USDA-ARS/CIMMYT
Project Report 2024

Project Title:
"Identifying New Genetic Resources and Evaluating United States Wheat Germplasm to Stem Rust in Eastern Africa"

Objectives:
The two objectives of the project are:

1. Determine the reaction of US wheat and barley cultivars and germplasm to newly detected races of *Puccinia graminis* f. sp. *tritici* (the causal fungus of stem rust) in Eastern Africa.
2. Identify new sources of seeding and adult plant resistance to stem rust in improved CIMMYT wheat germplasm and sharing it with US wheat scientists

Partners:
USDA-ARS and US
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US Wheat and Barley accessions tested during Main season 2024
Kenya:
A total of 3,082 wheat and barley accessions were evaluated in Kenya during 2024 Main season. Out of these, a set of 1,970 winter wheat lines were screened and a set of 1,112 wheat and barley accessions were received from USDA collaborators and planted for evaluation against Ug99 group of races and evaluated during 2024 main season at KALRO, Njoro, Kenya.

Relevant races of stem rust were multiplied ahead of time and fresh inoculum was used in the field inoculation. Susceptible spreaders were planted and inoculated with the races specific to the spreaders to initiate the disease development and rust spores were dispersed with the wind movement.

Stem rust data was recorded on three intervals under artificial epidemics and yellow rust infections were recorded on all the lines on at least two occasions (natural infections). Recorded data was shared with USDA scientists.

General Observations on rust screening nurseries at KALRO

Crop established well during both off and main seasons in Kenya. Uniform disease development and high disease pressure was observed across during both crop seasons resulting in good stem rust variation for evaluation of wheat nurseries largely attributed to favorable cooler and wet conditions in the early months for YR development and SR development in the later months post booting as temperatures increased.

SR races in Kenya: TTKST (Ug99+*Sr24*), TTKTT (Ug99+*Srtmp*) and TRTTF were the predominant races in the screening nursery in Kenya along with the original TTKSK (Ug99) and variants of TTKTT carrying virulence to resistance derived from CIMMYT lines Kasuko and Kenya Fahari (*Sr8115b allele*) that was observed in higher frequency in 2024 off season.

YR races in East Africa
YR races namely PstS16 was dominant in 2024 offseason and mainseason causing increased susceptibility in both CIMMYT and International nurseries including USDA. PstS11 was identified in low frequency.

PstS11 Yr1,2,Yr3,(4),Yr5,6,7,8,Yr9,Yr10,Yr15,17,Yr24,Yr25,27,32,YrSp,AvS,YrAmb (+ PStS2 Kenya)
PstS16 1,2,3,4,Yr5,6,7,8,9,Yr10,Yr15,17,Yr24, 25,27,32,YrSp,AvS, YrAmb (Dominant in Ethiopia and Kenya)

Data on US Wheat Materials
Various scientist from the USDA-ARS, CIMMYT, KALRO have participated in recording stem rust and other data on wheat materials. Compiled data were returned on a timely basis to all US collaborators for further distribution after checking it. Data for various USDA-ARS materials are available with USDA-ARS and other cooperating scientists.

Ug99 resistant spring wheat germplasm from CIMMYT breeding program
First year yield trials (4,500 lines) and 2nd year yield trials (1,200) were evaluated in the off season 2023. These advanced lines comprised of several combinations of APR and major genes. During phenotyping in Njoro, Kenya using stem rust data from four seasons

combined data (off and main season 2021-22), 11% of entries showed the highest severity ranging from 0-20%, 33.5% entries showed between 20-40% severity, and 41% of the lines showed high to adequate levels of APR, while 18% of the lines carried race-specific genes. All data were used in the advancement decisions for Stage 2 yield trials.

The Ug99 effective race specific resistance genes that were predominant in the crosses are *Sr22, Sr25*, shortened *Sr26, Sr50, SrHUW234, SrND643, SrYanac, SrBavis* and some uncharacterized genes. APR sources include Danphe, improved Danphe crosses, Kingbird, Kiritati, Huirivis and several APR+ moderately effective race specific resistance genes showed enhanced levels of resistance. Some of the second- generation stem rust resistant materials derived from old Kenyan varieties such as Kenya Fahari and Kenya Kasuko still offer resistance to the current races in high yielding back grounds of Borlaug100 were used for screening in Kenya.

For YR against PstS16 over 40% of the CIMMYT advanced breeding material exhibited higher disease severity from 40-60%, Borlaug 100 variety has become susceptible to the new YR race which is present in several CIMMYT crosses and can be attributed to increasing susceptibility of CIMMYT breeding germplasm.

Molecular markers for effective stem rust resistance genes validated/optimized and used in developing backcross derivatives of important current and potential varieties with combinations of at least two resistance genes.

The target genes with their respective markers were: Fhb1 (snp3BS-8), Lr67 (Lr67SNPLr67-TM4), Sr2 (Sr2_ger9 3p, Sr2 ger9/wms350), Sr22 (cfa2123/cskp81), Sr25 (SCM009wmc221), Sr26 (Sr26#43/BE518579), Sr32 (csSr32#1csSr32#2), Sr47 (Xrwgs38), Sr50 (IB-267), SrND643 (wmc219/wms350), Yr39 (Xwgp36/Xwgp45), Yr41 (Xgwm410/Xgwm374), Yr15 (Yr15-R5/ Yr15-R8), Yr51 (Xbarc182/Xwgp5258, sun104), Yr52 (Xbarc182), Yr57 (gwm389BS00062676/Wms389), Yr59 (Xwgp5175/Xbarc32), Yr60 (wmc776/wmc219/wmc331) and Yrkk (Xgwm148) have been routinely used.

Overall, approximately 60% of the CIMMYT advanced wheat lines from Kenya possessed combinations of multiple major resistance genes including *Sr13*, *Sr22*, *Sr25*, *Sr26*, *Sr1RSamigo*

Capacity Building

As part of the DEWAS project, the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with Kenya Agricultural & Livestock Research Organization (KALRO) and Cornell University recently organized "Enhancing Wheat Disease Early Warning and Advisory Systems, Germplasm Screening and Evaluations," a training course offered to 27 wheat scientists from Bangladesh, Bhutan, Nepal, and Pakistan (9^{TH}-18^{TH} October 2024).

Journal Publications

Ogutu, E.A., Madahana, S.L., Bhavani, S., & Macharia, G. (2024). Genotype × environment interaction: trade-offs between the agronomic performance and stability of durum (Triticum turgidum) wheat to stem-rust resistance in Kenya. Frontiers in Plant Science, 15, 1427483. https://doi.org/10.3389/fpls.2024.1427483

2. Wang, X., Xiang, M., Li, H., Li, X., Mu, K., Huang, S., Zhang, Y., Cheng, X., Yang, S., Yuan, X., Singh, R.P., Bhavani, S., Zeng, Q., Wu, J., Kang, Z., Liu, S., & Han, D. (2024). High-density

mapping of durable and broad-spectrum stripe rust resistance gene Yr30 in wheat. Theoretical and Applied Genetics, 137(7), 152. https://doi.org/10.1007/s00122-024-04654-5

3. Singh, D., Ziems, L., Chettri, M., Dracatos, P., Forrest, K., Bhavani, S., Singh, R., Barnes, C.W., Zapata, P.J.N., Gangwar, O., Kumar, S., Bhardwaj, S., & Park, R.F. (2024). Genetic mapping of stripe rust resistance in a geographically diverse barley collection and selected biparental populations. Frontiers in Plant Science, 15, 1352402. https://doi.org/10.3389/fpls.2024.1352402

4. Vikram, P., Lopez-Vera, E.E., Bhavani, S., Thiyagarajan, K., & Singh, S. (2024). Identification of genomic regions associated with Ug99 adult plant resistance on wheat (Triticum aestivum L.). Plant Breeding, 54(1), 15. https://doi.org/10.1007/s11084-024-09655-4

5. King, J., Dreisigacker, S., Reynolds, M., Bandyopadhyay, A., Braun, H.-J., Crespo-Herrera, L., Crossa, J., Govindan, V., Huerta, J., Ibba, M.I., Robles-Zazueta, C.A., Saint Pierre, C., Singh, P.K., Singh, R.P., Achary, V.M.M., Bhavani, S., Blasch, G., Cheng, S., Dempewolf, H., Flavell, R.B., Gerard, G., Grewal, S., Griffiths, S., Hawkesford, M., He, X., Hearne, S., Hodson, D., Howell, P., Jalal Kamali, M.R., Karwat, H., Kilian, B., King, I.P., Kishii, M., Kommerell, V.M., Lagudah, E., Lan, C., Montesinos-Lopez, O.A., Nicholson, P., Pérez-Rodríguez, P., Pinto, F., Pixley, K., Rebetzke, G., Rivera-Amado, C., Sansaloni, C., Schulthess, U., Sharma, S., Shewry, P., Subbarao, G., Tiwari, T.P., Trethowan, R., & Uauy, C. (2024). Wheat genetic resources have avoided disease pandemics, improved food security, and reduced environmental footprints: A review of historical impacts and future opportunities. Global Change Biology, 30(8), e17440. https://doi.org/10.1111/gcb.17440

6. Edae, E.A., Kosgey, Z., Bajgain, P., Ndung'u, K.C., Gemechu, A., Bhavani, S., Anderson, J.A., & Rouse, M.N. (2024). The genetics of Ug99 stem rust resistance in spring wheat variety ‘Linkert‘. Frontiers in Plant Science, 15, 1343148. https://doi.org/10.3389/fpls.2024.1343148