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Poster Abstracts
Theme 4: Breeding for Rust Resistance

Edited by Robert McIntosh
bgri@cornell.edu
www.globalrust.org

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Initiation of genomic recurrent selection for slow-rusting adult plant resistance to stem rust in wheat

J. Rutkoski¹, R. P. Singh², J. Huerta-Espino³, S. Bhavani⁴ and M. E. Sorrells¹

¹Department of Plant Breeding and Genetics, 240 Emerson Hall, Cornell University, Ithaca, NY 14853, USA; ²CIMMYT, Apdo. Postal 6-641, 06600 El Batan, Mexico; ³Campo Experimental, Valle de México INIFAP, Apdo. Postal 10, 56230 Chapingo, Edo de México, Mexico; ⁴CIMMYT, ICRAF House, United Nations Avenue, Gigiri, Village Market-00621, Nairobi, Kenya. Email: rutkoski.jessica@gmail.com

Genomic selection (GS) is a new breeding technology that promises to increase the rate of genetic gain for quantitative traits. With GS, a prediction model for the trait(s) of interest is developed using a relevant population with existing phenotypic and genotypic data. The prediction model is then applied to a new set of breeding lines which have been genotyped in order to estimate the breeding values. Based on the predicted breeding values, lines can be selected for advancement or crossing to initiate the next selection cycle. This allows selection to occur before phenotypic information for the lines can be generated, therefore enabling faster selection cycles. In order to empirically evaluate the efficiency of GS relative to phenotypic selection (PS) for slow-rusting adult plant stem rust resistance (APR), two parallel recurrent selection (RS) schemes are underway, and are currently at the first selection cycle stage. Selections are based on phenotypes in the first scheme (RS-PS), and on genotypes and predicted breeding values in the second scheme (RS-GS). Based on cross-validation using the model training population, we expect the selection accuracy with GS to be 0.6. Based on phenotypic data from the same germplasm evaluated across four growing seasons, we expect the selection accuracy with PS to be 0.78. Because the minimum selection cycle duration is 8 months with GS and 12 months with PS, considering our estimates of selection accuracy we expect to achieve 1.15 times more genetic gain per unit of time with GS compared to PS.
Identification of high yielding, drought tolerant and stripe rust resistant facultative/winter wheat genotypes at ICARDA

W. Tadesse and S. Rajaram

Wheat breeding, ICARDA, P.O. Box 5466, Aleppo, Syria. E-mail: w.tadesse@cgiar.org

Stripe (yellow) rust and drought are the principal yield limiting factors for wheat production in the CWANA region. ICARDA’s germplasm development approach is to identify genotypes with high yield potential, high water use efficiency and resistance to stripe rust. Our aim is to minimize and maximize yield gains during drought and good seasons, respectively. Toward these objectives we make more than 500 crosses annually, and evaluate the segregating populations using a modified pedigree/selected bulk approach in Pst-inoculated irrigated nurseries. Preliminary and advanced yield trials are evaluated under both irrigated and rain-fed conditions. With this approach we have identified stripe rust resistant genotypes (5-10% severity) which yield as high as 6.5 and 2.5 t/ha under irrigated (450 mm) and rain-fed (232mm) conditions, respectively. These genotypes combine high yield potential, drought tolerance, stripe rust resistance and good grain quality. Some of the genotypes are candidates for release in some countries.
Stripe rust and leaf rust responses of a double haploid wheat population derived from Ducula-4/2*Brookton

M. S. Saharan¹, G. Singh¹, T. L. Setter², V. Panwar¹ and I. Sharma¹

¹Directorate of Wheat Research, Karnal, Haryana, India; ²Department of Agriculture and Food, South Perth, WA 6151, Australia. Email: mssaharan7@yahoo.co.in

Rusts are a threat to sustainable food production. In India leaf rust is a regular occurrence, but stripe rust can be more damaging even though it is less widespread. New sources of resistance are required to combat the regular emergence of new races. In the present study, 155 double haploid lines from Ducula-4/2*Brookton were screened against prevalent races of Pst (78S84, 46S119) and Pt (12-2, 77-2, 77-5, 104-2) at Karnal during 2009 - 2011. Lines were categorized by Area Under the Disease Progress Curve (AUDPC) values calculated from the rust severities recorded at regular intervals. Among 155 lines, 32 (group I) were stripe rust-free whereas other lines gave AUDPC values of 1-100 (group-II, 7 lines), 101-200 (group-III, 21 lines) and 201-500 (group-IV, 38 lines); the remaining lines gave higher values. For leaf rust, 20 lines were rust-free and 32, 9 and 52 lines were placed in groups II, III and IV, respectively. Group II - IV lines for both diseases were considered to be slow rusting as their AUDPC values were less than 20% of the checks. Such slow rusting lines can be used as parents for incorporating slow rusting genes into breeding populations.
Global variation of winter wheat in response to *Pst* race Ug99

A. Morgounov¹, B. Akin¹, Y. Kaya², M. Keser³, L. X. Yu⁴, Y. Jin⁵, S. Martynov⁶, Z. Mert⁷, M. Sorrels⁸ and R. Wanyera⁸

¹CIMMYT, P.O. Box 37, Emek, Ankara 06511, Turkey; ²International Agricultural Research Institute, P.O. Box 125, Karatay, Konya, Turkey; ³ICARDA, P.O. Box 37, Emek, Ankara 06511, Turkey; ⁴Department of Plant Breeding and Genetics, Cornell University, Ithaca, NY 14853, USA; ⁵USDA-ARS Cereal Disease Laboratory, 1551 Lindig Street, University of Minnesota, St. Paul, MN 55108, USA; ⁶Vavilov Institute, 44 B. Morskaya St., St. Petersburg, Russia; ⁷Central Field Crop Research Institute, Sehit Cem Ersever, Caddesi No:9-11, Ankara, Turkey; ⁸Kenya Agricultural Research Institute, P.O. Private Bag 20107, Njoro, Kenya. Email: a.morgounov@cgiar.org

The International Winter Wheat Improvement Program (www.iwwip.org) is was established as a joint project by the Ministry of Food, Agriculture and Animal Husbandry of Turkey, CIMMYT, and ICARDA in 1986. The objective of the program is to develop facultative and winter wheat germplasm for the Central and West Asia region. IWWIP also facilitates global germplasm exchange of winter wheat by assembling lines from various sources, and evaluating and distributing selected entries through its system of international nurseries. Resistance to rusts is a high priority along with adaptation and grain quality. Due to the obvious importance of *Pst* race Ug99, evaluation of germplasm for resistance in Kenya started in 2008. From 2008 to 2011, approximately 3,000 entries representing germplasm from all major winter wheat producing countries, except China, were evaluated. The average frequency of resistant entries was 15-20%. Close to 50% of resistant germplasm possessed APR and was susceptible at the seedling stage. The severities of infection for APR materials were 5-15% higher than lines possessing major genes. Genetic diversity analysis of a set of resistant genotypes using parentage information revealed three clusters: USA and USA-derived germplasm with a possible presence of the Amigo-derived 1A.1R translocation; East European germplasm with strong effect of Bezostaya in pedigrees, and IWWIP germplasm based on winter x spring crosses. Race Ug99-resistant germplasm was characterized for resistance to other diseases and agronomic traits, multiplied, and made available to IWWIP global cooperators for selection and utilization in their programs.
Studies of wheat species collections for resistance to harmful diseases

E. D. Kovalenko¹, T. M. Kolomiets¹, M. I. Kiseleva¹, L. F. Pankratova¹ and H. Bockelman²

¹All Russian Research Institute of Phytopathology, Moscow, Russia; ²USDA-ARS, National Small Grains Collection, 1691 S. 2700 W., Aberdeen, ID 83210, USA. Email: kovalenko@vniif.ru; harold.bockelman@ars.usda.gov.

Wheat accessions from NSGC (USA) and WIR (Russia) resistant to leaf rust, Septoria diseases and powdery mildew were selected in an infection nursery of ARRIP (Central Region of Russia). The accessions represented 17 subspecies of 6 wheat species, viz. *Triticum monococcum* (2n=14), *T. turgidum, T. timopheevii, T. ispahanicum* (2n=28), *T. zhukovskyi* and *T. aestivum* (2n=42). Resistance depended on ploidy. Diploid wheat *T. monococcum* accessions were very resistant to leaf rust and Septoria diseases. Tetraploid wheat accessions *T. ispahanicum, T. turgidum* ssp. *carthlicum*, and *T. turgidum* ssp. *turanicum* were resistant to leaf rust, and *T. turgidum* ssp. *dicoccon, T. turgidum* ssp. *turgidum*, and *T. timopheevii* ssp. *timopheevii* to septoria disease. Hexaploid wheat accessions were characterized by high disease susceptibility. Four accessions: PI 418584 - WIR 38555 (Georgia), PI 276007 - 103 (Spain), PI 348702 - 69Z6.886 (Spain), PI 277129 - Subletshchumicum (Switzerland) were the most important due to their joint resistances to leaf rust, Septoria diseases and powdery mildew.
Selection of wheat cultivars partially resistant to leaf rust and Septoria diseases

T. M. Kolomiets\(^1\), E. D. Kovalenko\(^1\), M. I. Kiseleva\(^1\), L. F. Pankratova\(^1\) and H. Bockelman\(^2\)

\(^1\)All Russian Research Institute of Phytopathology, Moscow, Russia; \(^2\)USDA-ARS, National Small Grains Collection, 1691 S. 2700 W., Aberdeen, ID 83210, USA. Email: kolomiets@vniif.ru; harold.bockelman@ars.usda.gov

Wheat cultivars partially resistant to leaf rust and Septorias were selected by study of the following components: area under the disease progress curve (in infection nurseries), latent period, size and quantity of pustules and spots (in the laboratory, growth cabinet or greenhouse). Wheat accessions CIGM90.845, BW27720, BW27725, BW27830, BW27832, BW27964, BW28091, BW28035 (Mexico) from NSGC (USA), Hubara 1 (Syria), Gerak 1, Saratovskaya 74 (Russia) from the WIR collection, and Omskaya 20, Omskaya 37, Omskaya 39, Lutestcens 4140 from the Siberian ARI were characterized by partial resistance to leaf rust. Partial resistance to SNB in 7 wheat cultivars, Cambridge Rivet (UK), Anderson, (USA), PI 94743 (290) (Russia), RAC 610, RAC 569, K-20 (South Africa) and SWS "A" №80 (Sweden), was caused by long latent period and small infectious spots. in 6 accessions: 69Z6.886 (Spain), Owens (USA), Trizo, Voronezhskaya 10, Lyra 98, and Legenda (Russia) it was caused by long latent period, and G2697 (Iraq), WIR 38555 (Georgia), PI 290518 (Hungary), Warigal (Australia), KS96WGRC40 (USA) and Enita (Russia) had smaller sized infectious spots than the susceptible check Priokskaya 1. Partial resistance to STB present in Azteca and Alondra (Mexico) was due to long latent period, in Piamontes (Argentina) due to small infectious spots, and in Galina (Russia) due to long latent period and fine infectious spots.
Phenotyping and genotyping of “Arsenal” accessions for resistance to \textit{Puccinia} species

I. F. Lapochkina$^1$, A. I. Morgunov$^2$ and G. Woldeab$^3$

$^1$Moscow Agriculture Research Institute “Nemchinovka”, Moscow Region, Russia; $^2$CIMMYT, P.K. 39 Emek 06511 Ankara, Turkey; $^3$Plant Protection Research Center, Ambo, Ethiopia. 

Email: inna-lapochkina@yandex.ru

The “Arsenal” collection comprises about 145 accessions of spring wheat and 150 accessions of winter wheat derivatives of hybrids involving various species, including \textit{Aegilops speltoides}, \textit{Ae. triuncialis}, \textit{Triticum kiharae} and \textit{Secale cereale}. About 40\% of spring genotypes are resistant to leaf rust (severities $< 20\%$) and 60\% are resistant to powdery mildew (severity $< 10\%$). In Ethiopia in 2010 part of the collection (31 spring wheat accessions) was evaluated against \textit{Pgt} race Ug99 in the field, and seedlings of 59 winter wheat accessions were evaluated in greenhouse seedling tests. Spring accession 113/00-4, a derivative of \textit{Ae. triuncialis} was immune in the field. Seven winter habit \textit{Ae. speltoides}, derivatives were resistant in the seedling tests (IT 0, 1, or 2). The collection was evaluated against yellow (stripe) rust in Turkey (Central Field Crop Research Institute, Hayman Station) where the pathogen population was avirulent for genes \textit{Yr1, 3, 4, 5, 10, and 15}. More than a half of the winter accessions in the collection were resistant. Postulation of the \textit{Lr} and \textit{Sr} genes in the resistant accessions is currently underway.
Resistance to stripe rust in promising lines and bread wheat cultivars

M. Khodarahmi\textsuperscript{1}, A. Omrani\textsuperscript{2} and F. Afshari\textsuperscript{1}

\textsuperscript{1}Seed and Plant Improvement Institute, P.O. Box 4119, Karaj, Iran; \textsuperscript{2}Department of Plant Breeding, Karaj Branch, Islamic Azad University, Karaj, Iran.

Email: Khodarahmi_m@yahoo.com

Five promising Iranian bread wheat lines and cultivars were evaluated for stripe rust response using 30 \emph{Pst} isolates collected from different locations in Iran. Among them cv. Aflak showed seedling resistance and the other genotypes were highly resistant in the field. To determine the genetics of resistance \textsuperscript{F1}, \textsuperscript{F2}, \textsuperscript{F3}, \textsuperscript{BC1} and \textsuperscript{BC2} generations from Aflak/Avocet S (susceptible) were evaluated using a randomized complete block design with three replications in the SPII greenhouse at Karaj. Seedlings were inoculated with a 1:4 urediniospore:talc mixture. Components of resistance, including infection type, latent period, pustule size and pustule density on single plants of each generation, were recorded. Generation mean and variance analysis showed that in addition to additive and dominance effects, epistasis also played a significant role in determination of resistance. All traits showed high broad-sense heritabilities, whereas estimates of narrow-sense heritabilities for resistance components varied from moderate to high. The number of segregating genes for each trait was estimated at between 1 and 2.
Screening for stem rust resistance (race Ug99) in East Africa

S. Bhavani¹, P. Njau², R. Wanyera², A. Badebo³ and B. Girma³

¹CIMMYT Kenya, P.O. Box 1041, Nairobi, Kenya; ²Kenya Agricultural Research Institute, Njoro Plant Breeding Research Center, P.O. Box Private Bag, 20107, Njoro, Kenya; ³Ethiopian Institute for Agricultural Research, Debra Zeit, Ethiopia. Email: s.bhavani@cgiar.org

International stem rust screening nurseries at KARI and EIAR play key roles in the DRRW project for identifying new sources of resistance, pre-breeding, CIMMYT-Kenya shuttle breeding, varietal release, mapping APR and major genes, and genomic selection. About 250,000 lines have been screened against *Pgt* race Ug99 and derivatives since 2005, and the screening capacity at KARI has increased from 20,000 to 50,000 lines each year. Significant investment in infrastructure and facilities has ensured reliable phenotypic data over years. The results from international nurseries show a shift to higher frequencies of lines with resistance to race Ug99. A training course organized at KARI each year focuses on standardized note-taking and evaluation of germplasm. Our future aim is to assess materials resistant over consecutive field seasons and greenhouse seedling tests. Studies in progress are assessing the stem rust response data in international nurseries as a means of gauging global diversity.
Developing single seed descent populations for combining biotic and abiotic stress tolerances in bread wheat

G. Singh¹, M. S. Saharan¹, T. L. Setter², M. K. Singh¹ and I. Sharma¹

¹Directorate of Wheat Research, Karnal 132001, India; ²Department of Agriculture and Food Western Australia, South Perth, WA 6983, Australia. Email: gysingh@gmail.com

High yield and enhanced tolerance to biotic and abiotic stresses are the most important objectives for wheat research on the Indo-Gangetic Plains. Among biotic stresses, leaf rust and spot blotch occur in all wheat growing zones, whereas stripe rust is important in the northern hills, north western plains zone and north eastern plains zones. In addition, tolerance to abiotic factors (salinity, water logging and terminal heat stress) will be necessary for future wheat genotypes. To meet these challenges, SSD populations of three crosses (PBW 550/Chirya 1, DBW 17/BH 1146 and DBW 16/BH 1146) were developed at DWR, Karnal. During 2011-12 1,140 F₄ lines were screened against leaf rust, stripe rust and spot blotch in inoculated nurseries. Many lines were highly resistant to all three diseases indicating that promising lines with combined multiple disease resistances can be achieved. In view of the various features of the parental lines, such as tolerance to water logging in DBW 17 and spot blotch resistance and aluminum tolerance in BH 1146, we are confident of developing lines with high yield, and resistance to biotic and abiotic stresses.
Evaluation of stem rust resistant wheat lines for commercial production in Kenya

P. Njau1, L. Karani1, S. Bhavani2, R. Wanyera1, J. Huerta-Espino3 and R. P. Singh2

1Kenya Agricultural Research Institute - Njoro, P.O. Box Private Bag, Njoro 20107, Kenya; 2CIMMYT, Apdo. Postal 6-641, 06600 Mexico, DF, México; 3Campo Experimental Valle de México INIFAP, Apdo. Postal 10, 56230 Chapingo, Edo de México, México. Email njaupnn@yahoo.com

The improvement of crop varieties adapted to different agro-ecological conditions is a priority in many breeding programs. High yields, resistance to abiotic and biotic stresses, high nutritional quality, and appropriate end use characteristics are paramount. Over the last seven years KARI has been actively involved in breeding and selection of wheat lines for stem rust resistance. In addition, advanced lines are screened for adaptation and adoption in Kenya. An Advanced Yield Trial comprising 48 entries and two checks was constituted after selection at Njoro. The trial, a randomised complete block with 3 replications was planted at six sites, viz. Naivasha, Narok, Kinamba, Njoro, Olkarau and Eldoret in 2010 and 2011. Data included disease response, plant type, grain yield and grain weight. In 2011, five lines (R1238, R1244, R1244, R1256 and R1273) outperformed the check variety, Robin. In 2010 R1238 (PASTOR//HXL7573/2*BAU/3/SOKOLL/WBLL) was the best yielding at 2.54 t/ha compared to the check at 1.9 t/ha. In 2011 the best line was R1256 (TACUPETO F2001*2/KUKUNA//JUCHI/6/WBLL1/4/HD2281/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/TAC UPETO F2001) at 2.49 t/ha. Robin was the best overall in 2 years in Eldoret, whereas R1238 was the best at Njoro. The best seven lines were submitted to the National Performance Trials (NPT) as candidates for future release.
The importance of yellow (stripe) rust on wheat in Algeria and release of varieties resistant to yellow rust and stem rust

A. Benbelkacem¹, N. Derbal² and C. Djenadi¹

¹INRAA/URC Station ITGC, Elkhroub 25100, Algeria; ²8 May 1945 University, BP401, Guelma 24000, Algeria. Email: benbelkacem@mail.com

Wheat is a high value crop in both high and moderate rainfall areas of Algeria. The new high yielding bread wheat cv. Hidhab (Neelkant) covering 80% of wheat growing areas after replacing local landrace cultivars, has become highly susceptible to yellow rust in both high rainfall and semi arid regions with losses of 20 to 80% being recorded almost annually. The present study was carried out to identify sources of stripe rust resistance that could be used to enhance cultivar improvement efforts. Durable resistance associated with genes such as $Yr_{18}$, and some very effective major effective genes such as $Yr_1$, $Yr_9$ and $Yr_{27}$ in superior parental lines were previously used in our breeding program to reduce the impact of yellow rust for over a decade. Virulence for $Yr_{27}$ now presents a serious threat. New material selected during a yellow rust epidemic in 2004 led to the release of four new cultivars (Tiddis, Boumerzoug, Akhamokh and Massine) this year. Seed has been distributed to high performing farmers for multiplication. In collaboration with the CIMMYT/ICARDA program we are promoting the new cv.Yacine which is resistant to to $Pgt$ race Ug99 ($Sr_2$, $Sr_{25}$).
Resistance to threatening of *Puccinia graminis* f. sp. *tritici* and *P. striiformis* f. sp. *tritici* races in Moroccan bread wheat cultivars and landraces

A. Ramdani¹, H. Ouabbou¹, S. Bhavani², K. Nazari³, R. Wanyera⁴, S. Lhaloui¹, F. Abbad-Andaloussi¹, N. Nsarellah¹, S. Bennani¹, J. Haddouri¹ and S. M.Udupa³

¹INRA – CRRA, P.O. Box 578, Meknès, Morocco; ²INRA – CRRA, P.O. Box 589, Settat, Morocco; ³CIMMYT, Gigiri, P.O. Box 1041, Nairobi, Kenya; ⁴ICARDA, P.O. Box 5466, Aleppo, Syria; ⁵KARI – Njoro, P.O. Private Bag, Njoro 20107, Kenya; ⁶INRA – Plant Protection Department, P.O. Box 415, Rabat, Morocco; ⁷ICARDA, Rabat Institute, P.O. Box 6299, Rabat, Morocco. Email: ramdani.abdelhamid@gmail.com

The widespread use of megavarieties following the Green Revolution has resulted in increased genetic uniformity in wheat varieties under commercial production in specific areas. Increased use of local varieties in breeding programs could enlarge the genetic variation and thereby reduce exposure to unknown threats. The aim of the present work was to test Moroccan bread wheat landraces and cultivars for responses to stem rust at Njoro, Kenya during 2010-11 and to stripe rust at Annoceur (2009-10) and Meknès (2010-11) in Morocco. A group of 144 landraces were evaluated at Annoceur and 60 of them were tested at Meknès and Njoro, in addition to 12 control cultivars. The prevalent diseases at Annoceur were stripe rust and leaf rust; 4 and 20 landraces were respectively immune to each disease. The evaluations at Meknès and Njoro revealed that 15 of 60 landraces were highly resistant to stem rust, but were susceptible to stripe rust at Meknès. One line was resistant to both diseases. Evaluation of the 12 control cultivars showed that the most widely grown varieties were susceptible to both diseases, except one that was highly susceptible to stem rust, but immune to stripe rust. Thus introgression of resistance to stem rust should be considered an urgent priority.
Seedling and adult-plant responses of Iranian wheat genotypes to \textit{Sr31}-virulent \textit{Pgt} races

F. Afshari\textsuperscript{1}, M. Aghaee\textsuperscript{1}, K. Nazari\textsuperscript{2}, M. Patpour\textsuperscript{1}, M. Esmaeilzadeh\textsuperscript{1}, G. Najafian\textsuperscript{1}, A. Yazdansepas\textsuperscript{1}, M. Vahabzadeh\textsuperscript{1}, S. Mahfouzi\textsuperscript{1}, M. Khodarahmei\textsuperscript{1}, A. Amini\textsuperscript{1}, M. Mohammadei\textsuperscript{1}, A. R. Mohammadi\textsuperscript{1}, M. R. Jalal Kamali\textsuperscript{3}, R. Wanyera\textsuperscript{4} and S. Bhavani\textsuperscript{5}

\textsuperscript{1}Seed and Plant Improvement Institute (SPII), P.O. Box 4119, Karaj, Iran; \textsuperscript{2}ICARDA, Aleppo, Syria; \textsuperscript{3}CIMMYT, Karaj, Iran; \textsuperscript{4}Kenya Agricultural Research Institute, Njoro, Kenya; \textsuperscript{5}CIMMYT, Njoro, Kenya. \textbf{Email: fafshi2003@yahoo.com}

\textit{Pgt} race Ug 99 (TTKSK) was first detected in southwest Iran in 2007 and subsequently in southern parts of the country in 2009 and 2010. Since the first detection, breeding for resistance was adopted as the first priority of the national wheat breeding program. The objective of the present study was to evaluate seedling and adult-plant resistance of the current wheat germplasm to Ug99. Seedling assessments were made at SPII using TTKSK, and adult-plant tests were conducted at Njoro, Kenya, with race raceUg99 + Sr24 virulent (TTKST). Fifteen (11.5\%) of 130 winter wheat genotypes were resistant in Kenya and clearly had pseudo-black chaff indicative of \textit{Sr2}. Among the 15 genotypes, seven exhibited low seedling responses to TTKSK. Among 49 spring genotypes, 116 (33.2\%) were resistant to TTKST in Njoro; 62 of these displayed low seedling infection types against TTKSK. Overall 27.3\% of genotypes had APR. Among the field resistant spring genotypes, 11 showed PBC. There has been significant recent progress in development of resistance to race Ug99 in the Iranian breeding germplasm. Further study is required to genetically characterise the seedling and adult-plant resistances of genotypes resistant to the \textit{Sr31}-virulent races.
Parsi, Sivand and Sirvan: Three new rust resistant wheat varieties for irrigated temperate areas of Iran

G. Najafian¹, H. Amin², M. Dadaein², E. Pazhoumand², A. R. Nikzad², Sh. Sarikhani², R. Nikooseresht³, A. Jafarnezhad³, A. Ghandi³, D. Afuni⁵, M. Khodarahmi¹, Gh. H. Ahmadi³, A. Amini¹, H. Abdi⁶, J. Hassanpour⁶, B. Shabanzadeh⁷, A. Z. Faizabadi⁴, F. Afshari¹, A. Malihipour¹, A. Zakeri², M. Yassaeri², S. Rajaei², M. Atahossaini⁴, R. Aghnoun⁴ and S. M. T. Tabatabaei⁸

¹Seed and Plant Improvement Institute (SPII), Karaj, Iran; ²Agricultural Research Center, Fars, Iran; ³Agricultural Research Center, Kermanshah, Iran; ⁴Agricultural Research Center, Khorasan, Iran; ⁵Agricultural Research Center, Isfahan, Iran; ⁶Agricultural Research Center, Tehran, Iran; ⁷Agricultural Research Center, Lorestan, Iran; ⁸Agricultural Research Center, Yazd, Iran. Email: goodarzn@yahoo.co.uk

The irrigated wheat area in the temperate climatic zone is 30% (700,000 ha) of the total irrigated wheat area in Iran. This region has cold to mildly cold winters and humid temperate springs providing good conditions for both wheat production and rust epidemics. Stripe rust is the main constraint to grain yield, but leaf rust and stem rust that appear in the late stages of crop development also have the potential to explode given susceptible varieties and favorable environmental conditions. The presence $Pgt$ race Ug99 in parts of the country has increased the risk of crop loss and presented a further challenge for breeding programs. In response to rust threats the irrigated wheat breeding program for the temperate zone has released varieties, Parsi, Sivand and Sirvan during the last 5 years. Parsi (Dove"S"/Buc"S"/2*Darab) and Sivand (Kauz"S"/Azadi) are spring wheats with good grain yield potential, resistance to stripe rust and stem rust (race Ug99), good grain quality, and adaptation to regional irrigated wheat farming practices. Resistance to stem rust was confirmed over several seasons in Kenya. These two varieties were produced from crosses of domestic and CIMMYT germplasm. Sirvan (PRL/2*PASTOR), selected from the CIMMYT 24th ESWYT nursery, is tolerant to terminal moisture stress and has resistance to all three rusts.
Breeding for resistance to *Pgt* race Ug99 in Kazakhstan by application of molecular markers

A. Kokhmetova¹, F. Ogbonnaya², M. Atishova¹, A. Morgounov³ and Sh. Rsaliev⁴

¹Institute of Plant Biology and Biotechnology, Timiryazev St. 45, Almaty, 050040, Kazakhstan; ²ICARDA, Syria, now GRDC Australia, P.O. Box 5367, Kingston, ACT 2604, Australia; ³CIMMYT-Turkey, P.K. 39 Emek, 06511 Ankara, Turkey; ⁴Institute of Problems of Biological Safety, Zhambyl Reg., Gvardeysky 080409, Kazakhstan. Email: gen_kalma@yahoo.com

Up to 80% of all Asian and African wheat varieties are susceptible to *Pgt* race Ug99, and wheat-producing nations to Iran’s east, including Kazakhstan, should be on alert. The aim of the present study was to screen advanced wheat lines with markers linked to genes *Sr22*, *Sr24*, *Sr25*, *Sr26*, *Sr39* and *Yr18/Lr34*. Among the 170 lines, 21 CIMMYT lines resistant to the 5 most aggressive Kazakhstani pathotypes were identified. Eight of 42 genotypes assessed with markers generated the DNA fragment associated with *Sr22*. No lines possessed *Sr25*, *Sr26* or *Sr39* based on marker analysis. Seven lines produced the DNA fragment associated with *Sr24* when amplified with primer Sr24#12. A high number of the lines, 25 of 42, were positive for *Yr18/Lr34*. Four of the lines have combined *Sr24* and *Yr18/Lr34*. A number of advanced lines showed high yield potential combined with resistance to race Ug99 and to other *Pgt* races predominant in Central Asia. These results will assist breeders in Kazakhstan in choosing stem rust resistant parents for crossing.
Breeding rust resistant wheat in Kyrgyzstan

M. Dzhunusova¹, A. Morgounov² and A. Yahyaoui³

¹Kyrgyz-Turk University “Manas”, Faculty of Agriculture, Chyngyz Aytmatov Campus, Djal, Bishkek 720044, Kyrgyzstan; ²CIMMYT - Turkey, P.K. 39, 06511 Emek, Ankara, Turkey; ³CIMMYT, Apdo. Postal 06600, Mexico D.F., Mexico. E-mail: dzh-mira@mail.ru

Bread wheat is an important strategic crop in Kyrgyzstan. It occupies more than half of the total cropping area in the country. Wheat yields are low and the grain quality is poor. The rusts are important and annual losses to stripe (yellow) rust and leaf rust may be as high as 10-30%. In 2001 a stripe rust epidemic caused losses estimated at 40-60%. Although wheat research in Kyrgyzstan began in 1936 a breeding for biotic stress resistance was initiated only recently. Monitoring of the Pst population started only in 1999 by way of the CWANA Yellow Rust Trap Nursery distributed by ICARDA. In 2002 wheat breeding program with a focus on stripe rust resistance was initiated in close collaboration with CIMMYT and ICARDA. In this program about 1,000 wheat lines were introduced and screened under natural epidemic conditions in the Chui region. Many resistant lines were selected and passed on to the breeding program for adaptation and yield trials. Varieties Azibrosh, Zubkov, Zagadka, Almira, Djamin, Hans and Petr were recommended for release.
Identification combined resistance to stripe rust and stem rust in Uzbek wheat germplasm

Z. M. Ziyaev¹, R. C. Sharma², A. I. Morgounov³, A. A. Amanov¹ and Z. F. Ziyadullaev¹

¹Kashkadarya Scientific Research Institute of Cereal Breeding and Seed Production, Beshkent 3km, Karshi, Uzbekistan, ²ICARDA - Central Asia and the Caucasus Regional Program, Osiyo St 100000, Tashkent, Uzbekistan, ³CIMMYT - Turkey, P.K. 39, 06511 Emek, Ankara, Turkey.
e-mail: zafaruzripi@gmail.com

The rusts are the most important biotic constraints to wheat production in Uzbekistan. Stripe (yellow) rust and leaf rust occur every year and cause substantial reductions in grain yield. Stem rust occurs in the foothills and flat-hilly zones with advancing crop maturity, but generally causes only limited yield reductions. The highest losses are caused by stripe rust. Both traditional and molecular breeding methods are used to improve rust resistance. The objective of the present study was to identify resistant genotypes; in Uzbekistan and Turkey for stripe rust, and in Kenya for Pgt race Ug99. Some varieties and advanced lines showed moderate to high levels resistance at all three locations. Markers were used to screen for the presence of Yr15, Sr22, Sr24, Sr26, Sr36 and Lr34/Yr18. According to marker data, 12 lines had Yr15, two lines Sr24, one line Sr26, four lines Sr22 and 49 lines carried Lr34/Yr18. Combined resistance was present in 12 new advanced breeding lines. Agri/Bjy // Vee/3/Bul 6687.12, Co724377/Nac // Seri/3/Erythrospermum5678/87, and Zhetisu//Pyn/Bau/3/ 338-k1-1 // Anb/Buc from international nurseries, and №1182004 and №1442004 from local sources, were identified as high yielding rust resistant lines. This work identified potentially new varieties for release to farmers as well as useful information on effective rust resistance genes, or resistance sources, for breeders.
Agronomic performance of winter wheat genotypes resistant to *Pgt* race Ug99 in Kenya and stripe rust in Uzbekistan

S. Islomov¹, R. C. Sharma², Z. Ziyadullaev¹, Z. Ziyaev¹ and Z. Khalikulov²

¹Kashkadrya Research Institute of Breeding and Seed Production of Cereal Crops, Karshi, Uzbekistan; ²ICARDA-CAC Regional Program, 6 Osiyo Street, P.O. Box 4564, Tashkent 100000, Uzbekistan. Email: r.c.sharma@cgiar.org

Winter wheat production is directly linked to food security in Uzbekistan. Stripe rust and leaf rust are perennial constraints to winter wheat production. *Pgt* race Ug99 is considered a potential threat. All commercial cultivars in Uzbekistan were susceptible to Ug99 in Kenya. Efforts to identify superior genotypes possessing resistance to Ug99 and stripe rust started in 2010 by evaluating the 1st Winter Wheat Stem Rust Resistant Screening Nursery distributed by the International Winter Wheat Improvement Program. Twenty one agronomically superior genotypes possessing resistance to stripe rust and Ug99 were selected, and evaluated in Karshi in 2011. Four improved cultivars (Esaul, Hazrati Bashir, Krasnodar-99, and Zamin-1) were used as checks. Several lines had grain yields equal to, or higher than, one or more of the checks; some of these lines also had high 1000-kernel weight and early maturity. Two lines (TCI972046 = ID800994.W/Kauz//Roller/4/WN158/Nsd//4105W/3/TAM200 and TX98D1170*2/TTCC365) selected for high grain yield and acceptable agronomic traits are being evaluated at five locations in Uzbekistan in 2012. Results to date show promise of identifying new high yielding winter wheat cultivars possessing resistance to stripe rust and Ug99. Such cultivars could also be suitable for irrigated winter wheat areas in other countries in Central and West Asia.
Stripe rust responses of wheat varieties released in Azerbaijan

Mohtasim Ahmadov

Azerbaijan Research Institute of Crop Husbandry, Sovkhoz N 2, Baku, Azerbaijan. E-mail: ahmedovagri@rambler.ru

Wheat is essential for food security in Azerbaijan. The area under wheat is about 0.65 million ha. Widely adaptable varieties are needed for the diverse climatic conditions and soil types. The Azerbaijan Research Institute of Crop Husbandry is a leading organization responsible for wheat breeding and has produced many varieties. To meet the future challenges of climate change, disease problems and abiotic stresses the Institute has strengthened its activities on breeding for resistance and has expanded work on both wheat landraces and modern varieties. Stripe rust was the most widely distributed disease in the country in 2010. To investigate the stripe rust responses of Azerbaijani and Russian wheat varieties under field conditions, 22 Azerbaijani and Russian bread wheat and durum varieties were assessed under irrigated and rainfed conditions. Bread wheat cv. Qobustan, Qirmizigul, Aran and Sheki, and durums Bereketli 95 and Tartar, were highly resistant. All the Russian varieties (Bezostaya 1, Tanya, Nota, Vostorg, Pamyat and Moskvich) were susceptible.
Stem rust responses of Azerbaijani bread and durum wheat accessions

M. Abbasov\textsuperscript{1,2}, R. Bowden\textsuperscript{2}, J. Raupp\textsuperscript{3}, S. Sehgal\textsuperscript{3}, S. Babayeva\textsuperscript{1} and B. Gill\textsuperscript{3}

\textsuperscript{1}Genetic Resources Institute, Azerbaijan National Academy of Sciences, 155 Azadlyg Ave., AZ1106 Baku, Azerbaijan; \textsuperscript{2}USDA-ARS Hard Winter Wheat Genetics Research Unit, 4008 Throckmorton Hall, Manhattan, KS 66506, USA; \textsuperscript{3}Wheat Genetic & Genomic Resources Center and Department of Plant Pathology, 4024 Throckmorton Hall, Kansas State University, Manhattan, KS 66506, USA. \textbf{Email: mehraj_genetic@yahoo.com}

Transcaucasia is a primary center of speciation of the genus \textit{Triticum}. Screening of wheat germplasm from this region for resistance to biotic and abiotic stresses is therefore of paramount importance. One hundred and twenty-one durum and bread wheat accessions, representing different botanical varieties and morphological traits, and 36 modern Azerbaijani durum and bread wheat varieties from the Azerbaijan Genebank were studied. Seedlings were inoculated with \textit{Pgt} races MCCFC (avirulence: \textit{Sr21, 9e, 11, 6, 8a, 36, 9b, 30, 9a, 9d, 24, 31, 38}; virulence: \textit{Sr5, 7b, 9g, 17, 10, Tmp, McN}), TPMKC (avirulence: \textit{Sr6, 9b, 30, 9a, 24, 31, 38}; virulence: \textit{Sr5, 21, 9e, 7b, 11, 8a, 9g, 36, 17, 9d, 10, Tmp, McN}) and RKQQC (avirulence: \textit{Sr9e, 11, 30, 17, 10, Tmp, McN}) and infection types (ITs) were recorded using the Stakman 0 to 4 scale at 12 to 14 days post-inoculation. Twenty-nine bread wheats were highly resistant and 33 were moderately resistant; 13 bread wheat genotypes were susceptible. Among the durums, 14 were resistant and 12 moderately resistant. Molecular screening revealed the presence of the T1RS·1BL rye translocation in 9 bread wheat accessions and all were highly resistant due to the presence of \textit{Sr31}. Material identified as stem rust resistant will be incorporated into the Azerbaijan breeding program as potential sources of resistance.
Reactions of Turkish wheat cultivars and breeding lines to Pgt race Ug99: 2006 - 2011

Z. Mert¹, K. Akan¹, L. Çetin¹, R. Wanyera², S. Bhavani³, D. Singh⁴ and F. Düşünceli⁵

¹Central Research Institute for Field Crops, Şehit Cem Ersever Cd. No.9, Yenimahalle/Ankara, Turkey; ²Kenya Agricultural Research Institute, Private Bag 20107, Njoro, Kenya; ³CIMMYT, United Nations Avenue, P.O. Box 1041, Gigiri Village Market 00621, Nairobi, Kenya; ⁴University of Sydney Plant Breeding Institute, Private Bag 4011, Narellan, NSW 2567, Australia; ⁵Agriculture Office, FAO, Viale delle Terme di Caracallai, 00153 Rome, Italy. E-mail: mert_zafer@yahoo.com

The aim of this study was to determine the reactions of wheat cultivars and advanced lines from Turkey to Pgt race Ug99 and derivatives. A total of 1,800 winter and 600 spring wheat genotypes, some of which were resistant also to local Turkish Pst and Pgt populations, were tested at KARI, Kenya, in main season trials between 2006 and 2011. Winter wheat entries were vernalized in pots for 6 weeks at +4°C prior to transplanting as hill plots in the field. Spring wheat entries were planted directly as twin 70 cm rows. Stem rust responses were scored twice each season for both severity and reaction type, which were converted to coefficients of infection (CI). CI levels <20 were accepted as resistant. Overall, 99 winter and 55 spring wheat genotypes were resistant to Ug99. These genotypes can be used as resistant germplasm for breeding activities.
Winter bread wheat breeding studies in the transitional rainfed zone of Turkey

S. Belen, N. Bolat, M. Çakmak, A. Yorgancilar and A. T. Kilinç

Transitional Zone Agricultural Research Institute, Karabayır Bağları 6. km. 26002, Eskişehir, Turkey. Email: savasbelen@hotmail.com

The objectives of our work are to improve wheat varieties with high yield, good quality, resistance or tolerance to important diseases, tolerance to abiotic stresses and wide adaptation, especially for the rainfed conditions of the Middle and Transitional Regions of Turkey. One objective is to demonstrate improved varieties to farmers. During 2006-2010, 1,200 crosses were made. In the the F2-F4 generations the bulk system is used, and in F5 a modified bulk system is used. Each year an average 15,000 head rows, and 550, 400, 121, 24 and 4 lines are tested in F5, the Screening Nursery, Preliminary Yield Trial, Yield Trials, Regional Yield Trials and Second-Year Regional Yield Trials, respectively. While early generation breeding materials are planted at Eskişehir and Hamidiye, Regional Yield Trials are also planted at Afyon, Kütahya, Uşak and Konya. Cultivars Müfitbey (good quality), Nacibey (good yield) and ES26 (resistance to yellow rust) were developed and registered between 2006 and 2010.
Wheat rust virulence in southern Russia

G. V. Volkova, O. F. Vaganova, E. V. Sinyak and Y. V. Shumilov

All-Russian Research Institute of Biological Plant Protection, Krasnodar, Russia. Email: galvol@bk.ru

Winter wheat is the most important crop in southern Russia and the rusts in the order of leaf rust, stripe rust and stem rust are regular threats in the region. Grain shortages in years, favorable for the rusts can be substantial. Seedling stage tests of local varieties with all three pathogens show a paucity of resistance. Leaf rust resistance genes \( Lr9, Lr42, Lr43, \) and \( Lr47 \) are fully effective whereas there are low frequencies of virulence on lines with \( Lr19, Lr24, Lr29, Lr32, Lr41, Lr45, \) and \( Lr52 \). Genes effective against stripe rust include \( Yr5 \) and \( YrSp \) and those effective against current races of \( Pgt \) include \( Sr9e, Sr26, Sr27, Sr29, Sr30, Sr31, Sr35, \) and \( SrWLD \). These various genes can be used in breeding for resistance.
Evaluation of stem rust responses in a spring wheat collection and lines with Sr genes in the southern forest-steppe zone of Western Siberia

V. P. Shamanin¹, A. I. Morgounov², M. A. Levshunov¹, Y. I. Zelenskiy³, Sh. Rsaliev⁴, I. V. Pototskaya¹ and S. L. Petukhovskiy¹

¹Omsk State Agrarian University, Breeding, Genetics and Plant Physiology Department, 644008 Institutskaya Square, 2, Omsk Russia; ²CIMMYT - Turkey, P.O. Box 39, Emek 06511, Ankara, Turkey; ³CIMMYT - Kazakhstan, P.O. Box 1446, Astana 010000, Kazakhstan; ⁴Research Institute of Biological Safety Problems, 080409 Gvardeyskiy Settlement, Jambilskaya Oblast, Kazakhstan. Email: vpshamanin@rambler.ru

Western Siberia is a leading area for production of high quality spring wheat. However, in recent years there has been an increased threat of stem rust, which can cause grain yield losses of up to 50%. The need for resistance to race Ug99 is a further problem for the region. Lines with Sr9e, Sr24, Sr25, Sr26, Sr27, Sr31, Sr33, Sr35, Sr36, Sr38, Srdp-2, Sr7a + Sr12 + Sr and varieties Norm, Bacanora, and Cham 10 were highly resistant in 2009-2011. Lines with genes Sr9g, Sr11, Sr13, Sr26, Sr32, Sr2 + Sr23, Sr26 + Sr9g, Sr33 + Sr5 and varieties Cham 6, Gemmeiza-9, Chamran, Inqalab 91, Aguila l, and Altar 84 durum gave variable reactions. None of 164 varieties from the Siberian Agricultural Research Institute was resistant when tested in Kenya. The most virulent pathotypes in our region, TFR/NL and KKH/DG, were virulent for 8 and 7 respectively, of the 20 Sr genes. A spring wheat collection with resistance to Western Siberian Pgt races and to Ug99 was assembled for breeders in the region.
Leaf rust occurs with varying degrees of severity in all wheat growing areas of Bangladesh. Near-isogenic lines and wheat varieties from ICARDA and Bangladesh were evaluated for response to leaf rust under natural conditions during 2011-12. The Modified Cobb scale was used for assessment severity and response. A wide range of variability in reaction and severity was observed depending on location. The majority of lines with specific leaf rust resistance genes showed moderately susceptible to susceptible reactions, whereas the gene combinations in varieties were more effective. The majority of varieties displayed low disease severities with moderately resistant to moderately susceptible responses. Cv. Prodip showed moderate to high disease severities with susceptible reactions, whereas Sourav, Shatabdi, BARI Gom-27 and BARI Gom-28 were either free from infection or exhibited trace severities and MR-R reactions. Bijoy and Gourab were completely rust-free. This information is important for breeding and deployment of cultivars with effective sources of resistance.
Evaluation of wheat lines for resistance to stripe (yellow) rust in mid-hills of Nepal

S. Adhikari¹, S. M. Shrestha¹, G. B. Khatri-Chhetri¹, S. Sharma² and R. S. Poudel¹

¹Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal; ²Plant Pathology Division, NARC, Khumaltar, Lalitpur, Nepal. Email: s.adhikariaipkr@yahoo.com

Stripe (yellow) rust is a major problem in the mid-hills of Nepal. Ten wheat genotypes (WK1182, WK1204, WK1505, BL2879, Pasang Lhamu, Morocco, WK1123, Nepal 297, BL1473 and WK1320) with diverse levels of response to stripe rust were compared by Area under Disease Progress Curve (AUDPC) values. The trial was conducted for one year in 2008-09 at two different locations, viz., a farmer’s field in Baglung District and at the Khumaltar Research Station, in Lalitpur District. A randomized complete block design was used with three replications. Each line was planted in a single 3 m row with plant spacings of 10 cm. At Khumaltar, 22 day old seedlings were inoculated with mixture of pathotypes using an Ulva sprayer. At Baglung the infection was natural. Disease scores were taken 4 times at intervals of 7 days from 78 days after sowing (DAS) using the Modified Cobb scale. Disease levels reached maximum levels in the first week of March at Baglung and during the third week of March at Khumaltar. At Baglung the lowest AUDPC values were for genotypes WK 1204 (6.07) and WK 1505 (6.65) and the maximum was for Morocco (226.68) followed by Nepal 297 (181.77). At Khumaltar the maximum AUDPC values were also for Morocco (287.23) followed by Nepal 297 (123.63) whereas the values for WK 1204 and WK 1505 again the lowest. Incremental increases in stripe rust response over time indicated that early to mid-March is the period for rapid increase in disease expression in the mid-hills and is therefore the time for taking preventive measures.
Stem rust resistance in wheat lines from Bangladesh and Nepal

Z. A. Pretorius¹, R. Prins¹,², P. K. Malaker³, N. C. D. Barma⁴, M. A. Hakim³, D. Thapa⁵, R. F. Park⁶ and G. L. Cisar⁷

¹Department of Plant Sciences, University of the Free State, Bloemfontein 9300, South Africa; ²CenGen, 78 Fairbairn St., Worcester, South Africa; ³Wheat Research Center, BARI, Dinajpur, Bangladesh; ⁴Regional Wheat Research Centre, BARI, Gazipur, Bangladesh; ⁵Agriculture Botany Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal; ⁶University of Sydney Plant Breeding Institute Cobbitty, Private Bag 4011, Narellan, NSW 2567, Australia; ⁷International Programs, 252 Emerson Hall, College of Agriculture and Life Sciences, Cornell University, Ithaca, New York 14853, USA. Email: pretorza@ufs.ac.za

The Durable Rust Resistance in Wheat project aims to reduce the vulnerability of wheat cultivars to the *Pgt* race Ug99 group. As part of this initiative South Asian wheat germplasm was assessed for seedling response to *Pgt* race PTKST and genotyped using DNA markers associated with resistance genes. Most entries were susceptible to race PTKST. One entry from Nepal was mixed for infection types 1 and 3 (0 to 4 scale), whereas two lines showed intermediate 2+ responses. Except for two cultivars displaying infection types in the intermediate range, all entries from Bangladesh were susceptible. Marker analysis detected *Sr31*, which is ineffective against Ug99, in 44% and 48% of the entries from Bangladesh and Nepal, respectively. No line carried *Sr24* or *Sr36*, genes that have become ineffective against variants of Ug99. Six lines from Bangladesh and three from Nepal carry *Lr34/Yr18*. According to the csSr2 marker, none of the wheats from Bangladesh carried *Sr2* for adult plant resistance (APR) to *Pgt*, whereas seven from Nepal tested positive for *Sr2*. Based on these assays, South Asian wheats generally appear vulnerable to Ug99 infection. Field tests for adult plant response to race PTKST will be carried out to determine if additional APR genes occur in the material.
Elite wheat germplasm with resistance to stripe rust and stem rust for the Indian Northern Hills Zone

V. Rana¹, S. C. Bhardwaj² and S. K. Rana¹

¹CSK Himachal Pradesh Agricultural University, Rice & Wheat Research Center, Malan 176 047, India; ²Regional Station, Directorate of Wheat Research, Flowerdale, Shimla, India. E-mail: vijayrana_2005@rediffmail.com

Stripe rust recently emerged as a major threat to wheat-growing regions in south Asia. Although South Asian countries are striving to control Pgt race Ug99 before it arrives, India witnessed a significant outbreak of stripe (yellow) rust in 2010-11. Because the Northern Hills Zone is strategically important for safeguarding yield potential in the major wheat-producing zones, it is important to evaluate newly developed wheat lines for response to stripe rust prior to release. Fifty elite wheat strains were evaluated for seedling response to Pst races 78S84 and 46S119, Pt races 77-5 and 140-2 and Pgt races 40A and 117-6. Field responses to stripe rust were also evaluated during 2008-09 and 2010-11 under conditions of natural infection. HPW 312 and HPW 316 possessed seedling resistance to all three rusts along with a high degree of field resistance to stripe rust. Among the others, HPW 305, HPW 307, HPW 376 and HPW 379 displayed seedling and field resistance to stripe rust. These lines are recommended as suitable for release or as future breeding parents.
The National Coordinated Wheat Program in Pakistan

M. Y. Mujahid¹, M. A. Khan¹ H. Makhdoom², A. Bari³, M. Tila⁴, H. Manzoor⁵, M. Tariq⁶, A. Arian⁷ A. Muneeer⁸, A. Rattu⁹, J. I. Mirza¹⁰, K. Shafiq¹¹ and R. Ward¹²

¹National Coordinated Wheat Program PARC, National Agricultural Research Center, Park Road, Islamabad 44000, Pakistan; ²Wheat Research Institute, Ayub Agricultural Research Institute, Jhang Road, Faisalabad 38000, Pakistan; ³Cereal Crops Research Institute-Pirsabak, Nowshera 24100, Pakistan; ⁴Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar 25000, Pakistan; ⁵Regional Agricultural Research Institute, Bahawalpur 63100, Pakistan; ⁶Barani Agricultural Research Institute, Chakwal 48800, Pakistan; ⁷Nuclear Institute for Agriculture (NIA), Tandojam, Hyderabad 71000, Pakistan; ⁸Agricultural Research Institute, Sariab Road, Quetta 87300, Pakistan; ⁹Crop Diseases Research Program PARC, National Agricultural Research Center, Park Road, Islamabad 44000, Pakistan; ¹⁰Crop Diseases Research Program PARC, Sunny Bank, Murree 47140, Pakistan; ¹¹Directorate of Agriculture, Muzaffarabad 13100, AJK-Kashmir, Pakistan; ¹²CIMMYT Global Wheat Program, National Agricultural Research Center, Park Road, Islamabad 44000, Pakistan. Email: yaqubmujahid@hotmail.com

Wheat is the staple food crop in Pakistan and was harvested from over 8.5 million ha in 2012 with a production target of 25 million tonnes. The National Coordinated Wheat Program (NCWP) of Pakistan Agricultural Research Council was established in 1978 following a leaf rust epidemic when a need was realized by policy makers for coordinated efforts to mitigate future yield losses in wheat production caused by abiotic and biotic stresses. When the NCWP was established the objective of all stakeholders from the four provinces and AJ&K (Azad Jammu and Kashmir) was to make the country self-sustaining in wheat production. Through the Wheat Productivity Enhancement Program (W-PEP) financial arrangements are managed through CIMMYT, and as an amplification of the NCWP, a platform is provided to collaborators to attend the planning meetings, participate in travelling wheat seminars, request international germplasm and test advanced breeding materials in National Trials, a pre-requisite for a variety release. Services are also provided to breeders for access to an off-season summer wheat nursery at Kaghan and for screening materials against stem rust and stripe rust at Njoro, Kenya, on a regular basis.
Resistant wheat varieties can mitigate the *Pgt* race Ug99 threat to food security

A. K. Joshi\(^1\), M. Azab\(^2\), M. Mosaad\(^2\), M. Moselhy\(^3\), R. Sharma\(^4\), S. Gelalcha\(^5\), G. Bedada\(^5\), M. R. Bhatta\(^6\), N. R. Gautam\(^6\), S. R. Updahyay\(^6\), N. C. D. Barma\(^7\), D. B. Pandit\(^7\), A. Hakim\(^7\), P. K. Malaker\(^7\), M. E. Haque\(^8\), T. P. Tiwari\(^8\), A. Majid\(^9\), M. Y. Mujahid\(^10\), Z. Bishaw\(^11\), T. Payne\(^12\), R. P. Singh\(^12\), and H. J. Braun\(^12\)

\(^1\)CIMMYT South Asia Regional Office, P.O. Box 5186, Kathmandu, Nepal;  \(^2\)Field Crops Research Institute, Agricultural Research Center (ARC), Egypt;  \(^3\)Central Administration for Seed Production (CASP), Cairo, Egypt;  \(^4\)CIMMYT, Kabul, Afghanistan;  \(^5\)Ethiopian Institute of Agricultural Research (EIAR), Kulumsa, Ethiopia;  \(^6\)Nepal Agricultural Research Council, Bhairahwa, Nepal;  \(^7\)Wheat Research Centre, Bangladesh Agricultural Research Institute (BARI), Dinajpur, Bangladesh;  \(^8\)CIMMYT, Dhaka, Bangladesh;  \(^9\)ICARDA, Islamabad, Pakistan;  \(^10\)PARC, Islamabad, Pakistan;  \(^11\)ICARDA, Aleppo, Syria;  \(^12\)CIMMYT, Apdo. Postal 6–641, C.P. 06600, D.F. Mexico. Email: a.k.joshi@cgiar.org

Food security in Asia, Africa and many other countries is threatened by *Pgt* race Ug99. A concerted effort to replace currently susceptible varieties with agronomically superior resistant varieties includes evaluation of newly developed resistant lines, and pre-release seed multiplication and faster dissemination in south Asia and Africa. These accelerated multiplication activities were initiated in crop cycle 2008-09 in Afghanistan, Bangladesh, Egypt, Ethiopia, Nepal and Pakistan, in addition to countries such as Kenya, Iran and India. The objective was to multiply sufficient seed of resistant varieties to plant about 5% of the wheat area in each country. This would ensure sufficient seed of resistant genotypes to displace current varieties. The principle applied in each country was evaluation of new resistant candidate varieties and pre-release seed multiplication of those found promising. The organized effort was successful in that more than a dozen resistant varieties were released in the six countries, and amounts of seed available at the time of release were several times higher than achieved by earlier release systems. The results also showed that new Ug99-resistant varieties possessed yield superiority over the most popular current varieties. This successful seed multiplication and distribution effort has provided confidence that participating countries can meet the threat of Ug99. Spill-over effects should also benefit other countries in the region.
Assessment of partial resistance to stripe rust in elite wheat lines

S. A. Safavi¹ and F. Afshari²

¹Agricultural and Natural Resources Research Center of Ardabil, Iran; ²Department of Cereal Research, Seed and Plant Improvement Institute, Karaj, Iran. Email: safavi_502002@yahoo.com

Race-specific resistance of wheat to stripe (yellow) rust is often short-lived. Partial resistance, a kind of quantitative resistance, has been reported to be durable. Partial resistance parameters, including final rust severity (FRS), apparent infection rate (r), relative area under disease progress curve (rAUDPC), and coefficient of infection (CI), were evaluated in field plots of a set of 26 wheat genotypes along with a susceptible control at Ardabilin 2010-2011 following two inoculations. The inoculum carried virulences to resistance genes Yr2, Yr6, Yr7, Yr9, Yr22, Yr23, Yr24, Yr25, Yr26, Yr27, YrA, and YrSU. Seedling reactions were also evaluated in a greenhouse with race 66E0A+, Yr27+. Lines C-89-4, C-89-17, C-89-16 and the susceptible control had the highest values of FRS, CI, and rAUDPC, and were classified as moderately susceptible or susceptible. Lines C-89-7, C-89-8, C-89-9, C-89-10, C-89-13, C-89-14 and C-89-20 were susceptible as seedlings, but had low levels of infection at the adult plant stage; these lines were considered to have partial resistance. The remaining 16 lines showed no or very low levels of infection, and were classified as resistant. The correlation coefficients between different parameters of slow rusting were highly significant.
Effect of stripe (yellow) rust on yield components of barley cultivars with race-specific and slow rusting resistances

S. A. Safavi, A. B. Ahari, F. Afshari and M. Arzanlou

1Department of Plant Protection, College of Agriculture, University of Tabriz, Tabriz, Iran; 2Department of Cereal Research, Seed and Plant Improvement Institute, Karaj, Iran. Email: safavi_502002@yahoo.com

Stripe (yellow) rust is an important disease of barley in some parts of the world. We compared the effectiveness of different types of resistance in field plots at Ardabil Agricultural Research Station during 2010-2011. Yield components along with slow rusting parameters, including final rust severity (FRS), apparent infection rate (r), relative area under disease progress curve (rAUDPC) and coefficient of infection (CI) were evaluated for 25 barley cultivars. Two cultivars with race-specific resistance, 19 cultivars with various levels of slow-rusting resistance and four susceptible cultivars were included in two experiments with and without fungicide protection under high disease pressure. Barley cultivars with slow-rusting resistance displayed a range of severity responses indicating genetic diversity. Mean thousand kernel weight (TKW) losses for susceptible, race-specific resistant and slow rusting genotypes were 31, 0.3 and 12%, respectively, and reductions in mean kernels per spike (KPS) were correspondingly 19, 0.2 and 8%. Correlation coefficients of mean TKW and KPS reductions with epidemiological parameters rAUDPC, r, CI and FRS were highly significant. Slow-rusting cultivars with low values for the various parameters and genotypes with low yield component losses despite moderate disease levels were identified. Such genotypes can be used for breeding barley lines with high to moderate levels of resistance and negligible yield losses.
Slow stripe rusting resistance in Iranian barley

S. A. Safavi, A. B. Ahari, F. Afshari and M. Arzanlou

Department of Plant Protection, College of Agriculture, University of Tabriz, Tabriz, Iran; Department of Cereal Research, Seed and Plant Improvement Institute, Karaj, Iran. Email: Safavi_502002@yahoo.com

Race-specific resistance in barley to stripe (yellow) rust caused by *Puccinia striiformis* f. sp. *hordei* (*Psh*) is often short-lived. Slow rusting resistance is reported to be more durable. A set of 20 Iranian barley cultivars along with resistant and susceptible controls was tested in field plots at Ardabil during 2009-2010 and 2010-2011 to identify slow rusting genotypes using epidemiological variables, including final rust severity (FRS), apparent infection rate (*r*), relative area under disease progress curve (rAUDPC), and coefficient of infection (CI). Differential sets of seedlings were inoculated for race determination of *Psh* isolates collected from the field trials. Cultivars Makouee, Dasht, Fasih and Arass had low values of FRS, CI, *r* and rAUDPC compared with the susceptible check against the pathogen population which had virulences for resistance genes *rps2*, *Rps1.b* and resistance in cv. Topper. Cv. Walfajre, Abidar and Sahand were identified as possessing moderate levels of slow rusting. The remaining 12 cultivars, with high values for the quantitative parameters, had low levels of slow rusting or were susceptible. Correlations between the different parameters of slow rusting were highly significant (*r* = 0.83-0.98). Genes *rpsEm1*, *rpsEm2*, *rpsHF*, *Rps4*, *Rps1.c*, *rpsVa1*, *rpsVa2* and *rpsAst* conferred low seedling reactions over the two years.
Effect of temperature on resistance to stripe (yellow) rust on wheat

R. Bryant¹, C. Uauy¹, S. Dorling², L. Boyd¹ and C. Ridout¹

¹Department of Disease and Stress Biology, John Innes Centre, Norwich Research Park, Colney Lane, Norwich NR4 7UH, U.K.; ²School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, U.K. Email: ruth.bryant@jic.ac.uk

Expression of disease resistance can vary from year to year due to the environment, causing concern to growers and therefore being of interest to breeders. Climate change is likely to add to environmental instability and therefore a better understanding of environmental effects on plant defence will be essential for coping with changes. We are studying temperature-sensitive resistance responses in the interaction between wheat and *Pst*. We established controlled environment experiments using various wheat varieties. In variety UC1041 there was no significant difference in leaf pustule cover between plants kept at day temperatures of 18°C and 25°C. However when plants were shifted following infection with *Pst* to the cooler day temperature, resistance was notably compromised with percent infection increasing more than twofold. In contrast, plants shifted from the 18°C to 25°C were virtually resistant. Alpowa shows a similar trend to UC1041 under the same temperature treatments, yet other varieties do not appear to follow this trend when plants undergo a temperature shift in either direction. We hypothesise that temperature fluctuations in the field may compromise resistance in some wheat varieties, whereas resistance in other varieties might be more stable. Further experiments are being performed to establish whether these effects occur in other wheat varieties and whether a similar resistance phenotype is observed with the powdery mildew and other pathogens. Our results will help breeders in developing wheat varieties with more stable resistances.
Ethiopian farmers’ preferences for attributes of bread wheat: A gender-responsive conjoint analysis

K. Nelson¹, S. Davidson², R. Nelson³, Y. Chiche⁴, L. Sperling⁵, S. Hunduma⁶ and S. Abebe⁶

¹Department of Crop and Soil Sciences, Cornell University, Ithaca, NY 14851, USA; ²Department of Plant Breeding and Genetics, Cornell University, Ithaca, NY 14851, USA; ³Department of Agricultural Economics and Rural Sociology, Auburn University, Auburn, AL 36849, USA; ⁴Ethiopian Institute for Agricultural Research, Addis Ababa, Ethiopia; ⁵The International Center for Tropical Agriculture, Arusha, Tanzania; ⁶Kulumsa Agricultural Research Center, Kulumsa, Ethiopia. Email: kmn46@cornell.edu

Most wheat breeding programs focus on increasing the percentage of grain yield in relation to total biomass. However, many farmers in developing countries depend on other attributes of wheat varieties such as baking qualities and plant dry matter (used for other purposes such as animal fodder, fuel, and roofing material). Limited information is available on the degree to which features of different wheat traits influence a farmer’s willingness to adopt a new variety. We surveyed 305 Ethiopian farmers in four villages in the Hetossa district and evaluated their preferences for six bread wheat attributes: number of productive tillers (2, 5 or 8); density of kernels per spike (lax or dense); response to rust (resistant or susceptible); size of grain (large or small); color of grain (white or red); and price in Ethiopian Birr per 100 kg bag of seed (650, 850 or 1050). In total 158 male heads of household, 70 female heads of household and 77 female non-heads of household were interviewed using gender-responsive methods. A conjoint analysis of their responses to 18 trait combinations revealed that the number of tillers was the most important variety attribute. However, cluster analysis revealed seven distinct respondent segments characterized by primary preferences for high-priced seed, rust resistance, high tillering capacity, large seed, white seed, small/red/lax seed, and low-priced seed. Segment membership was weakly correlated with gender, socio-economic status, usage factors, and constraints to production (e.g. prevalence of rust and drought). The methodology and results should be useful to breeders in evaluating trade-offs among various traits.
Combining resistance to leaf rust and terminal heat tolerance in wheat for the Eastern Gangetic Plains of India

C. Tiwari¹, B. Arun¹, V. K. Mishra¹, R. Dhari¹, U. Kumar², H. Wallwork³ and A. K. Joshi¹, ⁴

¹Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 21005, India; ²The Energy and Resources Institute, India Habitat Centre, New Delhi 110003 India; ³South Australian Research and Development Institute, Glen Osmond, SA 5064, Australia; ⁴CIMMYT-South Asia; Post Box 5186, Singha Durbar Marg, Kathmandu, Nepal. Email: genchhavi@gmail.com

Leaf rust is an important wheat disease in South Asia where terminal heat stress is also a major problem. These two stresses, if overcome through enhanced resistance/tolerance, will help to ensure food security in the region. A Berkut/Krichauff doubled haploid (DH) population of 140 lines (including parents) was evaluated under heat stress conditions at Banaras Hindu University, Varanasi (25.18N, 83.03E, 123.93 m ASL) during 2007-2010. The field trial was conducted in three replications with plot sizes of 4.5 m²/line. Screening for leaf rust response was conducted separately under artificial epiphytotic conditions. Berkut is moderately heat tolerant and possesses APR to leaf rust whereas Krichauff has higher heat tolerance with moderate resistance to leaf rust. Significant variation was observed among DH lines for grain yield and canopy temperature (CT) under heat stress. The performance of seven lines was significantly superior to the parents for CT and 10 lines were superior in grain yield. Composite interval mapping detected two QTLs each for yield (QLY.bhu-7D, QLY.bhu-2A) and CT (QLCt.bhu-2B, QLsCt.bhu-7D). More than half (88) of the DH lines displayed significantly higher resistance than the parents. Five heat tolerant lines were resistant to leaf rust. These results demonstrate that heat tolerance and leaf rust resistance can be combined in DH lines. The tolerant lines are under further evaluation for use in crossing programs and for promotion to national trials.
Evaluation of barley germplasm for seedling and adult plant responses (APR) to \textit{Pgt} race \textit{Ug99}

M. Wamalwa\textsuperscript{1}, J. Owuoche\textsuperscript{1}, R. Wanyera\textsuperscript{2} and S. Bhavani\textsuperscript{3}

\textsuperscript{1}Egerton University, P.O. Box 536-20115, Njoro, Kenya; \textsuperscript{2}Kenya Agricultural Research Institute – Njoro, P.O. Private Bag 20107, Njoro, Kenya; \textsuperscript{3}CIMMYT, P.O. Box 1041, Village Market-00621, Nairobi, Kenya. Email: \texttt{wamash03@yahoo.com}

Stem rust is a disease of economic importance to barley as well as wheat. The objective of this study was to determine the seedling and adult plant responses of barley accessions to \textit{Pgt} race \textit{Ug99}. Two hundred and eighty introductions from North America, South America, Europe, Asia and East Africa were screened for seedling response in the greenhouse and for adult plant response in the field for two seasons. Variable disease severities ranged from 0 to 70S with 40\% of the germplasm showing slow disease progress. Although disease severity depended on the season, over 60\% of the introductions were susceptible to race \textit{Ug99}. At the seedling stage, 67\% of the germplasm exhibited low infection types with no sporulating uredinia. However, lines originating from Canada, Bangladesh, England, North Dakota State University, Utah State University and Wisconsin gave infection types of 2+ to X; these types of reactions were typical of 33\% of the lines. Twenty two lines (22\%) that were resistant in the field constituted cultivars that had a mesothetic (X) seedling infection type. The study indicated that there is limited germplasm resistant to race \textit{Ug99} and efforts to identify and characterize new sources of resistance are imperative to prevent future losses and to maintain resistance diversity.
Evaluation of Nepalese wheat genotypes for seedling and adult plant resistance to leaf rust

S. Baidya¹, S.C. Bhardwaj², M. Prashar², H. K. Manandhar¹, S. Sharma¹, S. K. Shrestha³ and A. K. Joshi⁴

¹Plant Pathology Division, Khumaltar, Nepal Agricultural Research Council, Nepal; ²Directorate of Wheat Research, Indian Council of Agricultural Research, Shimla, India; ³Institute of Agriculture and Animal Science, Chitwan, Tribhuvan University, Nepal; ⁴CIMMYT South Asia Regional Office, Kathmandu, Nepal. Email: suraj_baidya222@yahoo.co.in

Leaf rust is economically important in all sub-tropical river basin and plain areas of Nepal. One hundred and twenty-five Nepalese wheat lines, including most of the released varieties and new advanced breeding lines were subjected to multi-pathotype leaf rust evaluations at the seedling and adult plant stages at the Directorate of Wheat Research, Shimla, India. Sixteen pathotypes were used for seedling evaluation and the two most predominant pathotypes, 121R63-1 (THTTS) and 21R55 (PHTTL), were used to screen for APR. Thirty-five lines were susceptible at both growth stages. Different combinations of six resistance genes, viz Lr1, Lr10, Lr13, Lr19, Lr23 and Lr26, were identified among the other lines. The most commonly detected genes were Lr26 (40% of tested lines), Lr13 (34%), Lr23 (31%), Lr10 (28%), Lr1 (10%) and Lr19 (1%). Additional unidentified seedling resistance genes were present in some lines. Thirty-one lines showed APR to both pathotypes, among which 11 were susceptible in seedling tests. Similarly, 44 lines showed APR to 121R63-1; among them, 20 were susceptible at the seedling stage. Fifty seven lines had APR to pathotype 21R55, and of those, 18 were susceptible at the seedling stage. The information on resistance genes and race-specific adult plant resistance of the tested materials can be used for future breeding programs and for promotion of resistant varieties.
Breeding for resistance to *Mycosphaerella graminicola* in wheat

S. M. Tabib Ghaffary\(^1,5,7\), J. D. Faris\(^2\), T. L. Friesen\(^2\), O. Robert\(^3\), V. Laurent\(^3\), P. Lonnet\(^3\), E. Margalé\(^4\), T. A. J. van der Lee\(^5\), R. G. F. Visser\(^6,7\) and G. H. J. Kema\(^5\).

\(^1\)Safiabad Agricultural Research Center, P.O.Box 333, Dezful, Iran; \(^2\)USDA-ARS Cereal Crops Research Unit, Northern Crop Science Laboratory, 1307 18\(^{th}\) Street North, Fargo, ND 58102-2765; \(^3\)Florimond Desprez, 3 Rue Florimond Desprez, BP41, 59242 Cappelle-en-Pévèle, France; \(^4\)Serasem, 60, Rue Léon Beauchamp, 59930 La Chapelle d’Armentières, France; \(^5\)Plant Research International, Biointeractions and Plant Health; P.O. Box 16, 6700 AA Wageningen, The Netherlands; \(^6\)Laboratory of Plant Breeding, Wageningen University, P.O. Box 386, 6700AJ Wageningen, The Netherlands; \(^7\)Graduate School of Experimental Plant Sciences, Wageningen University Building Radix, 6708 PB Wageningen, The Netherlands. Email: gert.kema@wur.nl; Mahmoud_ghaffary@yahoo.com

Septoria tritici blotch (STB) caused by the ascomycete fungus *Mycosphaerella graminicola* ( Fuckel) J. Schröt, is a biotic foliar disease, reducing wheat yield up to 50% in favorable conditions. STB management has strongly focused on chemical control as well as host resistance, although, frequently emerging fungicide resistance strains within *M. graminicola* population reduce the efficacy of fungicide application and consequently increase the importance of breeding approaches. The number of resistance genes to STB is very low compared to the detected resistance genes for other wheat diseases. The aim of the project was to identify and characterize new genes for resistance to STB and identification of closest linked molecular markers to facilitate application of the associated *Stb* genes in breeding programs. Wide range wheat germplasm screening, using genetically divers *M. graminicola* isolates identified distinctive parental lines and corresponding isolates for further MapQTL analysis of wheat recombinant inbred lines and double haploid populations. Three new resistance genes were detected on chromosomes 3DL, 5AL and 6DS that were designated as *Stb16*, *Stb17* and *Stb18*, respectively. In addition, strong epistatic and additive effects as well as positive influence of *Stb* gene stacking were identified in QTL interactions. Finally the general overview of critical review provide comparison between past methodologies and the current alternatives to increase the resolution and better characterization of STB resistance. Furthermore, this research provided improved phenotyping protocols to stabilize data generation that will contribute to enhanced genotyping and mapping analyses and hence to successful commercial deployment of *Stb* genes.