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Multiple disease resistance in durum wheat (*Triticum turgidum* L. var. *durum*)

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SUMMARY – Host plant resistance plays a major role in reducing losses from disease; however, monoculture of a limited number of durum wheat varieties over large areas resulted in faster spread of diseases such septoria leaf blotch (*Mycosphaerella graminicola*) in North Africa, and yellow rust (*Puciinia striiformis* f.sp. *tritici*) in West Asia. The identification of durable sources of resistance to the prevalent durum wheat diseases is an important objective of the CIMMYT/ICARDA Durum Wheat Improvement Program for the Mediterranean region. In West Asia and North Africa (WANA) region, resistance to rusts, septoria leaf blotch, and tan spot is essential. Virulence analysis of leaf rust (*Puccinia recondita*) showed that ten "Lr" resistance genes (Lr_1, Lr_{2a}, Lr_9, Lr_{15}, Lr_{19}, Lr_{24}, Lr_{25}, Lr_{26}, Lr_{28}, and Lr_{29}) were effective on bread wheat, six on durum wheat (Lr_1, Lr_{2a}, Lr_{20}, Lr_{25}, Lr_{26}, and Lr_{30}), and six among these "Lr" genes were effective on both crop species. Known resistance genes to yellow rust (*Puccinia striiformis* f.sp. *tritici*) were evaluated for their effectiveness against yellow rust in Syria, Lebanon, Turkey, Tajikistan, Uzbekistan, Iran, Ethiopia, and Yemen. Four resistance genes to yellow rust "Yr" were effective at all sites (Yr_8, Yr_{cv}, Yr_{15}, and Yr_{17}). For the diverse climatic conditions and cropping systems in Center West Asia amd North Africa (CWANA), the development of multiple disease resistance is essential. Durum wheat breeding nurseries were screened for multiple disease resistance. Genotypes that conferred resistance to combination of foliar diseases were identified.

Key words: Durum wheat, disease, multiple resistance, virulence.

RESUME – *"Résistance multiple aux maladies chez le blé dur* (Triticum turgidum *L. var.* durum)". *La résistance génétique joue un rôle important pour réduire les pertes engendrées par les maladies. Toutefois la monoculture d'un nombre limité de variétés de blé dur a contribué au développement des épidémies de certaines maladies, telles la septoriose* (Mycosphaerella graminicola) *en Afrique du Nord et la rouille jaune* (Puciinia striiformis *f.sp.* tritici) *à l'Ouest de l'Asie. Le développement de résistance multiple est parmi les priorités majeures du programme d'amélioration de blé dur CIMMYT/ICARDA dans les pays du bassin méditerranéen. Dans la région de CWANA (Centre Ouest de l'Asie et Afrique du Nord) la résistance aux maladies telles la septoriose, les rouilles, et la tache bronzée sur blé dur est essentielle. L'analyse de virulence de rouille brune* (Puccinia recondita) *a permis d'identifier les gènes de résistance efficaces sur blé tendre (Lr_1, Lr_{2a}, Lr_9, Lr_{15}, Lr_{19}, Lr_{24}, Lr_{25}, Lr_{26}, Lr_{28}, et Lr_{29}), sur blé dur (Lr_1, Lr_{2a}, Lr_{20}, Lr_{25}, Lr_{26}, et Lr_{30}), et six gènes de résistance sont efficaces sur les deux espèces. Les gènes conditionnant la résistance à la rouille jaune ont été évalués en Syrie, au Liban, en Turquie, au Tadjikistan, en Ouzbékistan, en Iran, en Ethiopie, et au Yémen. Quatre gènes de résistance (Yr_8, Yr_{cv}, Yr_{15}, et Yr_{17}) se sont montrés efficaces dans tous ces sites. Vu la diversité du climat et les systèmes de production pratiqués dans la région de CWANA, le développement de la résistance multiple est essentiel. Pour ce faire, toutes les pépinières de blé dur ont été évaluées pour ce type de résistance. Des génotypes ayant la résistance multiple ont été identifiés.*

Mots-clés : *Blé dur, maladies, résistance multiple, virulence.*

Introduction

Durum wheat is cultivated under widely variable climatic conditions in West Asia and North Africa (WANA), and is the most sustainable crop in the Mediterranean basin. Durum wheat production in WANA is severely affected by a number of diseases and insect pests. The most important of these pests are: septoria, tan spot, leaf and yellow rust, common bunt, root rot, Hessian fly, Russian wheat aphid, wheat stem saw fly and sunn pest. Research on these pests has focused on host plant resistance, and several sources of resistance have been identified and utilized in the durum wheat breeding programs. However, varietal monoculture is common among many farming communities in WANA region. Large farm operations get used to manage and commercialize a given variety and often do not accept to change it; small farmers, on the other hand, cannot cope with rapid varietal changes.

Durum wheat cultivars with a good resistance level to common bunt, leaf and stripe rusts cover over 40% of the wheat growing area in WANA. These cultivars include the following durum varieties: Karim, Marzak and Omrabi 3. The variety Karim occupies about 50 to 80% of the wheat area in Morocco and Tunisia respectively, and in Syria, Cham 3 occupies more than 75% in the dry areas and more than 60% of the cereal area under supplemental irrigation (M. Nachit, pers. comm.). These varieties and others probably meet the demand of the market for quality and that of the farmer for productivity. Unfortunately, they also fit pre-requisites of disease epidemic development. Karim and Cham 3 are widely cultivated and have become very susceptible to septoria and yellow rust, respectively. In addition, both are susceptible to leaf rust.

During favorable years in WANA region, yield loss due to diseases can reach up to 40%. In this region, cereal diseases have caused important economic losses. Country reports showed showed that losses in epidemic years reached up to 50% due to leaf rust in Egypt, over 60% losses due to septoria tritici in North Africa, and over 40% due to yellow rust in Turkey, Iran, and Syria. The latter was mostly on bread wheat. Research on foliar diseases has focused on host plant resistance, and several sources of resistance have been identified and utilized in the wheat breeding programs. Consequently, no major epidemic has been reported during the past five years. Introduction of improved cultivars with good level of resistance prevented the chronic yield losses in the WANA region, hence a direct contribution to yield increase.

The identification of sources of resistance to the prevalent durum wheat diseases is an important objective of the CIMMYT/ICARDA durum improvement program for the Mediterranean region. At ICARDA, durum wheat germplasm is routinely screened for disease resistance under controlled and field conditions using Syrian local isolates of fungal pathogens. Selected lines are further evaluated by collaborators in the WANA region under field conditions in disease hot spots. Identified resistant entries are advanced for further selection. Advanced resistant lines are further tested for yield performance and/or incorporated in the crossing program.

Disease incidence in WANA

The comprehensive information on pathogen virulence and variation, and the epidemiological information on pathogen movements, provide a basis for the development of an early warning system to farmers growing potentially susceptible cultivars. Durum wheat is grown under a wide range of climatic conditions that are conducive to the development of an array of fungal diseases. In the WANA region, at least two of the rusts will appear simultaneously. It is common to observe the development of stripe rust and leaf rust in Syria, and leaf rust and stem rust in Egypt. The rusts are also associated with other diseases such as septoria leaf blotch and tan spot. Resistance to septoria and leaf rust is essential for durum wheat targeted to North Africa and the coastal areas of the Mediterranean region.

Studies of disease incidence, virulence patterns and shifts of most common diseases were realized through surveys, trap nurseries, and evaluation under controlled environments. Pathogenicity studies were also conducted under controlled environment, and under artificial inoculation in the field.

Virulence analysis of leaf rust, *Puccinia recondita*

In 1997, the leaf rust seedling test, was conducted initially with 25 selected differential genotypes. In 1998, the number of differential genotypes was increased to 37 entries to allow better differentiation between isolates. The virulence analysis showed that the inoculum obtained from bread wheat could overcome the following known “Lr” resistant genes: Lr_{2b}, Lr_{2c}, Lr_{3}, Lr_{3Ka}, Lr_{3Bg}, Lr_{10}, Lr_{11}, Lr_{12}, Lr_{13}, Lr_{14b}, Lr_{16}, Lr_{17}, Lr_{18}, Lr_{20}, Lr_{21}, Lr_{22a}, Lr_{23}, Lr_{30}, Lr_{32}, Lr_{33}, Lr_{34}, Lr_{35}, and Lr_{36}. The inoculum obtained from durum wheat can overcome the following known “Lr” resistant genes: Lr_{2b}, Lr_{2c}, Lr_{3}, Lr_{3Ka}, Lr_{3Bg}, Lr_{9}, Lr_{10}, Lr_{11}, Lr_{12}, Lr_{13}, Lr_{14a}, Lr_{14b}, Lr_{15}, Lr_{17}, Lr_{18}, Lr_{19}, Lr_{21}, Lr_{22a}, Lr_{23}, Lr_{24}, Lr_{32}, Lr_{33}, Lr_{34}, Lr_{35}, and Lr_{36}.

The “Lr” resistant genes Lr_{1}, Lr_{2a}, Lr_{9}, Lr_{15}, Lr_{19}, Lr_{24}, Lr_{25}, Lr_{26}, Lr_{28}, and Lr_{29}, were shown to be highly effective for bread wheat under artificial inoculation at Tel Hadya. The “Lr” resistance genes Lr_{1}, Lr_{2a}, Lr_{20}, Lr_{25}, Lr_{26}, and Lr_{30}, were highly effective for durum wheat. Leaf rust isolates tested showed host preference against certain resistance genes. Resistance genes Lr_{9}, Lr_{15}, Lr_{19}, Lr_{24}, Lr_{28}, and Lr_{29} were effective for bread wheat but not for durum wheat, whereas, resistance genes Lr_{20} and Lr_{30} were effective for durum wheat and not for bread wheat. Six “Lr” resistance genes Lr_{1}, Lr_{2a}, Lr_{2}, Lr_{26}, Lr_{28}, and Lr_{29}, were effective for both crop species.

Yellow rust (*Puccinia striiformis* f.sp. *tritici*), pathotypic identification and virulence analysis

Yellow rust pathogenic variation, in Central and Western Asia, and North Africa (CWANA), is the underlying cause of the elusive rust resistance. During the last decade, several yellow rust epidemics have occurred in most countries in the region and resulted in severe loss particularly in bread wheat. In the 1991/92 cropping season, yellow rust spread into the Baluchistan region of Pakistan for the third consecutive year and caused significant losses in the common cultivar 'Local White' (Ahmad *et al.,* 1991). Yellow rust epidemics occurred in most of the wheat-growing areas in Iran and caused over 30% crop loss (Torabi *et al.,* 1995). Yield losses were also recorded in Lebanon, Turkey, Iran, Yemen, and Ethiopia (Babedo and Bayu, 1992; Torabi *et al.,* 1995; Dusunceli *et al.,* 1996), particularly where the susceptible variety Veery was grown over large areas. In Turkey, the wheat cultivar 'Gerek 79', grown on more than one million hectares, withstood losses of 26.5% due to the yellow rust epidemic of 1991, and over 50% in 1998 (Braun and Saari, 1992). In the southern region of West Asia, severe epidemics of yellow rust also have been recorded. In Yemen, losses in grain yield ranged from 10 to 50% during the 1991-96 period (Bahamish *et al.,* 1997). Yellow rust epidemics and significant yield losses in 1996 and in 1999 have been observed in Azerbaijan.

Based on a May 1999 disease survey, yellow rust was considered a major wheat disease in other CWANA countries, where it continues to incur wheat crop losses. Known resistance genes to yellow rust ("Yr" genes) were evaluated for their effectiveness against yellow rust (*Puccinia striiformis* f.sp. *tritici*) in Syria, Lebanon, Turkey, Tajekistan, Uzbekistan, Iran, Ethiopia, and Yemen. Resistance genes: Yr_{8}, Yr_{CV}, Yr_{15}, and Yr_{17} were effective in all the testing sites in the countries mentioned above. Yr_{SD} and Yr_{SU} resistance genes were effective at all sites but Syria. Yr_{7} and Yr_{2+} were effective at all sites but Syria and Lebanon. The latter genes could be still used in Central Asia, but should be avoided in Syria and Lebanon. A combination of the resistance genes such as "Yr_{15} and Yr_{1}", "Yr_{17} and Yr_{3N}", "Yr_{CV}, Yr_{Sp}, and Yr_{8}", and "Yr_{18} and Yr_{1}" could offer a durable resistance to yellow rust in CWANA region.

Septoria tritici blotch (*Mycosphaerella graminicula*) incidence in North Africa

Among foliar diseases, septoria has been recognized as the most economically serious disease in the Maghreb. CIMMYT initiated a strong breeding program for septoria resistance following the epidemic recorded in 1968 in Morocco. Adequate resistance level was developed in bread wheat cultivars but not in durum wheat, hence durum wheat in North Africa is usually more cultivated in dryland areas where septoria occurrence is less severe than in high rainfall areas. Severe septoria incidence still occurs on durum wheat in Tunisia, and less so in Algeria and Morocco. This indicates that pathotypes in Tunisia are more adapted to durum wheat than bread wheat. The inverse situation exists in Morocco, where bread wheat is the major crop affected by septoria. This may explain further that specificity of septoria pathotypes exists in wheat. Moreover, it appears that the magnitude of the virulence and disease incidence are variable and closely related to the frequency of the variety used in a particular area as well as the proportion of durum wheat area as compared to that of bread wheat. High and significant Isolate x Genotype interactions were found in Tunisia, suggesting a differential virulence pattern (M. Harrabi, pers. comm.).

Common bunt *(Tilletia laevis* and *Tilletia tritici)* in WANA

Smuts are among the most prevalent wheat diseases in WANA. Common bunt disease is caused by two closely related species of *Tilletia*: *T. laevis* and *T. tritici*. In WANA region, there is a strong selective advantage of bread wheat for *T. laevis*, whereas durum wheat is equally infected by both species. In most countries in WANA, particularly large with State farm operations, fungicides are well used and provide a good control measure for smuts. However, the most recommended and cost-effective method of control is the use of resistant cultivars that come at no extra cost to farmers.

Sources of resistance (Table 1) to both species of common bunt (*T. laevis* and *T. tritici*) were identified in bread and durum wheat germplasm and are being exploited in the CIMMYT/ICARDA wheat program. Sources of resistance were identified in landrace cultivars grown on a large scale in WANA, e.g. Haurani in the Middle East region, Jennah Khetifa or Tamgurt in the Atlas region, and Kobak in The Anatolian plateau.

Table 1. List of resistant durum wheat lines to common bunt

Name/pedigree
61/130//414/3/44/4/AA/5/Zf/Lds//Kobak 2916/3/61-130/4/Tag.B.B
Cit71/MexI//Shwa/3/PtL
Haurani

Source of multiple-disease resistance in durum wheat germplasm

Under field conditions, diseases more often can be caused by different pathogens, hence, the ultimate objective in the search for genetic resistance to biotic stresses is to develop durum wheat varieties that offer resistance to as many diseases as possible.

At ICARDA, all the potential durum wheat germplasm is screened for resistance to the predominant diseases in WANA such as yellow rust, leaf and stem rust, septoria, and common bunt. Breeding nurseries are initially screened at ICARDA (Tel Hadya), then within the region in collaboration with National Agricultural Research System (NARS). Over 900 entries were screened in 1998, 130 advanced lines were tested for specific disease resistance, and about 800 were first tested for multiple disease resistance at ICARDA, then within the region in collaboration with NARS.

Resistance to rusts and to septoria leaf blotch

Special nurseries for specific diseases (325 lines) were evaluated under field conditions in Syria, Lebanon, and Romania, and under controlled environment at ICARDA. The diseases considered were yellow rust (YR), leaf and stem rust, and septoria leaf blotch. Resistance to yellow rust was relatively good in all the nurseries tested. The number of entries showing good resistance to stripe rust was over 57% for Durum Aleppo Crossing Block (DACB) and Durum Preliminary Disease (DPD), and exceeded 40% in durum yellow rust (DYR) and durum wheat key location disease (DKL) nurseries (Figs 1-3).

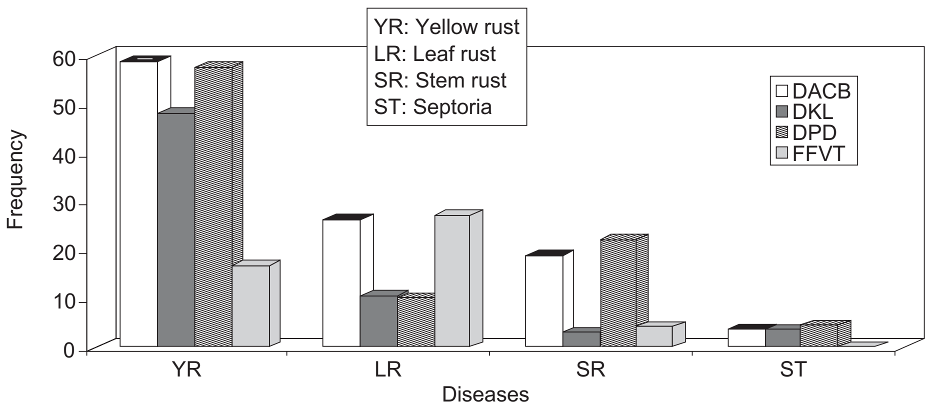

Fig. 1. Frequency distribution of resistant durum wheat lines in four screening nurseries. DACB: Durum wheat Aleppo Crossing Block; DKL: Durum Key Location; DPD: Durum Preliminary Disease and FFVT: Farmer Verification Trials.

The durum wheat germplasm screened in 1998 showed a relatively low resistance level to septoria, and to stem rust (Figs 1 and 2). A relatively large number of lines showed intermediate type of resistance to stem rust (45.7% in DSR) and to septoria (40% in DST) (Fig. 1). This type of resistance is considered as "tolerance" and can be very useful in the improvement of resistance to septoria in durum wheat. Sources of resistance to stem rust and septoria should be improved in the Aleppo Crossing-Block nursery.

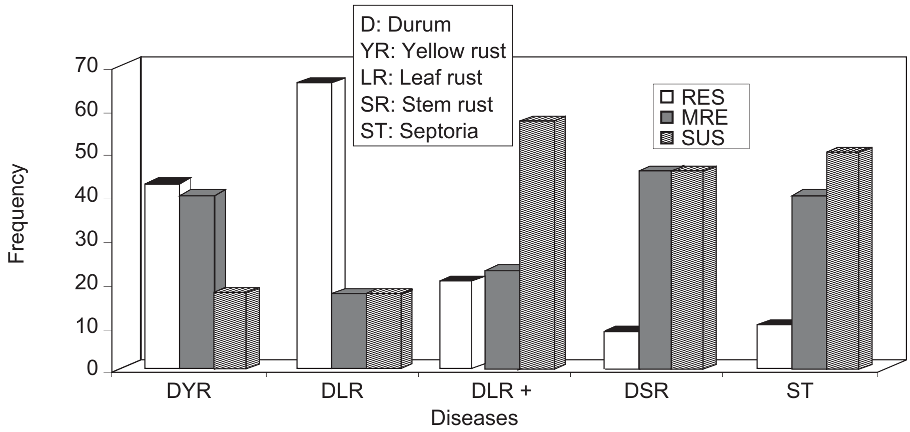

Fig. 2. Frequency distribution of different resitance levels in durum wheat nurseries to five diseases. RES: resistant; MRE: intermediate resistant types; SUS: susceptible.

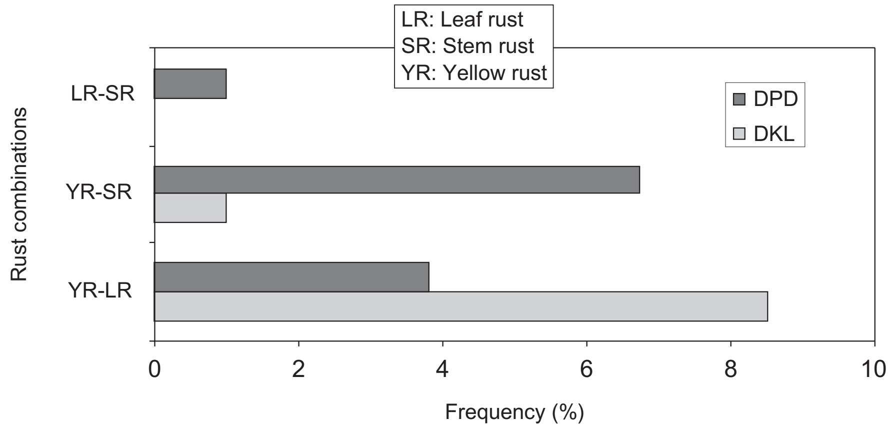

Fig. 3. Frequency distribution of combined resistance to rust in two durum wheat nurseries. DPD: Durum Preliminary Disease; DKL: Durum Key Location disease nursery.

The nurseries tested for multiple-disease resistance showed a good level of resistance to yellow rust (Fig. 3). However, the proportion of resistant lines to septoria, among all the nurseries, did not exceed 5%. Durum wheat lines in the DPD and DKL nurseries showed good resistance to combinations of two rusts (Fig. 3). In the DPD nursery 27 entries showed good resistance to both yellow and stem rust, 15 entries were resistant to stripe and leaf rust, and only four entries showed resistance to leaf and stem rust. In the DKL nursery, 17 entries showed resistance to stripe and leaf rust, two entries were resistant to yellow and stem, rust but none of the lines tested showed resistance to both stem and leaf rust. Among all the genotypes tested, only four entries (0.43%) showed resistance to the three rusts (Table 2). Resistance to septoria and rust was identified from different nurseries (Table 2).

Future prospects in breeding for multiple disease resistance

Emphasis on breeding for disease resistance for the CIMMYT/ICARDA durum wheat program will target the following areas: (i) consolidate studies on disease development and screening for resistance undertaken by sub-networks within the Maghreb and Nile Valley and Red Sea regions; (ii) target resistance to prevalent diseases within agroecological zones; (iii) identify effective resistance genes and attempt, with NARS, to develop gene deployment strategies; (iv) develop and adopt marker-assisted selection and new biotechnological tools to monitor resistance genes in durum wheat germplasm and virulence genes in prevalent cereal pathogens; and (v) at the farm-level, initiate an integrated disease management approach that can reinforce the ICARDA-IPM project in its attempts to develop cost-effective disease management control measures in WANA.

Table 2. List of resistant durum wheat lines to disease combinations

Name/pedigree	
Durum wheat lines resistant to yellow rust, leaf and stem rust	
Hel/3/Bit/Corm//Shwa/4/T.mon1450/5/Mtl6	ICD92-0721-WABL-0AP-0TR
Ossl1/Gdfl	ICD92-0940-CABL-0AP-5AP-0TR
Hel/3/Bit/Corm//Shwa/4/T.mon 1450/5/Mtl-6	ICD92-0721-W-0AP-3AP-0TR
Stj3/3/Gdfl/T.dicdsSy20013//Bcr	ICD94-1010-W-0AP-21AP-0AP
Durum wheat lines resistant to septoria and yellow rust	
Unk/5/PI178043/3/61-130/Lds//Gla/4/Vls//Ge5	YA06128-0A-0AP
DF9-71/3/VZ466//61-130/414-44/4/Ergene	TE01061-23A-1A-1A-0A-0AP
HFN94N MOR NO 21/Mrb5	ICD94-0172-T-0AP-24AP-0AP
BD272/C Jucci//Stj1/3/Mna1	ICD93-0257-T-0TR-12AP-6AP-OAP
Krf/T.monIC 2165//Chah88	ICD93-0257-T-OTR-12AP-10AP-0AP
Ruff/Fg//Turk1/3/Gil3	ICD92-0723-W-0AP-2AP-0TR-3AP-3A
Ruff/Fg//Turk1/3/Stj6	ICD92-0081-H-2AP-0AP-14AP-0AP
	ICD92-0087-H-3AP-0AP-18AP-0AP
Durum wheat line resistant to septoria and leaf rust	
Shwa/Stk//Bit/3/Kyp/4/Chah88	ICD92-0020-MABL-2AP-0TR-4AP-0AP
Durum wheat line resistant to septoria and stem rust	
SD-19539 (USA)//Awl2/Bit/3/Gil4	ICD92-0507-t-0AP-9AP-0TR-2AP-0A

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References

Ahmad, S., Rodriguez, A., Farid Sabir, G., Roidar Khan, B. and Panah, M. (1991). *Economic losses of wheat crops infected with yellow rust in highland Baluchistan.* MART/AZR Project Research, Report # 67.ICARDA Quetta, p. 15.

Badebo, A. and Bayu, W. (1992). The importance of stripe rust in the major bread wheat producing regions of Ethiopia during 1998-90. In*: Proceedings 7th Regional Wheat Workshop for Eastern, Central and Southern Africa,* Tanner, D.G. and Mwangi, W. (eds), Nakuru (Kenia), 16-19 September 1991. CIMMYT, Mexico, pp. 196-202.

Bahamish, H.S., Al-Ansi, A., Baswaid, J., Obeid, A.S. and Al-Mahfadi, K. (1997). Studies on wheat rusts in Yemen. In: *Nile Valley and Red Sea Regional Program on Cool-Season Food Legumes and Cereals,* Annual Report 1996/97, pp. 34-49.

Braun, H-J. and Saari, E.E. (1992). An assessment of the potential of *Puccinia striiformis* f.sp. *tritici* to cause yield losses in wheat on the Anatolian Plateau of Turkey. In: *Proceedings 8th. European and Mediterranean Cereal Rusts and Mildews Conference,* Zeller, F.J. and Fischbeck, G. (eds), Wheihenstephan (Germany), 8-11 September 1992, pp. 121-123.

Dusunceli, F., Getin, L., Albustan, S. and Beniwal, S.P.S. (1996). Occurrence and impact of wheat stripe rust *(Puccinia striiformis)* in Turkey in 1994/95-crop season. In: *Proceedings 9th European and Mediterranean Cereal Rusts and Powdery Mildews Conference,* Kema, G.H.J., Niks, R.E. and Daamen, R.A. (eds), Lunteren (The Netherlands), 2-6 September 1996, p. 309.

Torabi, M., Mardoukhi, V., Nazari, K., Afshari, F., Forootan, A.R., Ramai, M.A., Golzar, H. and Kashani, A.S. (1995). Effectiveness of wheat yellow rust resistance genes in different parts of Iran. *Cereal Rusts and Powdery Mildews Bulletin,* 23(1): 9-12.