedings of the 9th European and Mediterranean Cereal Rust and Powdery Mildew Conference. 2-6, September 1996. Lunteren, The Netherlands.

Johnson, R., Stubbs RW., Fuchs E., Chamberlain NH. 1972. Nomenclature for physiologic races of *Puccinia striiformis* infecting wheat. *Trans. Br. Mycol. Soc.*, 58: 475-480.

Kema GHJ. and Lange W. 1992. Resistance in spelt wheat to yellow rust. II. Monosomic analysis of the Iranian accession 415. *Euphytica* 63: 219-224.

Little R. and Manners JG. 1969. Somatic recombination in yellow rust of wheat (*Puccinia striiformis*). I. The production and possible origin of two new physiologic races. *Trans. Br. Mycol. Soc.*, 53: 251-258.

Louwers JM., van Silfhout CH., and Stubbs RW. 1992. Race analysis of yellow rust in wheat in developing countries report 1990-1992. IPO-DLO, report 92-11, Wageningen, The Netherlands.

McNeal FH., Konzak CF., Smith EP., Tate WS., and Russel TS. 1971. A uniform system for recording and processing cereal research data. USDA, Agri. Research Service 34-121. 42 pp.

McIntosh RA., and Brown GN. 1997. Anticipatory breeding for resistance to rust diseases in wheat. *Ann. Rev. Phytopathol.*, 35: 311-326.

Röbbelen G. and Sharp EL. 1978. Mode of inheritance, interaction and application of genes conditioning resistance to yellow rust. *Z. Pflanzenzüchtung* 9: 1-88.

Stubbs RW. 1985. Stripe rust. pp. 61-101. In: Roelfs, A.P., and W.R. Bushnell (eds.). The Cereal Rusts. II. Diseases, distribution, epidemiology, and control. Academic Press, New York.

Stubbs RW. 1988. Pathogenicity analysis of yellow (stripe) rust of wheat and its significance in a global context. pp. 23-38. In: Simmonds, N.W., and S. Rajaram (eds.). Breeding strategies for resistance to the rusts of wheat. CIMMYT, Mexico.

Wellings CR. and McIntosh RA. 1990. *Puccinia striiformis* f. sp. *tritici* in Australasia: Pathogenic changes during the first 10 years. *Plant Pathology 39: 316-325.*

Zadoks JC. 1961. Yellow rust on wheat: Studies in epidemiology and physiologic specialization. *Neth. J. Plant. Pathol.*, 67: 69-256.