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*Lead author is a graduate student.
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A century of bread wheat production in Kenya: Past genetic gains and anticipation of future gains in the backdrop of adverse production environments

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Breeders aim to improve crop varieties primarily to benefit humankind. Ever since wheat was introduced to Kenya, numerous varieties have been released and cultivated to varying extents. Past genetic gains indicated in terms of better varieties have been fragile due to the emergence of virulent races of rust pathogens, and more recently, to Russian wheat aphid and drought. Whereas phenotypic selection has been the exclusive method of identifying superior varieties, the use of molecular techniques is slowly increasing. Here, a review of past wheat production challenges is provided vis-à-vis mediation strategies at different times in the history of the breeding program. Key highlights that define Kenyan wheat breeding over time will be described. Contemporary models adopted by highly successful global wheat programs, including applications in biotechnology are invoked to argue for the future of wheat in Kenya, especially with respect to fast tracking the wheat breeding process and mitigating tenacious environmental challenges. Lastly, the legacy of the Nobel laureate, Dr. Borlaug to the Kenyan wheat landscape will be highlighted.
Evaluation of Kenyan and introduced wheat germplasm for seedling and adult plant resistance to *Puccinia graminis f. sp.tritici* race Ug99

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Stem rust is still an alarming disease worldwide causing severe losses to wheat production. Mutation of *Pgt* race Ug99 (TTKSK) to more virulent variants (TTKST and TTTSK) has increased interest in looking for different sources of resistance. The objectives of this study were to determine adult and seedling responses to race Ug99 in Kenyan and introduced wheat germplasm. Two hundred and fifty three bread wheat germplasms from the East African region, 20 recently selected Kenyan lines, and 79 CIMMYT lines were evaluated for adult plant response in the field over two seasons and for seedling response in the greenhouse. Response variation of 0 - 80S was observed between and within seasons. Forty six percent (46%) of the tested germplasm were susceptible in the 2013 season compared to 16% in the 2012. All the Kenyan Selected Lines (KSL), except KSL1, KSL2 and KSL 3, were considered to have slow rusting resistance due to low area under disease progress curve values (AUDPC). About 70% of the KSL lines were resistant performing better than CIMMYT lines (PCB) and collections from the East African region over the two seasons. Kenya Kanga, K6280 bulk, Kenya Chiriku, Kenya Swara, and Kenya Kongoni are among old Kenyan varieties that showed seedling (1 to 2+) and adult plant resistances to race Ug99. These varieties also had pseudo black chaff, a trait linked to *Sr2*. Entries PCB52, PCB54, PCB73, PCB75, KSL7, KSL15, KSL17, and KSL18, among others, had both seedling and APR resistances. The resistant lines should be used to improve more locally adapted commercial varieties and to contribute to improved wheat production in Kenya.
The importance of wheat stripe rust in Ethiopia: Historical perspective, current status, and future directions

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Endemic to the cool highlands above 2,400 masl — an ecology that accounts for more than 60% of Ethiopia’s wheat area — stripe rust was first reported in the 1940s, with major outbreaks in 1977, 1980, 1986, 1988, 1998 and 2010. Farmers suffered moderate to severe yield losses on those occasions and several susceptible wheat cultivars went out of production. Fungicide-based assessments indicated 58 - 70% yield reductions on commercial bread wheat cultivars, seriously affecting the national wheat industry. Farmers who cultivated susceptible varieties in hotspot areas lost their harvests in epidemic years. In 2010, damage was curtailed through speedy government intervention to raise awareness, provide fungicides, and multiply and disseminate seed of new, resistant bread wheat varieties. CIMMYT, the DRRW Project, ICARDA, USAID, AGRA and FAO together with the national wheat research program, and private and public seed enterprises played a significant role in variety selection, accelerated seed multiplication and deployment of rust resistant varieties. It is estimated that rust resistant varieties are now sown on more than 700,000 ha and their use has brought many farmers’ yields above the world average. Despite good progress the challenge of varietal diversification remains. Wheat is a traditional crop in Ethiopia. It is grown under rainfed conditions on 1.6 million hectares by 5 million households. The country produces more than 3 million tonnes annually - about 64% of domestic needs. Future demand is expected to increase steadily due to changing diets, population growth and urbanization. The national average yield for wheat is about 2 t/ha - far below the world average. However, progressive small-scale farmers produce 4-5 t/ha and the potential yield in key wheat-growing areas is even higher.
Agronomic performance of promising bread wheat varieties in Rwanda


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Adoption of disease resistant wheat varieties with high and stable yields and good processing qualities will help to increase national wheat production and farmers’ incomes in the highlands of Rwanda. Thirteen elite bread wheat lines and one commercial wheat variety (EN161) were evaluated in replicated trials at Rwerere Research Station in two seasons in 2012. Differences among the genotypes were significant for stripe rust and stem rusts scores, but not for leaf rust, barley yellow dwarf (BYDV), Septoria leaf spot, Fusarium head blight and Helminthosporium leaf spot ratings. Plant heights among the genotypes ranged from 82 to 99 cm, time to flowering from 67 to 75 days, and time to physiological maturity from 110 to 117 days. Grain yields varied from 1.17 to 3.00 tonnes/ha. The most promising lines identified, based on important agronomic characters, including stem rust resistance, were SAWYT 317, SAWYT 309, SAWYT 314 and SAWYT 348. These genotypes will be evaluated in farmers’ fields in the wheat zone to select the best for commercial production by 2015.
Preliminary evaluation of Ethiopian emmer land races to wheat rusts and Septoria leaf blotch in southeastern Ethiopia

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Emmer wheat (Triticum dicoccoides) was introduced to Ethiopia 5,000 years ago by early Hamite immigrants. Farmers still grow emmer land race varieties in south eastern Ethiopia in two seasons, August – December and April – August. Ninety-one emmer land race accessions were collected from farmers’ fields. During 2007 these land races and two improved emmer varieties were planted in 4-row plots at Sinana Agricultural Research Center in southeastern Ethiopia, and evaluated for response to the rusts and Septoria leaf blotch under natural conditions. Rust and Septoria leaf blotch data were recorded using the Modified Cobb and percentage scales, respectively. Terminal disease severities were used for comparing the response levels of genotypes. The land race varieties were resistant to stem rust, yellow rust and Septoria leaf blotch, but most of them were susceptible to leaf rust. The results indicate that sources of resistance to stem rust, yellow rust and Septoria leaf blotch are available in Ethiopian emmer land races.
Breeding for resistance to stem rust in South Africa

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Stem rust is a common disease of bread wheat in the winter-rainfall regions of South Africa (SA). Although resistant germplasm is widely used in breeding programs, the genetic bases of many SA cultivars are not fully understood. Recent evidence has indicated a high frequency of the durable resistance gene Sr2 in historic wheat cultivars. Examples of ineffective race-specific resistance genes postulated in SA cultivars include Sr5, Sr9e, Sr24, Sr31, and Sr36. The results of race surveys have contributed to breeding and deployment of resistant cultivars. More than 30 Pgt races were identified during the past three decades. Predominant races detected in recent years include variants of race Ug99 and those virulent on Sr27 which is present in some triticales. Four of the eight races in the Ug99 race group have been confirmed in SA. This is significant as most of the current spring wheat lines and cultivars are susceptible to variant PTKST. Diversity of the Pgt population in SA is influenced by foreign introductions and mutations in existing races. Currently, combinations of effective resistance genes such as Sr2, Sr25, Sr26 and Sr39 are being incorporated into adapted germplasm and significant emphasis is put on stewardship of these resistance sources. Marker-assisted selection is widely used to fast-track the development of resistant cultivars and relevant molecular techniques are being employed to complement traditional race surveys. This presentation will focus on outcomes of race surveys conducted during the past 10 years, impacts of recent virulence changes on commercial cultivars and breeding lines, supportive molecular techniques for traditional race analysis, and current pre-breeding efforts to develop stem rust resistant lines.
Screening for rust resistance and grain quality in CIMMYT advanced lines under Moroccan conditions

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Durum wheat is a strategic cereal crop in Morocco. It is planted in all agro-ecological regions of the country. Breeding programs have produced many varieties suitable for most regions. Numerous biotic stresses, especially leaf rust, limit the profitability of this crop and cause yield and quality losses, mainly in the northwest. Resistance to leaf rust and yellow flour pigment are important traits for release of varieties that fulfil farmers’ requirements. Nurseries from CIMMYT offer a range of durum lines containing genes for rust resistance and grain quality. They are tested under irrigated conditions in which rust is predominant and quality is difficult to achieve. Some of them are sown in advanced trials. The presentation will report on selection of lines with outstanding resistance to leaf rust and other diseases, and with high yellow pigment content. Some lines are currently under multiplication for eventual addition to the national catalog of registered varieties.
Effectiveness of *Yr* genes under high inoculum pressure: *Yr15* was the most effective one under Moroccan conditions during the 2012-2013 cropping season

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Stripe (yellow) rust, which was limited to areas near the Atlas Mountains during the late 1980s, has become a real threat to wheat production across almost all cereal-growing areas in Morocco. This may be due to changed cultural practices, more susceptible cultivars, increased virulence and/or aggressiveness in the pathogen population, or climatic changes making the environment more conducive to epidemic development. In order to monitor virulence changes in the pathogen and to assess the effectiveness of resistance genes, the Avocet S near-isogenic lines and other varieties/lines with known resistance genes were grown under field conditions and tested for rust responses at three locations during the 2012-13 cropping season. Scoring occurred during grain filling. At all sites coefficients of infection (CI) on susceptible lines hovered around 100. Of lines possessing *Yr1*, *Yr10*, *Yr15* and *YrSP* that were completely rust-free across Morocco during the previous season, only the line with *Yr15*, and to some extent the line carrying *YrSP*, remained rust-free in 2013. The line carrying *Yr27* was completely destroyed at Marchouch. Thus *Yr27* is no longer effective under Moroccan conditions, and *Yr15* is the most effective resistance gene. In order to ensure long lasting effectiveness of the major genes, combinations with minor genes should be a wise strategy.
The leaf rust situation and resistance in wheat cultivars deployed in northwestern Pakistan

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Among the Southeast Asian countries, Pakistan has the 2nd highest wheat area of which 5.8 million ha (80%) are vulnerable to leaf rust. In 2012 studies were made on the variety distribution and leaf rust severities over 1,000 ha of wheat in 26 regions of five foothill districts (viz. Peshawar, Nowshara, Charsada, Mardan and Swabi) of Khyber Pakhtunkhaw (KPK) province. These areas are located in the migratory pathway of rust pathogens. Leaf rust occurred in all five districts. Infection rate, used as the parameter of epidemic development, was fastest in district Charsadda whereas its impact was greatest in district Nowshara as assessed by a Field Impact Factor (FIF). We identified 21 varieties with known \((Lr1, Lr3a, Lr13, Lr26, Lr27+Lr31)\) and unknown leaf rust resistance genes. Six genotypes, including Atta Habib, Bahkhar-2002, Fakhre-e-Sarhad, Sehar-2006, Pirsabak-2004, and Zam-04, occupied 94% of the wheat area. Sehar-2006 and Pirsabak-04 covered 80% of the area. Sehar-2006 \((Lr26)\) was susceptible in most locations in the foothills as well as the National Wheat Disease Screening Nursery (NWDSN) at four locations in Sindh and at two locations in Punjab. High levels of resistance were displayed by Pirsabak-04 \((Lr1+Lr26)\) in Sindh and Punjab, but at Nowshara it was highly susceptible. Recent leaf rust samples from the five foothill districts indicated the presence of race FHPSQ carrying virulence for several genes including \(Lr26\). Resistances in Sehar-2006 and Pirsabak-04 are based on \(Lr1+26\) and \(Lr26\), respectively. Cultivation of both genotypes should be replaced by novel varieties including Pirsabk-08, NIFA Bathoor-08 and Hashim-08 for avoiding future epidemics in the region as the resistance of both these genotypes is narrow and based on defeated genes.
Understanding genetic bases of wheat varieties in Pakistan: A prerequisite for combating wheatrusts

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Among biotic factors affecting wheat yields, stripe (yellow) rust and leaf rust are the most important diseases in Pakistan. Understanding the genetic bases and genetic diversity of wheat varieties grown in the country is very important from the point of view of assessing genetic vulnerability. Pedigree-based diversity analyses will be undertaken using coefficient of parentage, cluster analysis and multidimensional scaling analysis (MDS). The weighted average diversity and the average age of wheat cultivars will be determined. This will provide feedback to wheat breeders to enable better targeting of crossing programs and for deploying varieties with diverse genetic backgrounds. Anecdotal evidence indicates that nearly 34\% of the wheat area is occupied by varieties that are <5 years from release. However, the major challenge will always be to improve and sustain wheat productivity by reducing genetic vulnerability to rust diseases both in time and space should there be a rust epidemic as much of the wheat area is still covered by older susceptible varieties. A concerted effort must be made to accelerate the delivery of genetically diverse new varieties by co-ordinating final testing of candidate varieties with seed multiplication and delivery to farmers. A strengthened seed system that targets smallholder farmers and overall food security needs to be innovative and decentralized, and must involve participation by government and all major stakeholders of the seed industry, as well as farmers.
Genetic diversity analysis of pre- and post-green revolution wheat varieties of Pakistan based on RAPDs

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Colonial wheat research in current India and Pakistan led to the release of variety C518 in 1933. Later, C271 and C273 were released having genetic constitutions of landraces. During the green revolution in the 1960s, MexiPak 65 was introduced. It had a dwarfing gene permitting response to high fertilizer usage that boosted yields several-fold. The present research was carried out on 94 commercial wheat varieties released in Pakistan during 1933 - 2006 to characterize genetic diversity based on RAPD markers. Seventy-eight polymorphic loci were identified using six primers that revealed an average genetic diversity of 0.2924. Cluster analysis grouped the varieties in two major clusters lying well apart from each other. Cluster I includes varieties released during the colonial period of research and during the 1970s and 80s. Cluster II mainly includes varieties released during and after the 1990s. The most diverse sub-group was in cluster II and was composed of modern varieties.
Seedling stem rust responses of Pakistani wheat varieties

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The appearance and increased incidence of *Pgt* races with virulence for major seedling resistance genes during the last decade changed the focus of wheat breeding in many countries. In 2011-12, 29 mega- and newly released wheat varieties in Pakistan were tested for seedling resistance at the Cereal Disease Laboratory at the University of Minnesota using nine North American *Pgt* races (QFCSC, QTHJC, MCCFC, RCRSC, RKQQC, TMPKC, TTTTF, SCCSC, and QCCSM), and one race from each of Yemen (TRTTF), Pakistan (RRTTF) and East Africa (TTKSK = Ug99). All varieties produced resistant reactions (IT<3) with US races SCCSC and QCCSM and only two, Auqab 2000 and Dharabi-11, were susceptible to the predominant US race QFCSC. With all other common US races most of the varieties were resistant except for TTTTF, which was virulent (IT>3) on 18 varieties. The Yemeni race TRTTF was also virulent to 12 wheat varieties. In Pakistan only race RRTTF is prevalent and among the tested varieties 18 were resistant. The mega varieties Faisalabad 2008 and Seher 06, together covering more than 50% of the wheat area in the country, were also susceptible to race RRTTF. Among the wheat varieties evaluated, only NARC 2011 was resistant to race TTKSK. Although this presents an alarming situation for wheat production in Pakistan if race Ug99 or a derivative is introduced, the Pakistani wheat productivity enhancement program (WPEP) is increasing the diversity of stem rust resistance genes in wheat varieties using both classical and molecular tools. The phenotypic profiles of current Pakistani varieties will be provided.
Genetic diversity in adult plant resistance to leaf rust in bread wheat

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There is an increasing worldwide interest in APR since most examples of durable resistance to wheat leaf rust are this type. Twelve bread wheat genotypes were studied for adult plant reactions in the F1, F2, and F3 generations using Pt race 121R63-1 (77-5), the most prevalent and widely virulent race on bread wheat in India. Resistance was controlled by a pair of dominant and recessive genes in each of CPAN 1676 and CSP44, and by two independent dominant genes in each of CPAN 1796, Frontana, HD 2009, HD 2135, HUW 37, HW 517, Nainari 60, Pavon 76, VL 404, and WG 138. Intercrosses of resistant lines revealed the presence of at least five genes, including one recessive, among these genotypes in addition to Lr34, Lr46, Lr48, and Lr49. Parent lines with these genotypes can contribute to achieving greater diversity in leaf rust resistance in Indian bread wheat improvement programs.
Status of stripe rust resistance in popular wheat cultivars in India

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Stripe (yellow) rust is the most important disease of wheat in the North Western Plain and Northern Hill Zones of India. Since 2008-09 severe stripe rust levels have developed at many locations in the northern plains. The present study was undertaken to identify stripe rust resistant wheat genotypes. Two hundred and twenty seven advanced lines and current cultivars were evaluated in 10 multilocation nurseries inoculated with \textit{Pst} races 78S84 and 46S119 (located at Karnal, Ludhiana, Gurdaspur, Jammu, Kudwani, Dhaulakuan, Malan, Bajoura, Pantnagar and Durgapura) during the 2012-13 crop season. Average coefficients of infection (ACI) were calculated. Of 101 AVT 2nd year entries, 26 were resistant (ACI up to 10). Of these 26 genotypes, eight varieties, HS 542, HPW 349, HS 490, HS 507, VL 829, HD 3086, PBW 660 and WH 1105 have been recommended for cultivation in six states in Northern India. Of 120 AVT 1st year genotypes, 31 were resistant. All entries in both nurseries were categorized into distinct groups based on Area Under the Disease Progress Curve (AUDPC) values. Thirty nine genotypes were rust free, 38 had AUDPC values of 1-100, 47 had values 101-200, 60 had values 201-500, and the remaining lines had higher values up to a maximum of 1800. Apart from the rust-free lines, genotypes with AUDPC values of less that 200 had rust levels <20\% of the susceptible controls and were considered slow rusting.
Status of rust resistance genes in wheat cultivars of central and peninsular India

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Primary inoculum of stem and leaf rusts of wheat grown in peninsular and central India commences from Nilgiri hills where weather permits obligatory survival of pathogen all over the year. This nonstop host – pathogen collectiveness ensues pathogenic mutations fostering new rust virulences which ruin the resistance of existing cultivars in peninsular and central India. Appraisal of resistance genes hitherto protecting cultivars from Nilgiri borne inoculum is one of the prime objectives of IARI, Regional station, Wellington situated in Nilgiri hills. An analysis on effectiveness of rust resistance genes present in cultivars of central and peninsular India to the existing rust flora in Nilgiris is presented here in respect of five years surveillance and race analysis of stem and leaf rusts. Genes commonly deployed in peninsular and central India are Lr1, Lr3, Lr10, Lr13, Lr14a, Lr24 and Lr26 in case of leaf rust and Sr5, Sr9b, Sr9e, Sr11 and Sr24 in case of stem rust. Strength of resistance imparted by these genes was assessed by percentage of avirulent field isolates on the respective stocks. Only Lr24 for leaf rust and Sr31 for stem rust showed complete resistance while all others were susceptible to one or more pathotypes. Though varieties possessing Lr24 and Sr31 grow rust free in central and peninsular India yet these are under threat in case Ug99 gains access to India. Genes Sr2, Sr22, Sr27, Sr29, Sr32,Sr33, Sr35, Sr36, Sr39, Sr40 etc. for stem rust and Lr 9, Lr19,Lr24, Lr25, Lr28, Lr32 etc. for leaf rust show promise if used as pyramids in permutation and combinations.
Developing wheat varieties resistant to \textit{Pgt} race Ug99

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India has been successful in avoiding rust epidemics for more than 35 years due to constant release and dissemination of rust resistant wheat varieties. Food security in many countries, including South Asia, was considered to be under threat from \textit{Pgt} race Ug99 and its variants. Anticipatory breeding for resistance to Ug99 was initiated as a consequence. An important component of the initiative is access to testing facilities in Africa and conducted under project “Cereal System Initiative in South Asia (CSISA)” involving six major wheat centers in three production zones. Approximately 50 simple crosses and 30 top crosses or backcrosses are made each year by each center using at least one Ug99-resistant parent. Segregating generations are advanced following the selected bulk approach and F\textsubscript{3}/F\textsubscript{4} populations are sent each year to Kenya and Ethiopia for response evaluation by Indian and CIMMYT scientists. Nearly 1,000 F\textsubscript{3}/F\textsubscript{4} lines have been sent since 2011. Resistant lines are then promoted in breeding programs in India. As a consequence of the program about 30\% of lines in national trials are Ug99 resistant. Twenty-one resistant varieties have been identified in the last 5 years and many of them are undergoing seed multiplication.

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Development of rust resistant wheat varieties for food security in Bangladesh

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Wheat is the second most important cereal crop after rice in Bangladesh. It covers about 400,000 ha with annual production of 1 m tonnes. The current annual consumption is about 4 m tonnes. The shortfall is met through imports. Spot blotch and leaf rust are the most important diseases. Stem rust was last observed in the mid 1980s, and stripe (yellow) rust occurs occasionally in the northern parts of the country. Recent varieties developed by the Wheat Research Centre at BARI are resistant to leaf rust and yellow rust. The most common rust resistance genes in these varieties are \textit{Lr13}, \textit{Lr26}, \textit{Sr5}, \textit{Sr31} and \textit{Yr9}. Slow rusting gene \textit{Lr34/Yr18} is also evident in some varieties and advanced lines that exhibit clear leaf tip necrosis under field conditions. Wheat lines and cultivars are regularly screened against stem rust at KARI in Kenya. Two varieties, BARI Gom 26 with moderate APR and BARI Gom 27 (Francolin#1) with an acceptable level of APR to race Ug99 and derivatives, released for commercial cultivation, are capable of producing 10% higher yields than the standard national check variety Shatabdi. Breeder seed of these varieties is being supplied to the public seed sector. Training and demonstrations are provided to farmers, public and private sector workers and relevant NGOs. Resistant lines and varieties are included in the national hybridization scheme and targeted crosses are being made to increase genetic diversity of rust resistance and to breed for durable resistance aimed to mitigate future threats of virulent rust pathogen races while increasing national wheat production.
Status of wheat rust management in Bangladesh

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Leaf rust is the most important wheat rust in Bangladesh. It occurs in all wheat growing areas at varying levels of severity. Stripe (yellow) rust appears occasionally in the northwest, and stem rust has not been recorded in the last three decades. Early planting helps in avoiding the adverse effects of leaf rust during grain filling. Some fungicides are effective, but their use is limited due to cost and bother of spraying. Breeding for resistance receives high priority for sustainable rust management. Wheat varieties released since the late 1990s have maintained leaf rust resistance, although cv. Prodip released in 2005 is moderately to highly susceptible. Rust resistance genes postulated in Bangladeshi wheat varieties include Lr1, Lr3a, Lr10, Lr13, Lr23, Lr26 and Lr34; Sr2, Sr5, Sr7b, Sr8b, Sr9b, Sr11 and Sr31; and Yr2KS and Yr9. In addition, some adult plant resistances (APR) have also been recorded. Although none of the rusts occur in epidemic proportions in Bangladesh, the threat of future damaging epidemics cannot be excluded. In order to mitigate the threat of Pgt race Ug99 resistance breeding was initiated in collaboration with CIMMYT and BGRI. Advanced wheat lines and segregating materials from the national breeding program are regularly screened at KARI, Njoro, Kenya. Ug99-resistant varieties BARI Gom 26 and BARI Gom 27 (Francolin #1) were released during 2010-2012. Both varieties yield around 10% higher than other adapted varieties. Accelerated seed multiplication through Government- and CIMMYT-facilitated USAID funding led to significant adoption of these varieties. In the current crop cycle, about 20% of the national wheat area will be covered with Ug99-resistant varieties.
Screening of imported barley accessions and selection of suitable lines for the high hills of Nepal

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Barley remains an important food crop in Nepal, especially in the high hill areas. Its distinct traits and adaptive abilities allow it to better cope with the harsh weather than any other cereal. A screening trial of 400 barley accessions from ICARDA was set up on the governmental farm at Marpha, Mustang, a high hilly district of Nepal in November 2008. The initial performance evaluation was based on response severities to major diseases such as stripe rust and leaf rust. Sixty accessions were selected for further evaluation. Considering disease resistance and yield traits, 6 lines (accession numbers 36784, 36952, 37914, 37917, 37920 and 37950) were selected; 5 lines were 6-row and one was 2-row. Participatory Varietal Selection (PVS) was employed in farmers’ fields at Kunjo, Mustang, using the selected 6 lines, along with local checks for two consecutive years. This group of lines was also included in the national Coordinated Varietal Trial (CVT). The 2-row line 36952 outperformed the remaining lines in terms of grain yield (2.5 t/ha), and resistance to stripe rust, leaf rust, head blight and loose smut. Further trials involving PVS and Informal Research and Development (IRD) are underway to test the performance of these lines in other high hilly regions of the country. Suitable line(s) for the different sites will be identified based on farmer preference indices and registered for the specific regions. Dissemination and spread of the varieties will be monitored.
Combating stripe rust in the hills of Nepal through resistance gene deployment

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Wheat production plays crucial role in the food security of marginal farmers in the Nepali hills that represent 40% of the national wheat growing area. Farmers bear huge losses due to stripe rust epidemics, with the most devastating one in recent years occurring in 2004. Monitoring of the pathogen population during 1980-2008 showed race changes over time. Race analysis under field conditions and in the glasshouse during 2004 showed the presence of a Yr27-virulent race that was different from 7E150 and 46S119 recorded in the 1980s and 1990s. To determine the genes and germplasm providing protection a series of trap nurseries with known resistance genes, wheat differentials, commercial cultivars and advanced breeding lines were evaluated in inoculated nurseries and at natural hot spot locations during 2005-2010. The disease severities and responses varied greatly during the period. Four genes (Yr5, Yr10, Yr15 and YrSp) consistently conferred resistance. Genes Yr9 and Yr27 were ineffective, but were highly effective in combinations, such as in Opata 85 (Yr27+Yr18) and Super Kauz (Yr9+Yr27+Yr18). Other lines such as Parula with combinations of minor genes, Pastor with Yr31 and APR, and Cook with APR were also resistant or moderately resistant. Among 110 entries included in the International Disease Trap Nursery (IDTN) during 2006 to 2010, Amadina, Kukuna, Tukuru, Kakatsi and Buck Buck were resistant and consequently widely used in breeding programs. Advanced prerelease lines showing resistance for more than four years were Danphe#1, Danphe#2, Munal#1, Chyakhura#1, BL3623, BL3629, and WK2085. Varieties WK1204, Gautam, Gaura and Dhaulagiri released in recent years have rescued wheat farmers from stripe rust due to control with increased genetic diversity.
Evaluation of the Nepalese wheat gene pool for drought and stripe rust responses

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Wheat is the most important food crop in Nepal and has been cultivated as a major crop since human habitation. Nepalese wheat landraces may harbor genes for resistance to abiotic and biotic stresses. However, many farmers cultivate modern varieties released from national and international breeding programs. Previous results showed that some of these varieties lack resistance to one or more stresses. Therefore, a varietal enhancement program was initiated by assessment of local and exotic wheat varieties as potential donor parents. Eighty-one Nepalese wheat landraces, 28 modern Nepalese varieties and 8 exotic lines were screened for drought tolerance (DT) and yellow rust (YR) responses under heavy natural inoculum for two years at Khumaltar, Lalitpur. Thirty four landraces, 11 modern varieties and 6 exotic lines (Halberd, Mara, Sitta, Ciano 67, Pavon 76 and Francolin\#1) were resistant to YR. Exotic lines found superior for DT traits were Dharwar Dry (for yield under drought) and Halberd (for long coleoptiles). Sixty seven Nepalese landraces and 18 modern varieties were screened using published SSR markers linked with YR and DT genes. Dharwar Dry (for yield under drought), Francolin\#1 (for rust resistance) and Halberd (for longer coleoptile length) are currently being used as donor parents for improving Nepalese wheat varieties WK1204, BL3623, Pandur Local and BL1473.
Development of stem rust resistant germplasm using conventional and molecular methods

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Stem rust causes considerable damage in northern Kazakhstan. The aim of the present study was to identify wheat lines resistant to stem rust. The Pgt population in Kazakhstan comprises more than 20 pathotypes. Seedlings of 113 wheat accessions were tested with Pgt races TFK/R, TDT/H, PCR/G, Pgt-17 and Pgt-21 that are currently prevalent in Kazakhstan. The widely grown spring wheat cultivars Astana, Kazakhstanskaya 10, Karabalykskaya 92 and Omskaya 36 were susceptible to all five races. Zhenis, Saratovskaya 29 and Celinnaya 50 were moderately resistant in the field, but were susceptible to all Pgt races in seedling tests. Five accessions (Bayterek, Kazakhstanskaya RS, Karagandinskaya 70, E-776 and E-806) were resistant to one or three races. Cultivar Avangard was resistant to four races (TFK/R, PCR/G, Pgt-17 and Pgt-21). Molecular screening showed that 13 of 113 genotypes assessed with markers generated DNA fragments associated with Sr26; 12 lines produced the DNA fragment associated with Sr38/Lr37/Yr17 when amplified with primer LN/Ventrup; 8 lines generated DNA fragments associated with Sr25/Lr19 when amplified with primer GBF; 21 lines have Sr2 combined with Sr24/Lr24; and 14 lines were positive for Sr31/Lr26/Yr9/Pm8. No line possessed Sr22 or Sr39 based on marker analysis. A number of advanced lines showed high yield potential combined with resistance to race Ug99 and to other Pgt races predominant in Kazakhstan.
Assessment of a wheat collection for resistance to stem rust

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Wheat stem rust is a most feared disease due to its ability to inflict substantial losses. FAO estimates that 30 countries are either affected by Ug99 or at potential risk. There is a chance that Ug99 will reach Georgia where barberry is widespread. Because a large proportion of the world’s commercial wheat varieties are susceptible to Ug99, new sources of resistance are required for breeding improved varieties. The objective of this study was to evaluate the stem rust responses of a range of local varieties and wild relatives. Twenty accessions, including nine endemic wheat subspecies, four domestic varieties, seven new varieties (selected from international nurseries) were tested against four Georgian Pgt races (NCDSC, DCBDC, LHDBC, NHPGF), three Ug99 variants (TTKSK TTKST, TTTSK) and one Yemeni (TRTTF) race at the seedling stage. Of the 20 accessions, six endemic subspecies (T. monoccoccum var. laetissimum, T. timopheevii var. typicum, T. ibericum var. fuliginosum, T. ibericum var. stramineum, T. macha var. megrelicum and T. macha var. palaeo-imereticum) were highly resistant to all Kenyan and Georgian races. Two accessions (T. macha var. megrelicum and T. macha var. palaeo-imereticum) showed moderate resistance to the Yemeni race, but the remaining entries were susceptible. The Georgian varieties (Almasi, Vardzia and Tetri Ipkli, and Akhaltsikhis Tseteli Doli) were susceptible to all races. High levels of resistance to Kenyan and Yemeni races were present in five varieties selected from international nurseries and recommended for release in Georgia.
Cold tolerance, local rust, and Ug99 reactions of some wheat genotypes from the Eastern Anatolia Agricultural Research Institute, Erzurum, Turkey

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Stripe (yellow) rust, stem rust and cold tolerance are the principal yield-limiting factors for wheat production on the East Anatolian Plateau of Turkey. In this study, 30 genotypes from the in 2012 Advanced Yield Trial - Bread Wheat (AYT-BW) were used. The aim of the Eastern Anatolia Agriculture Research Institute’s germplasm development program is to identify genotypes with high yield potential, cold tolerance and resistance to the rusts (stripe rust and stem rust including race Ug99). The degree of cold tolerance of all the materials is determined under controlled conditions by testing at different temperatures. In addition to these activities, the AYT-BW materials were tested with local Pst and Pgt populations in Erzurum province and in Ankara. Cut-off levels for acceptable resistance were set a CI of ≤ 20. Materials were also evaluated at Kenya Agricultural Research Institute (KARI), Njoro, Kenya, during the May-October period of 2012. Coefficients of infection were calculated for assessment and cut-off levels for Kenya data were set at ≤ CI 30. The presentation will include data from these trials. Four genotypes could be potentially high yielding, cold tolerant, and resistant to local races of the stripe rust and stem rust pathogens (as well as Ug99).

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Assessment of seedling resistances to leaf rust, stem rust and stripe rust in Turkish wheat cultivars

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Cereal rusts have major historical significance. There are several areas worldwide where one or other, or the combined diseases, cause significant losses. The most environmentally friendly and cost-effective disease control strategy is to develop and grow resistant cultivars. There is a continuous need to identify, characterize, and deploy new sources of resistance because of the ability of rust pathogens to acquire virulence for resistance genes. To discover new sources of resistance and distinguish known resistance genes from potentially new ones, germplasm collections can be tested at the seedling stage with an array of rust cultures with known pathogenicity attributes (multipathotype tests) and infection types, and infection type arrays can be compared with those of wheat stocks with known resistance genes. The presence of known seedling resistance genes can then be postulated on the basis of gene-for-gene specificity. The genetic bases of rust resistances in most of the current Turkish wheat cultivars are unknown. Because all three rusts are important in Turkey, as well as in other Near East countries, it was anticipated that useful and potentially new resistance genes could be present in Turkish wheat cultivars. The current study characterized seedling resistance to leaf rust, stem rust and stripe rust in 95 Turkish wheat cultivars using selections of Australian isolates of the respective pathogens. Genes detected for resistance included Yr6, Yr7, Yr9, Yr27; Lr1, Lr3, Lr13 and Lr16, Lr17b, Lr20, Lr23 and Lr26; and Sr5, Sr6, Sr8a, Sr23, Sr30 and Sr31. The genes were present either singly or in combination. There were several instances of unknown seedling resistance genes, and these warrant further investigation. These cultivars will also be screened in the field to determine if they possess genes for adult plant resistance.
Resistance of some international bread wheat material to yellow rust in Central Anatolia

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Bread wheat is one of the most important cereal crops in Turkey. Stripe (yellow) rust is the most significant disease affecting wheat yield and quality in the Central Anatolian Plateau. The purpose of this study was to assess adult plant stripe rust reactions at the Central Research Institute for Field Crops using artificial inoculation in 2011-2012. We tested 25, 50, and 75 genotypes from the Advanced Yield Trial - Irrigated (AYT-IR), Advanced Yield Trial - Semiarid (AYT-SA), and Advanced Yield Trial - Supplementary Irrigated (AYT-SIR) nurseries, respectively. These genotypes were developed by the International Winter Wheat Improved Project (IWWIP-TCI). Each genotype was sown by hand in a 1 m row in October 2011. Susceptible cultivars Little Club, Michigan Amber and Seri 82 were sown around the experimental field and Little Club was also used as the susceptible control in every 10th row. Spore suspensions in mineral oil were inoculated to plants at two different times. A uniform epidemic was achieved, with susceptible genotypes exhibiting 90-100S. Reaction types and rust levels based on the modified Cobb scale were recorded at both locations. A minimum of two readings were made and the highest score was used for selection. Coefficients of infection (CI) were calculated and values below 20 were considered to be resistant. Seventeen (68%), 32 (64%) and 52 (69%) genotypes, were resistant to the local Pst race (virulent on Lee, Heines Kolben, Heines Peko, Kalyansona, Sonalika, Federation*4/ Kavkaz and Avocet S seedlings) in the AYT-IR, AYT-SA, and AYT-IR nurseries, respectively. The resistant lines will be useful to obtain resistant varieties.

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Reactions of Iranian wheat lines to Pgt race TTKSK in 2013

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Bread wheat is the most important and strategic foodstuff in Iran. Stem rust is one of the potentially important sporadic diseases affecting wheat yield and quality. In a search for new sources of resistance wheat lines were evaluated for seedling response to stem rust at SPII, Karaj, and at the adult plant stage in Njoro, Kenya. Among 401 genotypes, 70 lines (17.5%) were resistant at the seedling stage. In the field at Njoro 274 genotypes (68%) were resistant. Some of the lines susceptible in the seedling stage, but resistant as adult plants, could carry new sources of resistance to stem rust.

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Association analyses of leaf rust and stripe rust resistances in a panel of eastern U.S. winter wheat lines


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We report results from the first two years of a multi-year study to discover new disease and insect resistance genes within a diverse panel of 424 eastern U.S. soft winter wheat lines. The panel comprises both landrace and elite cultivars of current or historic importance to eastern U.S. wheat breeding programs. Lines were submitted by eastern U.S. wheat breeders for inclusion in the panel. The population is currently being evaluated for resistance to leaf rust and stripe rust. These diseases can significantly decrease yields of susceptible varieties in the eastern U.S.A. This population was tested for resistance to leaf rust at one location in 2012 (North Carolina), and two locations in 2013 (North Carolina and Georgia). In addition, seedling tests were performed at the USDA-ARS Cereal Disease Laboratory using four Puccinia triticina races. During 2013, stripe rust tests were conducted at four locations in Washington state and one location in Arkansas. Phenotypic data were used in an association analysis with 5,169 polymorphic SNP loci, and obtained using the Illumina iSelect 9k Wheat Chip. Results for leaf rust indicate the existence of several major seedling resistance genes in this germplasm and further analysis is underway. Preliminary results for both stripe rust infection type and severity across the five locations indicate significant loci for resistance on chromosomes 1A, 2A, and 3B, as well as several unmapped loci. We discuss the use of our results in discovering new genes for resistance to these diseases and also in providing breeders with additional tools for marker-assisted selection.
Evaluation of winter wheat in the northern Great Plains for resistance to leaf rust

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Winter wheat production in North Dakota is expected to increase in coming years. Wheat leaf rust (caused by \textit{Puccinia triticina}) is a continuous threat to winter wheat production in the U.S. northern Great Plains due to a disease-conducive environment during most of the growing season and the constant emergence of new, virulent races. Growing resistant cultivars is the most economic and environmentally friendly strategy of managing this important foliar disease. Limited information is available regarding resistance to local \textit{Pt} races. In this greenhouse study, we evaluated 64 winter wheat varieties and lines grown in the northern Great Plains for seedling response to \textit{Pt} races MCDL, MFPS, THBL, TBDG and TBDJQ that are predominant in the region. The majority of genotypes were susceptible to all five races. Twenty-eight (44\%) were resistant to race MCDL, 31 (48\%) resistant to THBL, 27 (42\%) resistant to TDBG, 23 (36\%) resistant to TBDJQ, and 20 (31\%) resistant to MFPS. A total of 13 genotypes (20\%) showed resistance to all five races whereas 22 genotypes (34\%) were susceptible. The data showed that many susceptible varieties are being grown. The results provide useful information with respect to resistance deployment and breeding for our region while winter wheat growers can use the information in deciding which cultivars to grow and how they might be managed in control of leaf rust.
Rust resistance in western Canadian winter wheat

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Winter wheat has shown a dramatic increase in popularity in western Canada over the past 20 years. Following a major surge in area in the late 1980s, severe drought, disease susceptibility, and a lack of cultivars adapted to the various agro-climatic regions resulted in the prairie area plummeting to less than 45,000 ha. Since 1997, cultivars with improved disease resistance (rusts, bunt, wheat streak mosaic, FHB) and agronomic characteristics have been registered, gradually restoring producer confidence in the crop. In 2012-13, the sown area of winter wheat was 500,000 ha, making it the third most important wheat class in western Canada. Despite great progress in a relatively short time, the durability of all types of rust resistance is of major concern, because in almost all cases, resistance is conferred by one or other of two deployed genes (Sr24/Lr24; Sr38/Lr37/Yr17). Strategies to broaden the genetic base of resistance and pyramid effective genes for adult and all-stage resistances to the three rusts, including *Pgt* race Ug99 and the more aggressive *Pst* races, have been developed and are underway. The status of these efforts, as well as genetic studies to characterize putatively novel sources of resistance, will be presented.