Enhancement of yield and yield stability of spring bread wheat in semi-arid Mediterranean areas of Central and West Asia and North Africa

PROJECT DETAILS

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<td>PROJECT TITLE:</td>
<td>ENHANCEMENT OF YIELD AND YIELD STABILITY OF SPRING BREAD WHEAT IN SEMI-ARID MEDITERRANEAN AREAS OF CENTRAL AND WEST ASIA AND NORTH AFRICA</td>
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Summary

Bread wheat is the main food source in the Central and West Asia and North Africa (CWANA) region. However, its production is limited by many abiotic and biotic stresses. This project aimed to enhance bread wheat productivity and yield stability in dry areas including Australia.

The outcome of the project is that wheat breeders, pre-breeder and researchers in CWANA and Australia have access to:

i) elite wheat germplasm, landraces, synthetic hexaploid wheats and their derivatives with resistance to fungal pathogens and insects pests

ii) improved wheat germplasm introgressed with useful traits to enhance variability and broaden the genetic base of resistance to prevailing stresses (e.g. drought).
Conclusions

This project aimed at enhancing bread wheat productivity and yield stability in dry areas of the CWANA region with rain-fed wheat production similar to Australian wheat environments by delivering new germplasm to breeding entities and pre-breeder entities to be used as sources of resistance and tolerance to major abiotic constraints such as drought and biotic stresses such as rusts, *Septoria*, Hessian fly and Russian wheat aphid (RWA). An additional objective included the transfer of useful genetic variation into CWANA and Australian locally adapted genetic backgrounds.

We successfully identified useful genetic variation (for drought, rusts, Hessian fly and RWA) in synthetic hexaploids and their derivatives, wheat landraces and the International Centre for Agricultural Research in the Dry Areas (ICARDA) elite germplasm and in transferring these into CWANA and Australian elite cultivars through conventional crosses. Both fixed and segregating populations for these stresses are being produced. Lines with enhanced yield performance compared to Australian checks and ICARDA's traditional check cultivars were selected and sent to Australia in 2008 and 2009. These are being trialled in seven sites across Australian wheatbelts. Some of the lines with significant yield advantage were sent to countries in the CWANA region as part of the ICARDA spring bread wheat yield trial (SBWYT) international nurseries in 2008 and 2009.

Recommendations

Yield in rain-fed wheat production systems worldwide, including Australia, appears to have plateaued, accentuated by climatic change. Reasons for this include: the complex nature of yield improvement under increasing drought, heat and fast evolving fungal pathogens, lack of genetic variability in elite germplasm used by breeders and demand for quality traits preferred by customers, inadequate understanding of underlying traits underpinning enhanced yield improvement and inadequate screening techniques.

ICARDA's wheat program is located at the centre of wheat diversity characterised by temporal and spatial variability in environmental flux. This presents both an opportunity and challenge; an opportunity to use ICARDA's germplasm to develop improved higher yielding wheat in locally adapted Australian varieties and the CWANA genetic backgrounds for use by breeders in developing appropriate varieties.
Recommendations arising from the project follow.

- Give more attention to evaluation of germplasm from the current project in crosses using Australian varieties.
- Give more attention to understanding the agronomic, genetic and physiological basis of ICARDA’s germplasm with enhanced performances under abiotic and biotic stresses. This knowledge would assist fast tracking useful genetic variation into Australian and CWANA elite varieties.
- Simultaneously evaluate selected ICARDA germplasm with Australian checks in southern and western Australia and ICARDA.
- Develop molecular markers for biotic stress resistance to accelerate the use and adoption of such resistance in Australia and CWANA countries.

Outcomes

The beneficiaries of this project will be wheat-breeding entities and wheat growers in Australia and National Agricultural Research Systems (NARS) in CWANA using germplasm possessing desirable traits identified in this project.

Economic benefits will be through adoption and use, in addition to increased availability of high yielding, drought-tolerant, disease- and pest-resistant germplasm from this project. This will enhance development of adapted varieties that would increase yield productivity.

Environmental benefits will flow from using diverse resistance genes to biotic stresses identified in this project for better and sustainable production through environmental protection due to reduced use of fungicide and insecticide.

Social benefits include increased production options for growers in Australia and NARS in CWANA with growers remaining on the land because of a reduction in production risks. In addition, increased farm incomes provide income security that leads to improved livelihoods for growers in drought and constantly evolving biotic stress-prone areas.

Achievements/Benefits

Enhancement of yield and yield stability in Mediterranean environments

Yield improvement of wheat in rain-fed environments has recently levelled off due to repeated occurrences of drought and heat, driving the exploitation of natural diversity in synthetic hexaploid as a means of improving productivity. Results from evaluation of 154 synthetic backcross lines (SBLs) derived from SW2/2*Cham-6 in diverse rain-fed environments with contrasting Mediterranean environments in CWANA showed that there was consistent transgressive segregation for yield in all of the locations with the extent of yield improvement over Cham-6 in the order of Terbol > Tel-Hadya > Breda at 70, 40 and 32 per cent, respectively. Cham-6 is known for its historical drought resistance attributes but its underlying physiological attributes are unknown. The performance of the best SBL to the recurrent parent, Cham-6, was 158 per cent in Terbol, 140 per cent in Tel-Hadya and 126 per cent in Breda (BR, 35°56’N; 37°10’E, elevation 300m) with a long-term average of 275mm (25 seasons). Thirty-six per cent of the top 10 per cent of the SBLs were higher yielding than the recurrent parent (P <0.05) and exhibited broad adaptation across the three sites. This indicates that SBL could be used to provide significant yield advantage and stability for locally adapted elite wheat cultivars in diverse environments.

We grew an F2:F7 derived recombinant inbred population (RIL) between Cham-6 x Cham-8 in two contrasting rain-fed environments, in Tel Hadya, Syria (TH, 36°01’N; 36°56’E, elevation 284m) with a mean average rainfall of 340mm (30 seasons), and Terbol, Lebanon (TR, 33°49’N; 35°59’E, elevation 890m) with a long-term average rainfall of 539mm (25 seasons). The predicted mean yield at Tel Hadya ranged from 2.29 to 3.58t/ha with an average yield of 2.98 t/ha, and that from Terbol was from 2.03 to 4.61t/ha, averaging 3.51t/ha. In both sites, transgressive segregation for yield was evident. In the moisture-limiting site in Syria that received 290mm rainfall, the top 20 genotypes had higher yields than both Cham-6 and Cham-8. The top 20 were all significantly higher yielding than Cham-6 (P<0.05) and five were also significantly higher yielding than Cham-8 (P<0.05). The average grain yield of the top five genotypes was 14 per cent and 22 per cent higher than Cham-8 and Cham-6, respectively, at Tel Hadya, and 15 per cent and 33 per cent higher at Terbol.

Agronomic/physiological traits underpinning improved yield performance

Many traits were positively correlated P<0.001 with grain yield at the lower moisture site at Tel Hadya, including emergence, plant vigour and ground cover at early tillering, elongation, booting, harvest index, threshing percentage, spike number per
square metre and peduncle length (cm). The results suggest that plant vigour and ground cover, especially at the early tillering stage, and stem elongation, play dominant roles in contributing to increased grain yield in bread wheat at the moisture-limiting site. It is most likely that the significance of early vigour at the moisture-limiting site may be due to a more vigorous root system that was more efficient in absorbing the available soil moisture, a trait required in water-stressed environments. Furthermore, the positive effects of ground cover could be attributed to soil moisture conservation by increased leaf canopy which reduces evaporation from the soil surface, in addition to increased photosynthetic rates during the vegetative phase that might be stored in the stem and remobilised during the grain-filling period. Further physiological characterisation of the population for traits related to drought adaptation is continuing in diverse dry sites. For complex inherited traits such as yield, it is imperative that at least three years of field evaluation in multiple environments is carried out, hence an additional trial this year is necessary.

Identification of useful genes for abiotic (drought, heat and cold) and biotic stresses (rusts Septoria, RWA, Hessian fly and wheat stem sawfly):

Using fungicides and insecticides to control most diseases and pests of economic importance is not sustainable for a number of reasons. These include: fungicide and pesticide resistance development, the costs of chemical treatment often beyond the means of resource poor growers, and adverse environmental footprints. Therefore, broadening the genetic base for resistance remains the most effective control strategy. The project team previously demonstrated that a limited set of synthetic hexaploid possessed multiple disease resistance to most fungal pathogens (Ogbonnaya et al., 2008; AJAR, 59, 421-431). In the absence of restrictions on the receipt of genetic resources by the Consultative Group on International Agricultural Research (CGIAR) centers such as ICARDA, this project has collected and collated synthetic hexaploid produced and held by different organisations from the International Maize and Wheat Improvement Center (CIMMYT)-Mexico, ICARDA-Syria, USA, Germany and Japan. Nine hundred and eighty of the synthetics were multiplied from December 2008 to June 2009. Of these, 914 were used in preliminary evaluation for resistance to stem rust in Ethiopia, yellow rust, RWA, Hessian fly and sunn pests’ resistance in Syria. 10% exhibited adult plant resistance to stem rust including Ug99. Twenty-nine per cent were resistant to yellow rust while 1, 2 and 15 per cent were resistant to RWA, Hessian fly and sunn pests, respectively. These promising results from preliminary evaluation will be confirmed for all diseases and insect pests in the current season's trials.

Introgression of potentially new sources of useful genes against major abiotic stresses in Australian and elite CWANA locally adapted cultivars

Some of the sources of resistance identified in ICARDA's elite germplasm including primary synthetics and their derivatives to major abiotic and biotic stresses such as drought and stem rust, are being transferred through conventional crossing into Australian and CWANA cultivars including Gladius, EGA Eagle Rock, WAWHT2726, Wyalkatchem, Annuello, Carnamah, Yitpi etc. and CWANA elite cultivars. About 1500 F2-F4 segregating lines in diverse genetic backgrounds have been produced through single seed descent. These will be bulked up in 2011 and trialled in 2012 and available for Australian and CWANA breeders representing various wheat entities to make selections in May 2012. In addition, some doubled haploid (DH) (e.g. Gladius/Hamam-4) and RIL (Attila-7/Qamar-8, Attila-7/Hamam-4), Annuello x Qamar-8, Wyalkatchem x Qamar-8 mapping populations comprising of parents with drought tolerance and high yield potential, RWA tolerance have also been produced. For example, the most drought tolerant line, ‘Hamam-4’, identified following the one-in-30-year drought in Syria in 2008 was used to make crosses to elite Australian cultivars (Gladius/Hamam-4; Yitpi/Hamam-4; WAWHT2726/HAMAM-4; Wyalkatchem/QAMAR-8; EGA Eagle Rock/HAMAM-4; Annuello/HAMAM-4).

Germplasm to Australia

In November 2008, 200 ICARDA elite lines were sent to Australia through the CIMMYT-Australia-ICARDA Germplasm Evaluation (CAICE) project to be distributed to all the breeding entities. An additional 50 lines were sent to CSIRO Plant Industry (PI), Brisbane, for further in-depth characterisation. The lines were selections from the 2008 drought trials, as well as Elite Observation Nurseries (EON) for continental and Mediterranean dryland sites. Some of the lines have resistance to Ug99, a stem rust virulent strain. In November 2009, 198 bread wheat advanced lines comprising 108 Australian breeders’ selected lines, 37 lines including selections from ICARDA international nurseries for SBWYT 09, 33 lines selected from preliminary yield trials (YT) of three mapping drought populations based on data from three sites with differential moisture gradients plus 20 lines from winter facultative drought YT in 2007-08 and 2008-09 were sent to Australia through the CAICE project. An additional 101 durum, 21 barley lines and 12 bread wheat lines for the RWA project were also included as a consolidated shipment to Australia by this project. See CAICE website (http://gwis.lafs.uq.edu.au/index.php/icarda-imports) for details of breeders’ imports.
Fostering interactions with Australian breeding entities and pre-breeders

ICARDA hosted a visit of Australian breeders in May 2010. This provided an opportunity to interact and exchange information but more importantly for the breeders to see the ongoing wheat activities supported by GRDC and ICARDA. The germplasm provided by this project is being used in various pre-breeding research activities in Australia through projects funded by GRDC and other funding agencies. For example, this project has supplied germplasm for the Pre-Emptive Breeding for RWA Resistance project led by Mehmet Cakir, Murdoch University following results from initial trials in Syria which identified lines resistant to the Syrian biotype, the most virulent biotype in the world. Similarly, the germplasm provided by this project is being used in drought and heat studies by Dr Fernanda Drecce, CSIRO, Plant Industry, Gatton Queensland, as well as for rust screening at the Plant Breeding Institute (PBI), Cobbitty.

Other research

In this project, the project team identified wheat germplasm with significant abiotic stress tolerance, in particular drought and resistance to biotic stresses and insect pests. Furthermore, we initiated the development of mapping populations for some of the stresses such as drought, stem and yellow rusts, Hessian fly and RWA. To consolidate the progress made in this project, there is a need to i) identify traits or sets of traits that determine or improve adaptation of wheat to drought and terminal heat stress in a range of wheat production environments, ii) transfer such tolerance genes into local Australian- and CWANA-elite wheat backgrounds and iii) identify molecular markers closely linked to such tolerance genes and validate these in diverse genetic backgrounds.

Further evidence from trials in other crops such as pulses suggests that ICARDA germplasm performs well in the southern and western regions. Less is known about the performance of ICARDA wheat germplasm in the Australian wheat-growing regions and the question asked should be, ‘Does ICARDA wheat germplasm provide benefits to Australian wheat growers?’.

Intellectual property summary

Germplasm is held in trust by ICARDA under the agreement between the governing body of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the International Agricultural Research Centres (IARCs). As indicated in the GRDC-ICARDA Alliance Agreement, ICARDA will record all third party intellectual property (IP) to be used in the project in an IP register.