

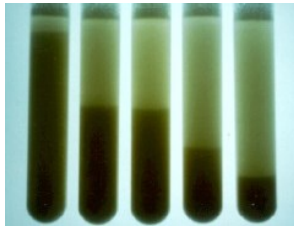
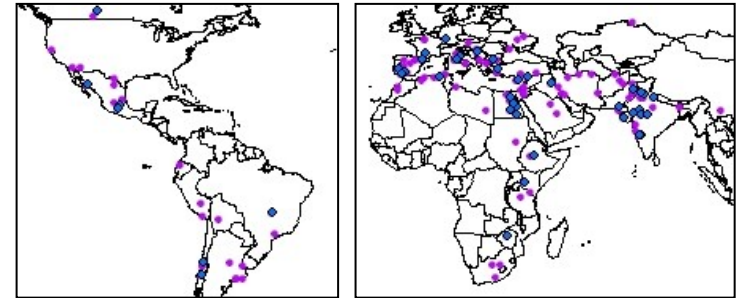
Industrial Quality Attributes of Globally Distributed CIMMYT Durum Wheat Germplasm: Historical Evolution, Recent Genetic Improvement Strategy and Current Status

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OUTLINE

1. Historical Evolution in Globally Distributed Germplasm from 1969 to 2011

- The IDYN: delivery vehicle for improved germplasm
- Germplasm assembled
- Experimental layout and traits measured
- Results for Yield vs. Protein
- Results for Yellow Color
- Results for Gluten Strength and Glutenin Allelic Combinations

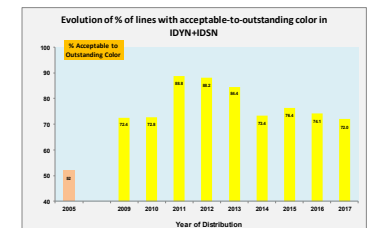
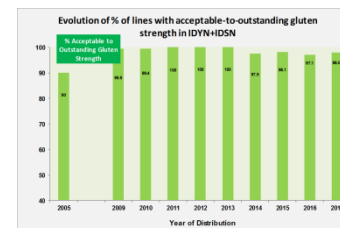


2. Current CIMMYT Strategy for Quality Improvement

- Integrating quality into breeding program for the world
- Crossing, selection, evaluations, important traits

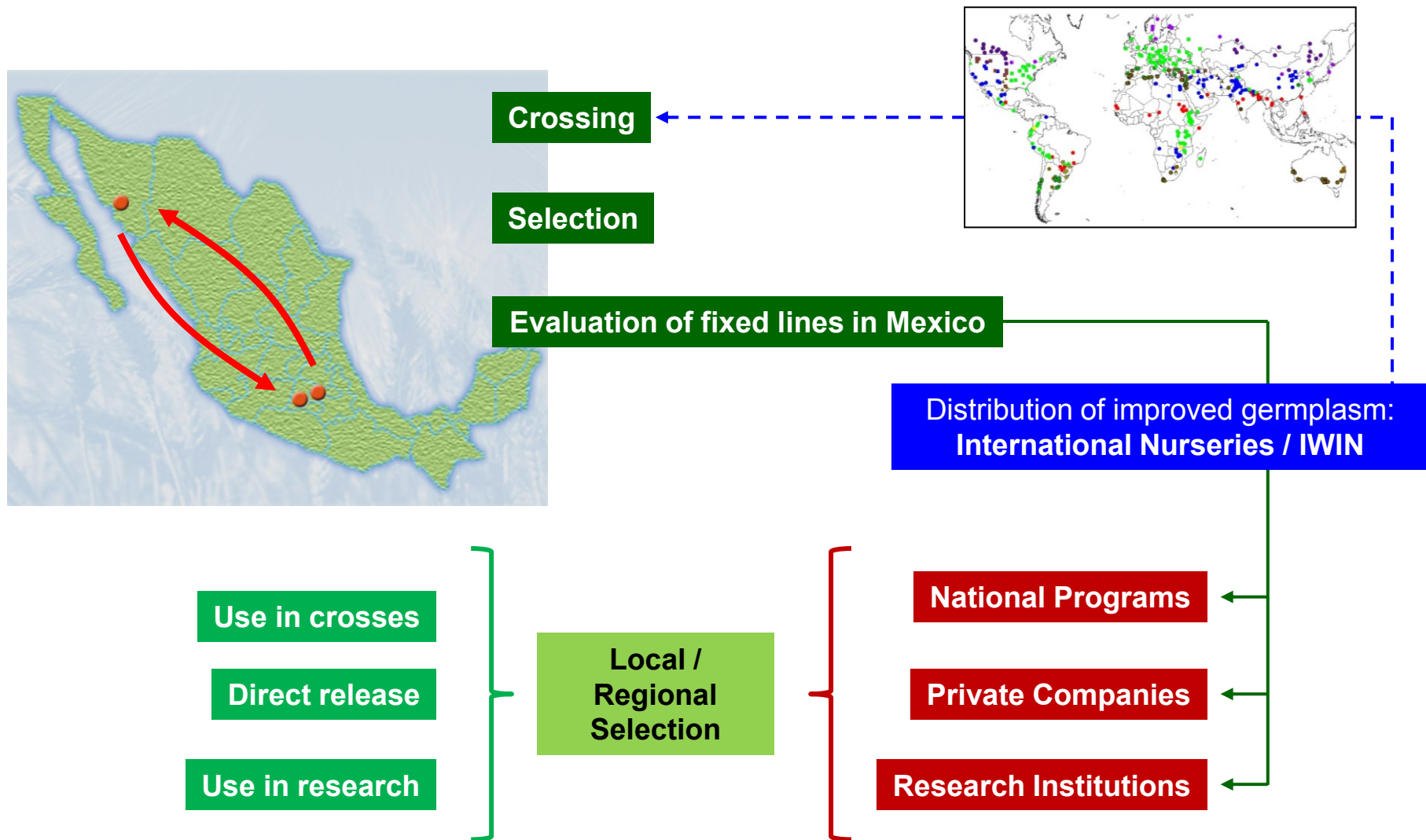
3. Recent Achievements & Current Status

- Maintenance of kernel size at medium to high levels
- Fixing the Gluten strength at good to outstanding levels
- Increasing the frequency of acceptable to outstanding lines for yellow color



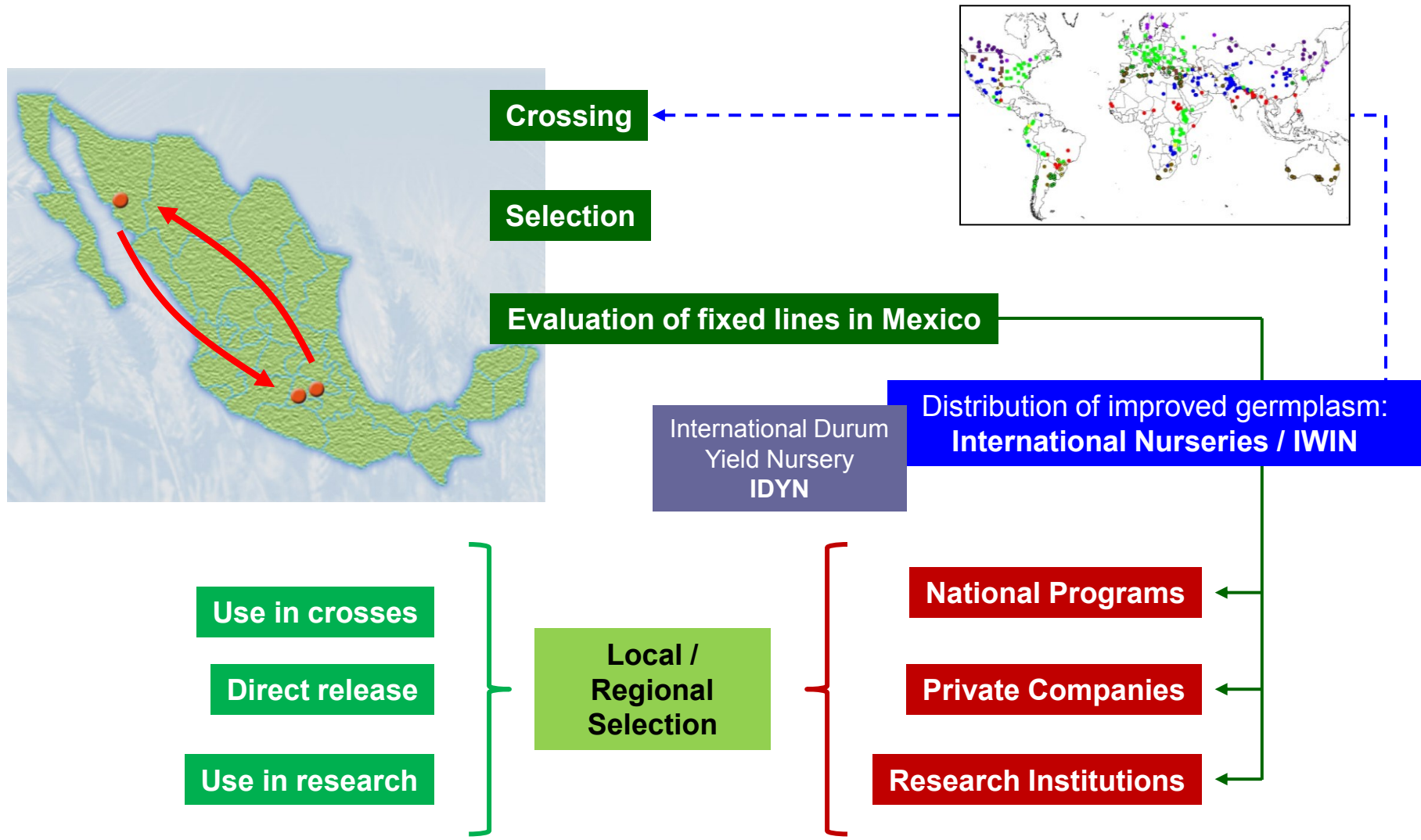
CIMMYT Spring Wheat Breeding (including Durum)

Mode of operation



CIMMYT Durum Wheat Breeding

IDYN: Output of best improved germplasm each year



Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 -43, Materials & Methods – Experimental

► All lines distributed from 1969 to 2011 in IDYN 1 to 43

- Assembled from CIMMYT germplasm bank
- 962 unique genotypes, including bread wheat and triticale checks and non-CIMMYT lines distributed
- **877** genotypes, only from CIMMYT breeding program included in present analysis

► Augmented design with repeated checks

- Sown as distributed
- Each IDYN as a sub-block with 3 modern checks
- 2 years: 2011 + 2012
- CENEB-CIMMYT, Obregon

► Optimal growing conditions for maximum yield potential expression

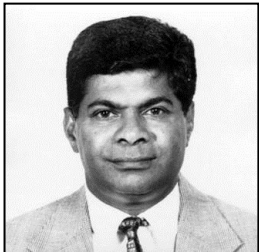
- Full irrigation + Fertilization
- Preventive fungicide application
- Protection against lodging



CIMMYT Durum Wheat Program

The breeders

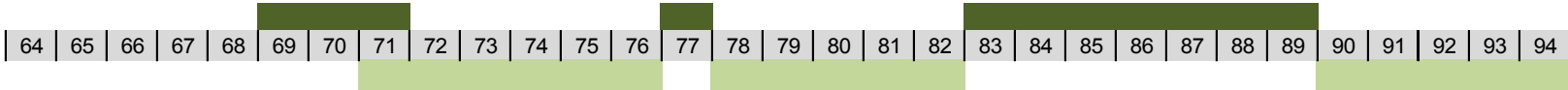
George Varughese



Dietrich Lerhner



Pedro Brajich



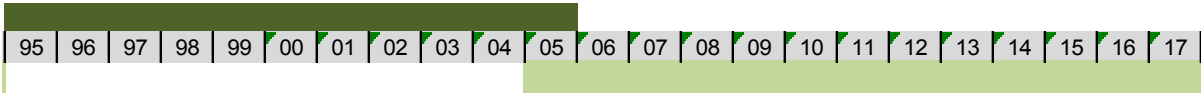
Marcos Quiñones



Gregorio Vasquez



Osman Abdallah



Wolfgang Pfeiffer



Karim Ammar



Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 -43, Materials & Methods – Traits measured

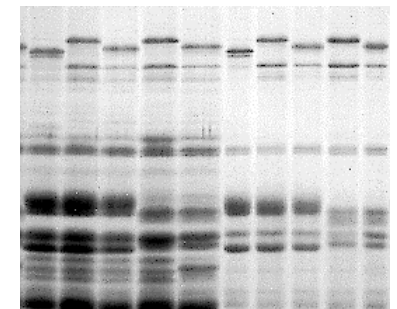
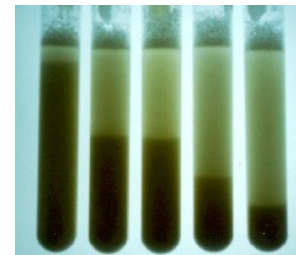


► Agronomic Traits

- Biomass (NDVI) at 3 stages
- Heading & maturity
- Plant Height
- Spike characteristics
- Grain yield

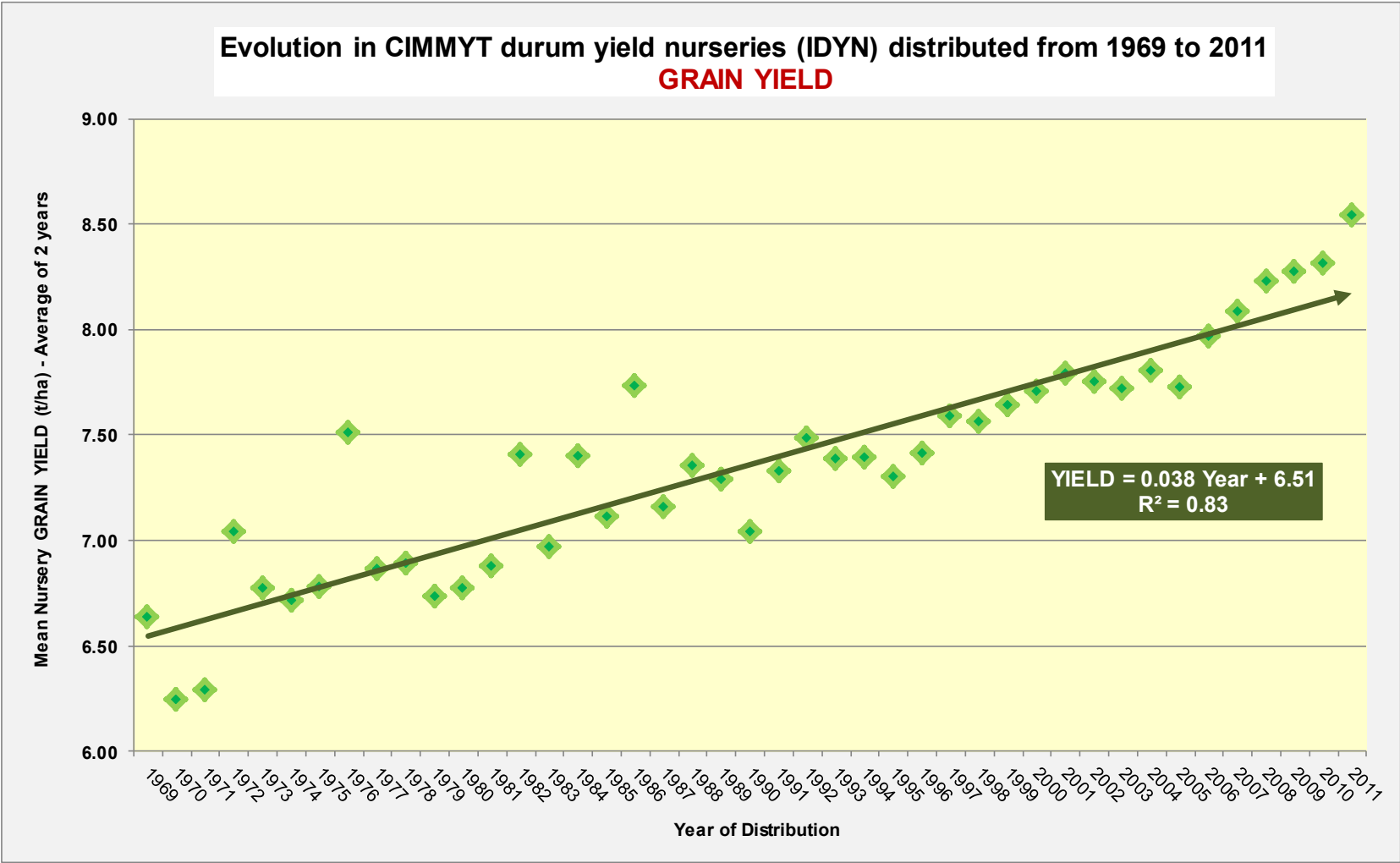
► Quality Traits

- 1000 Kernel Weight
- Kernel Characteristics (image analysis)
- Test Weight
- Grain Protein Content (NIR, 12.5% m.b.)
- SDS-Sedimentation Volume (1 gr. ground wheat)
- Sedimentation Index: Volume/GPC
- Yellow color (b-value, colorimeter, ground wheat)
- SDS-PAGE glutenin profile
(High & Low Molecular Weight Glutenin Sub-Units)



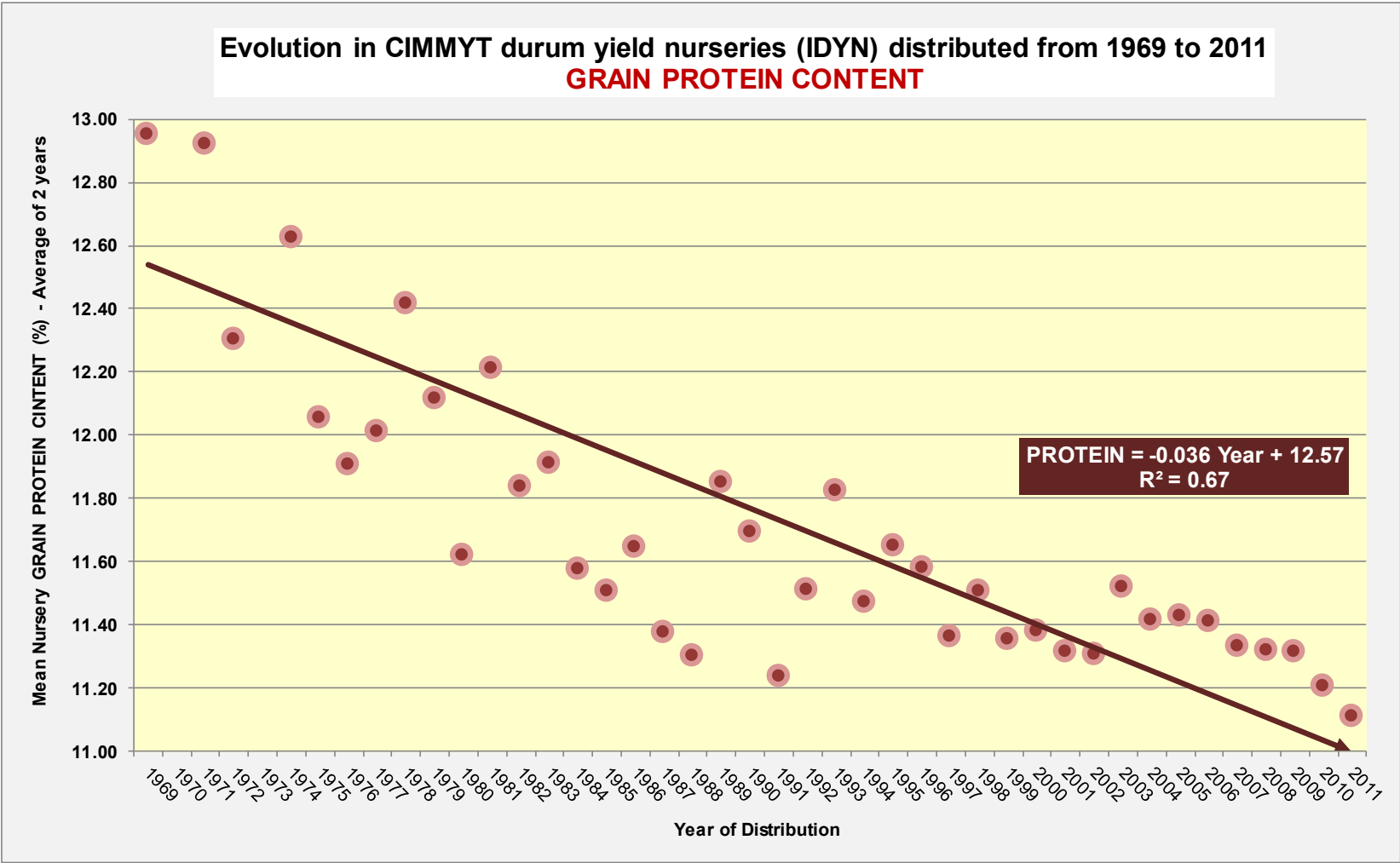
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: GRAIN YIELD



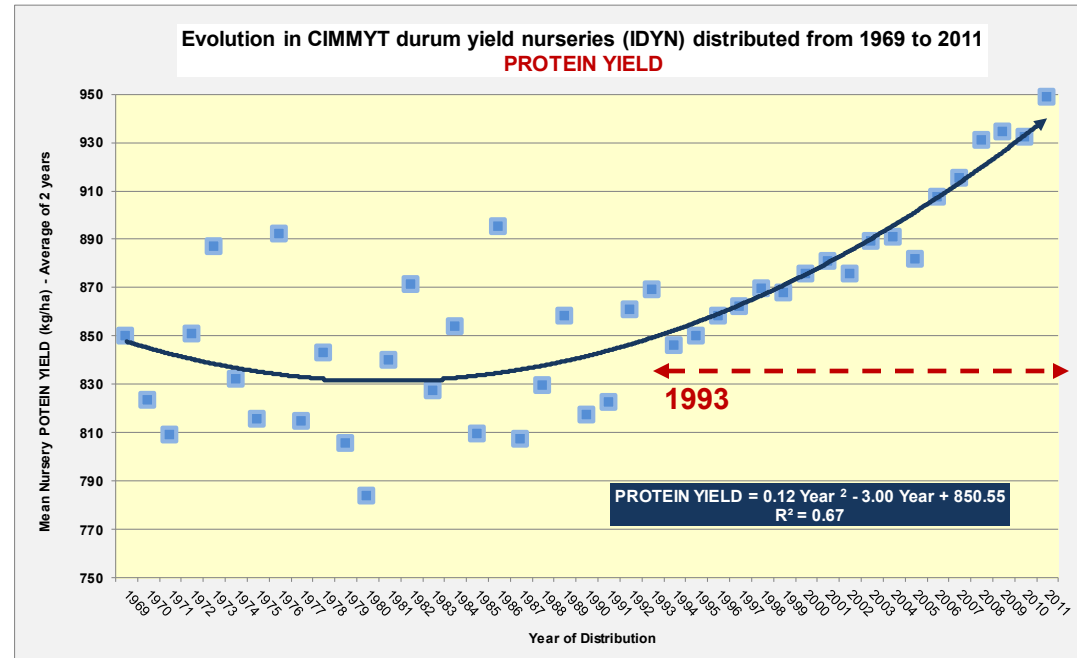
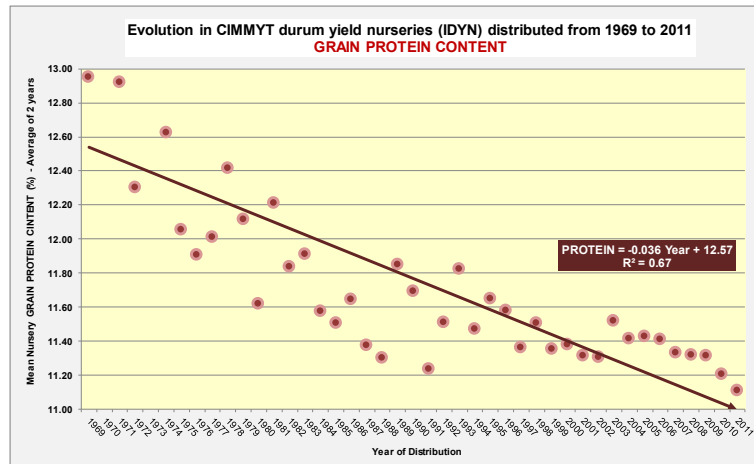
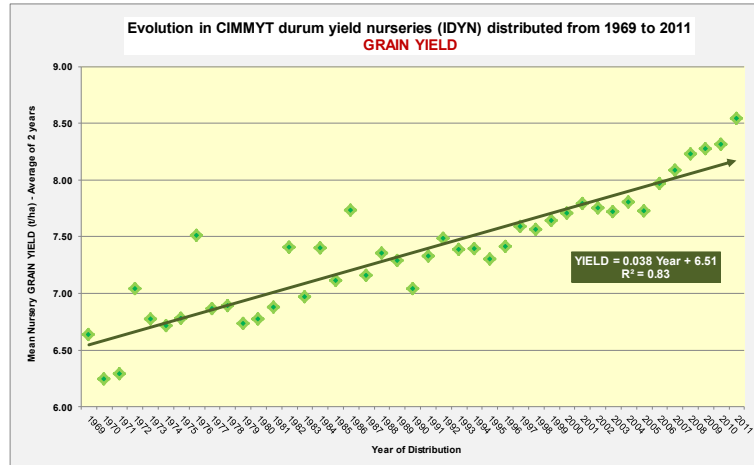
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: GRAIN PROTEIN CONTENT



Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: GRAIN PROTEIN YIELD

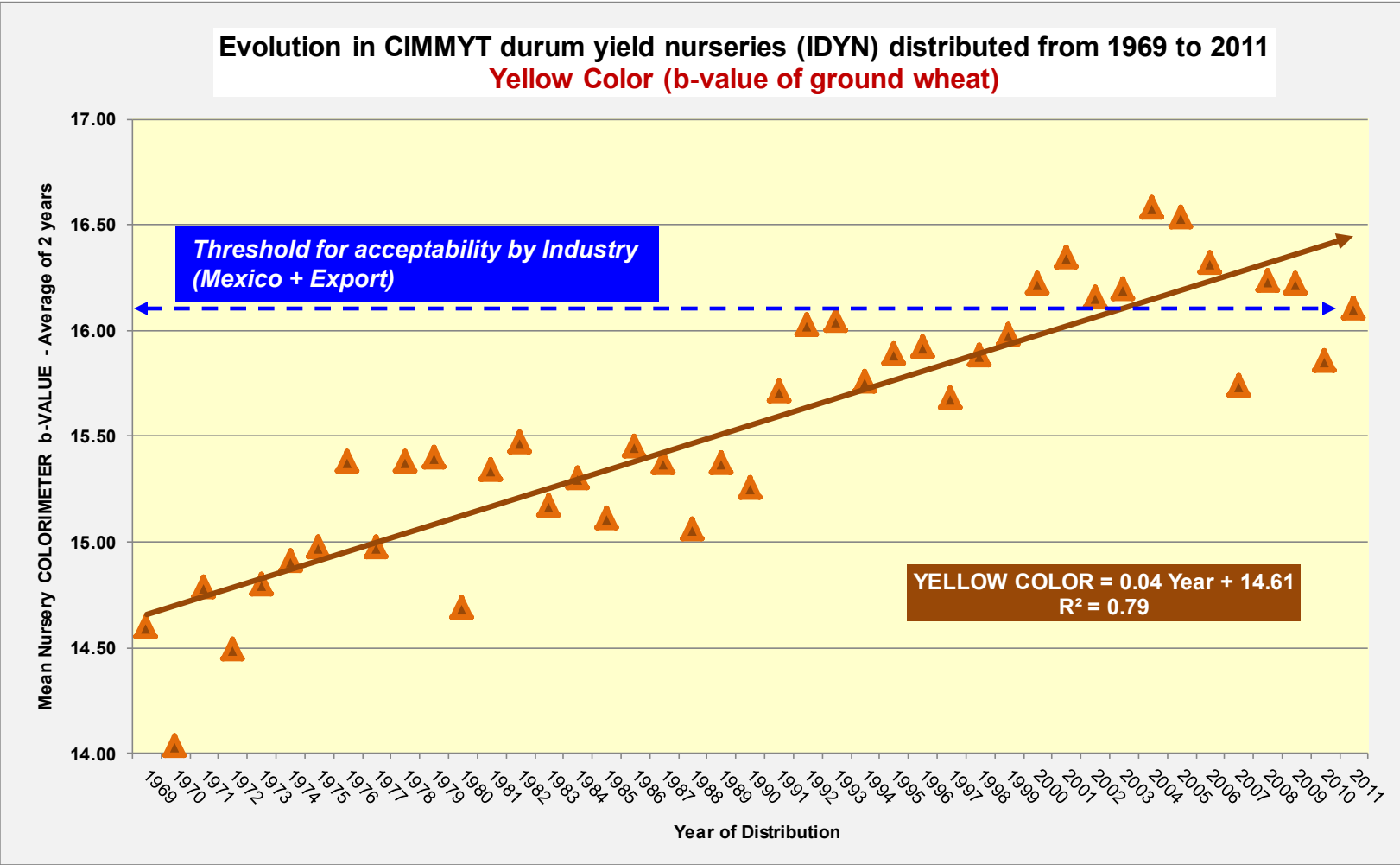


Yield vs. Protein

- Inversely evolving on average
- Since 1993, increased in yield is followed by increase in capacity to extract soil nitrogen and translocate it to grain
- Lowest levels of GPC can be corrected by adequate agronomic packages

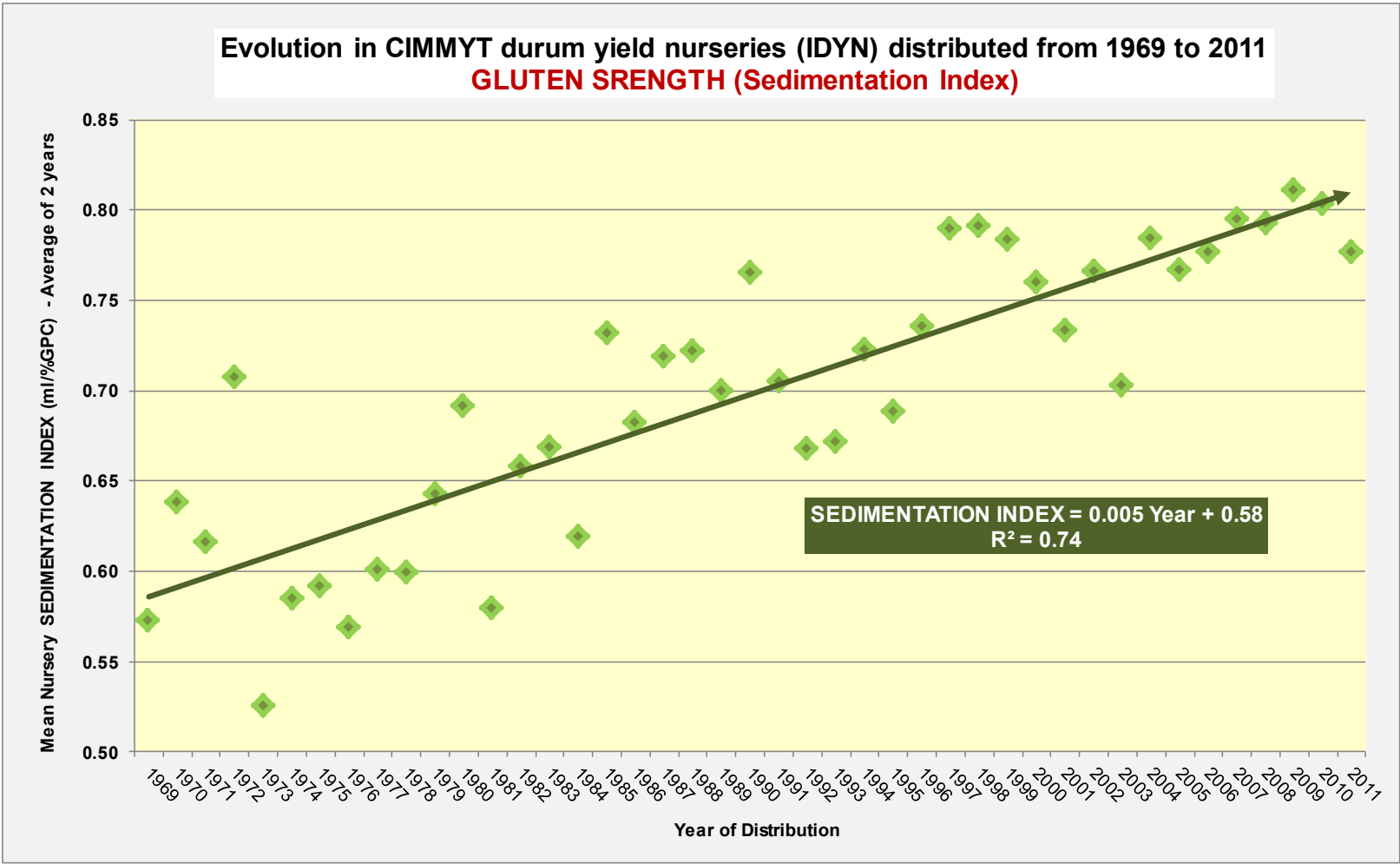
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: GRAIN YELLOW COLOR



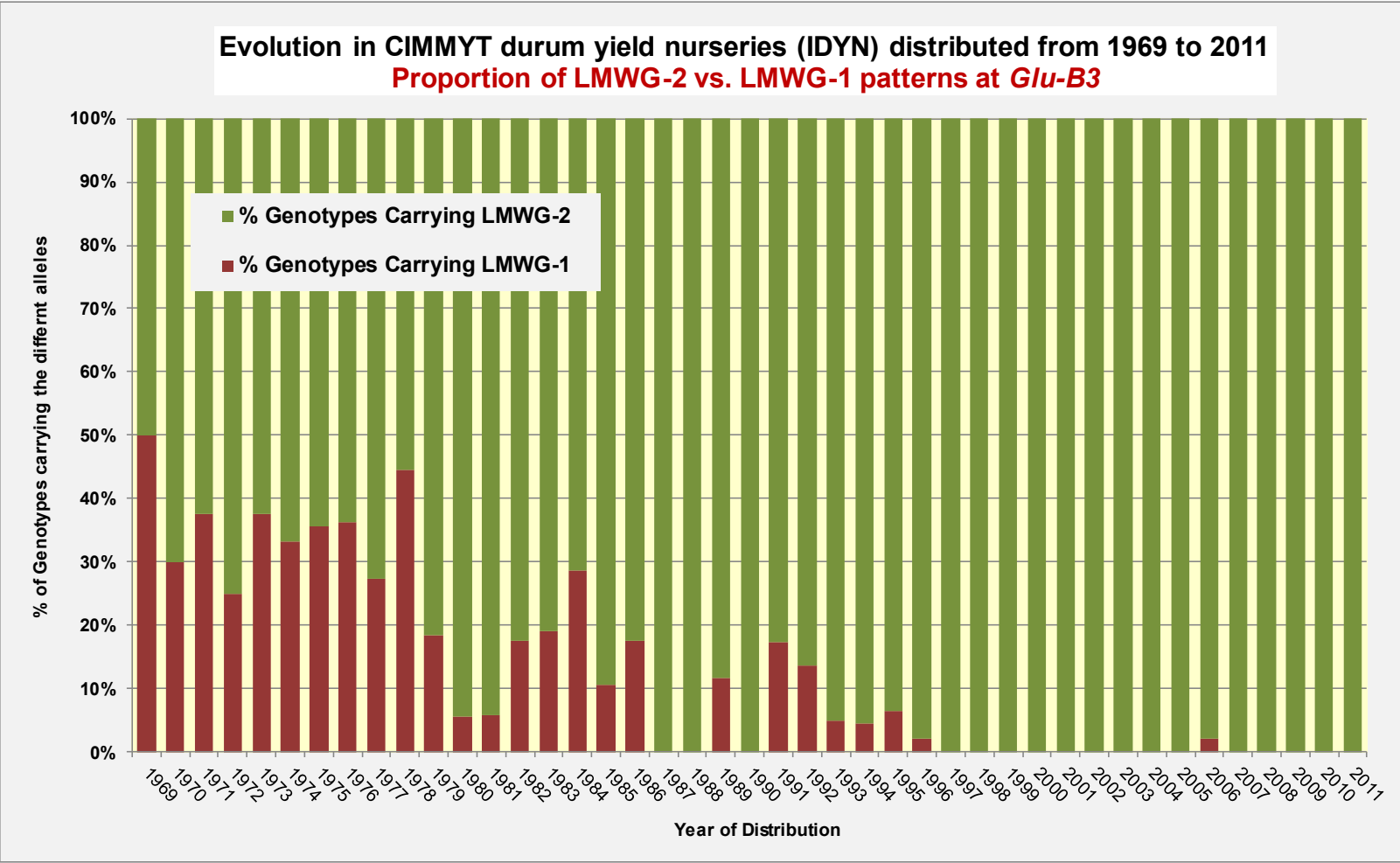
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: GLUTEN STRENGTH



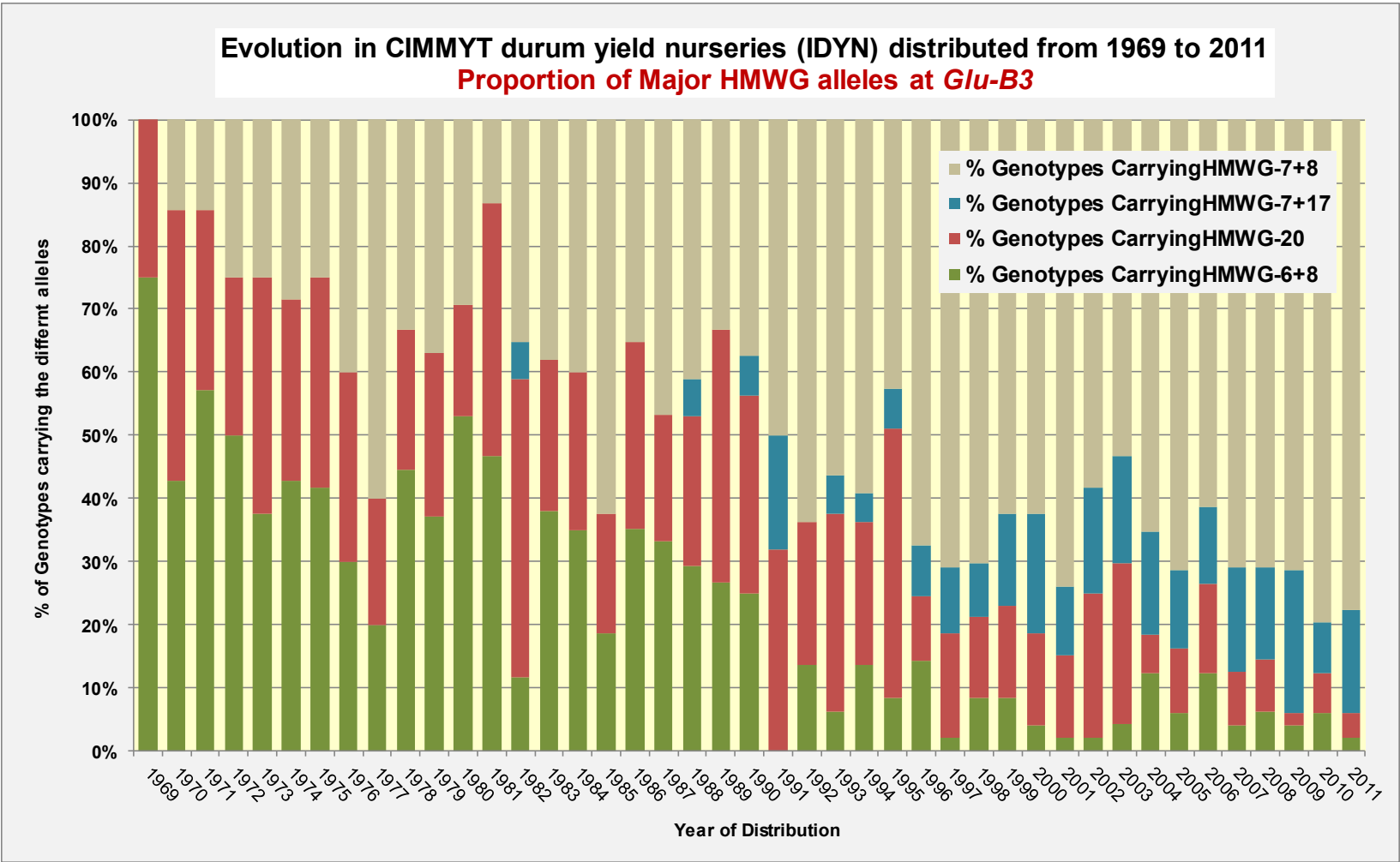
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: *Glu-B3*, strongly related to strength



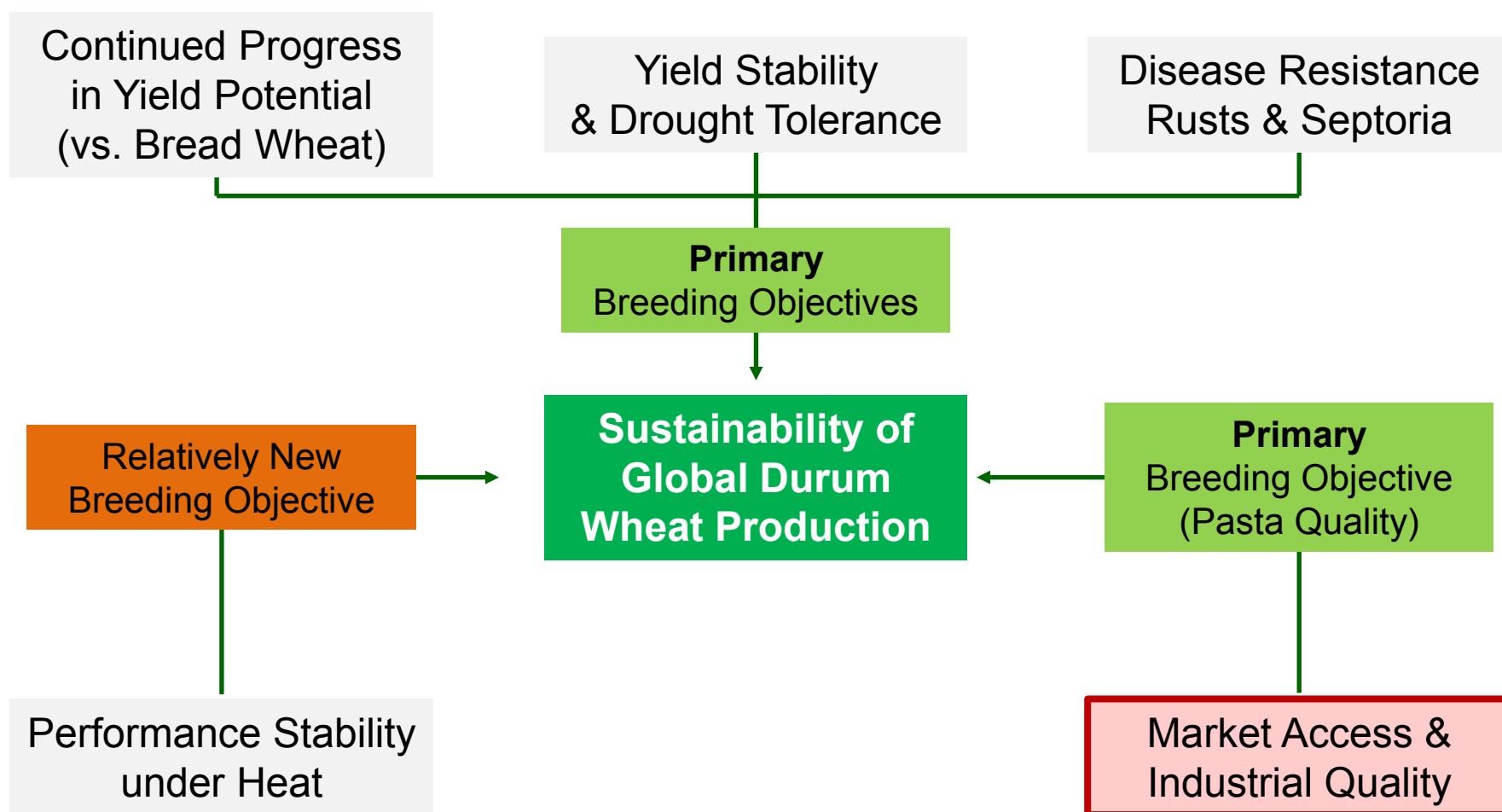
Evolution of Durum Germplasm Distributed from 1969-2011

Study of IDYN 1 - 43: *Glu-B1*, moderately related to strength



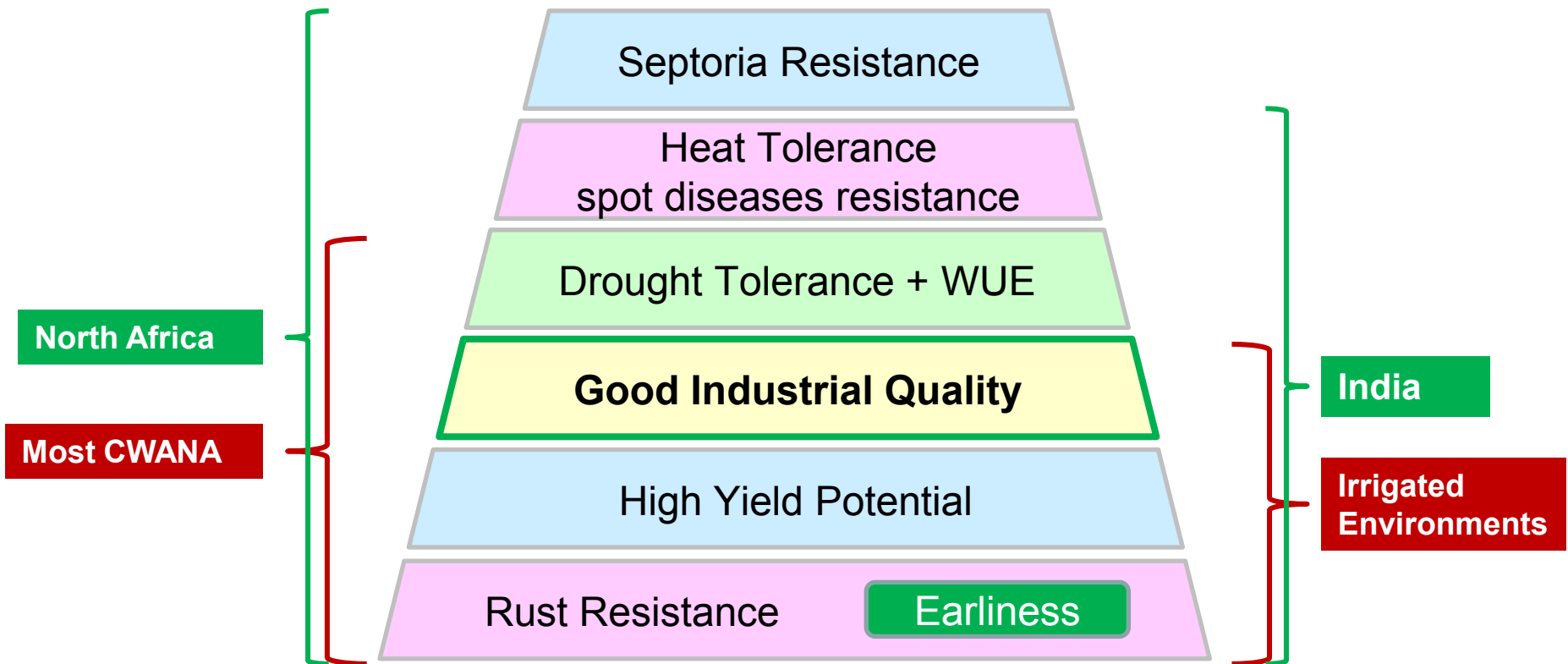
Sustainability of Global Durum Wheat Production

Enhancing industrial quality & market access – Critical for income



Breeding for Industrial Quality

Central part of CIMMYT's breeding strategy



Breeding for Industrial Quality

Globally important traits in durum wheat



► Grain Characteristics
Visually



► Yellow Color
Colorimeter: b-value



► Gluten Strength
Sedimentation test

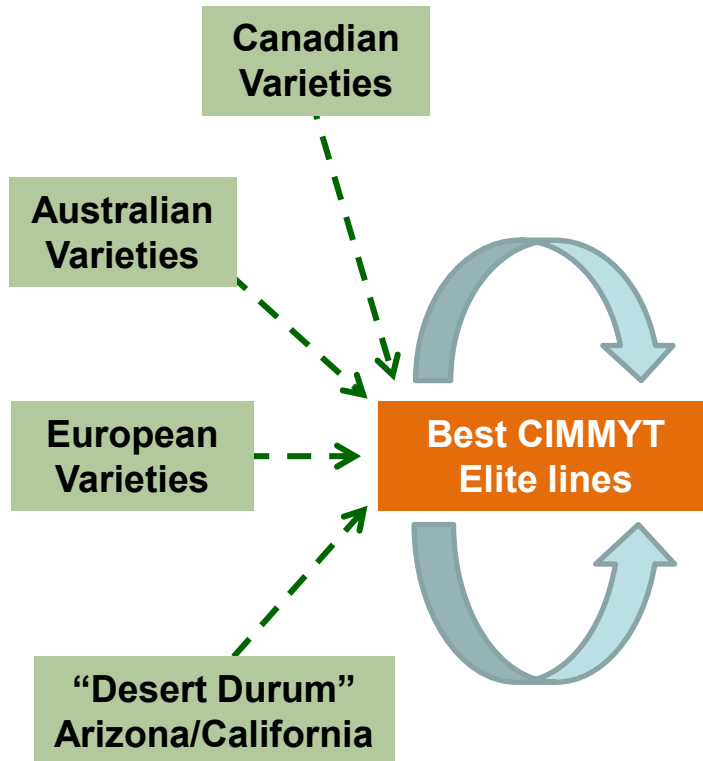


► Protein Content
(secondary, best managed agronomically)



Breeding for Industrial Quality

Crossing & selection strategy

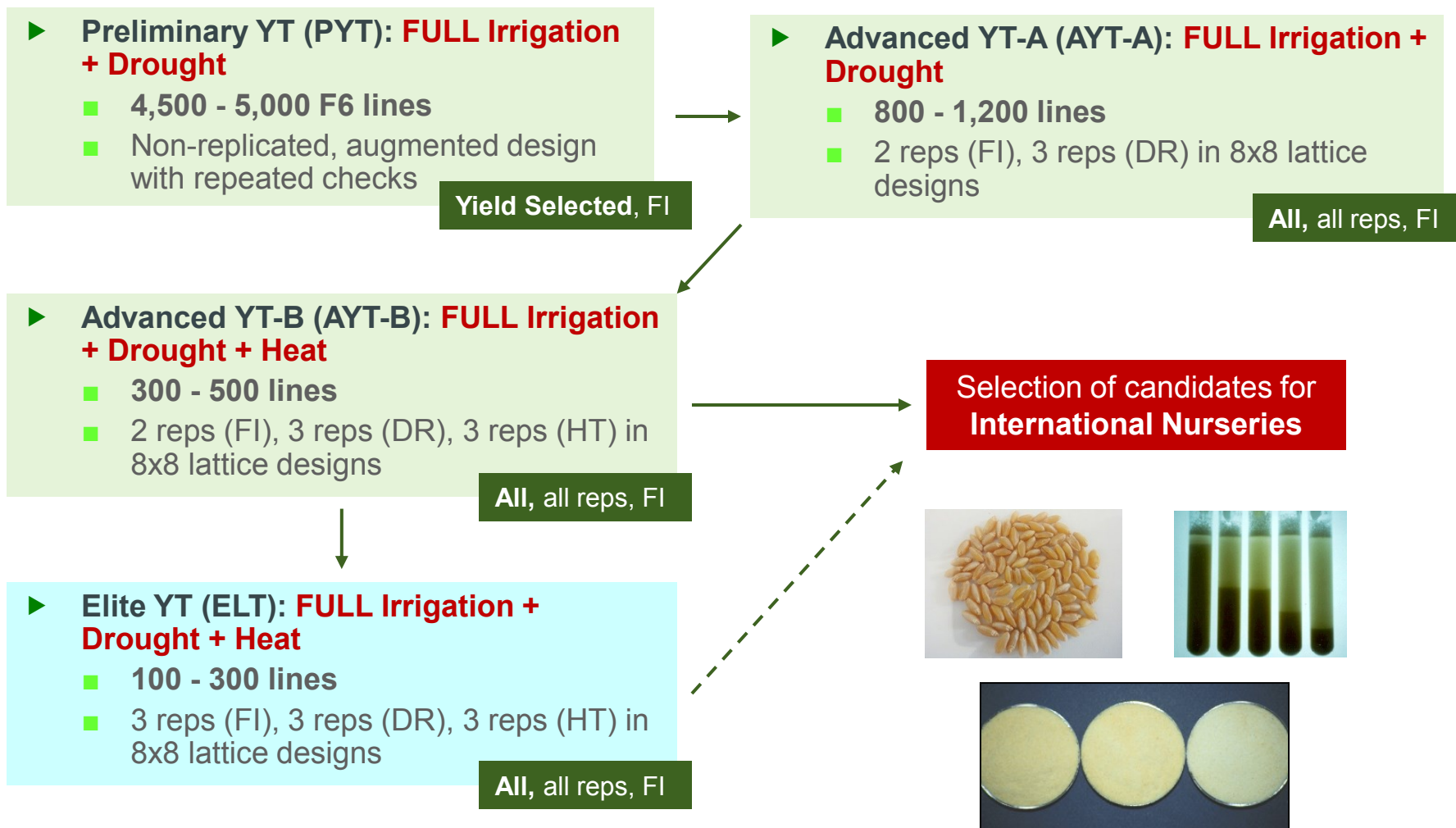


- ▶ **Detailed evaluation of parental lines: Guide for crossing**
 - From replicated yield trials or observation plots
 - At least 1 parent need to have good quality, 2 in the case of 3-way crosses
- ▶ **No early generation selection (segregating populations)**
- ▶ **12,000+ samples analyzed from Preliminary Yield Trials (F_6) to Elite Yield Trials: Any unacceptable line is not selected for distribution (few exceptions)**



Breeding for Industrial Quality

Stages of quality testing



Breeding for Industrial Quality

Globally important traits in durum wheat: GRAIN CHARACTERISTICS



► Vitreousness or non-starchy grains

- Greatly affect milling yield, penalized by industry!
- **Genetic component: low to moderate**
- **Environmental component: high (N fertilization)**
- Visually assessed in segregating plants and early fixed lines grown under favorable conditions
- Elimination of any lines with any incidence of starchy kernels



► Black point

- Creates black specks, penalized by industry!
- **Genetic component: moderate**
- **Environmental component: moderate**
- Visually assessed in segregating plants and early fixed lines, elimination of any lines with any incidence of black point



Breeding for Industrial Quality

Globally important traits in durum wheat: GRAIN CHARACTERISTICS



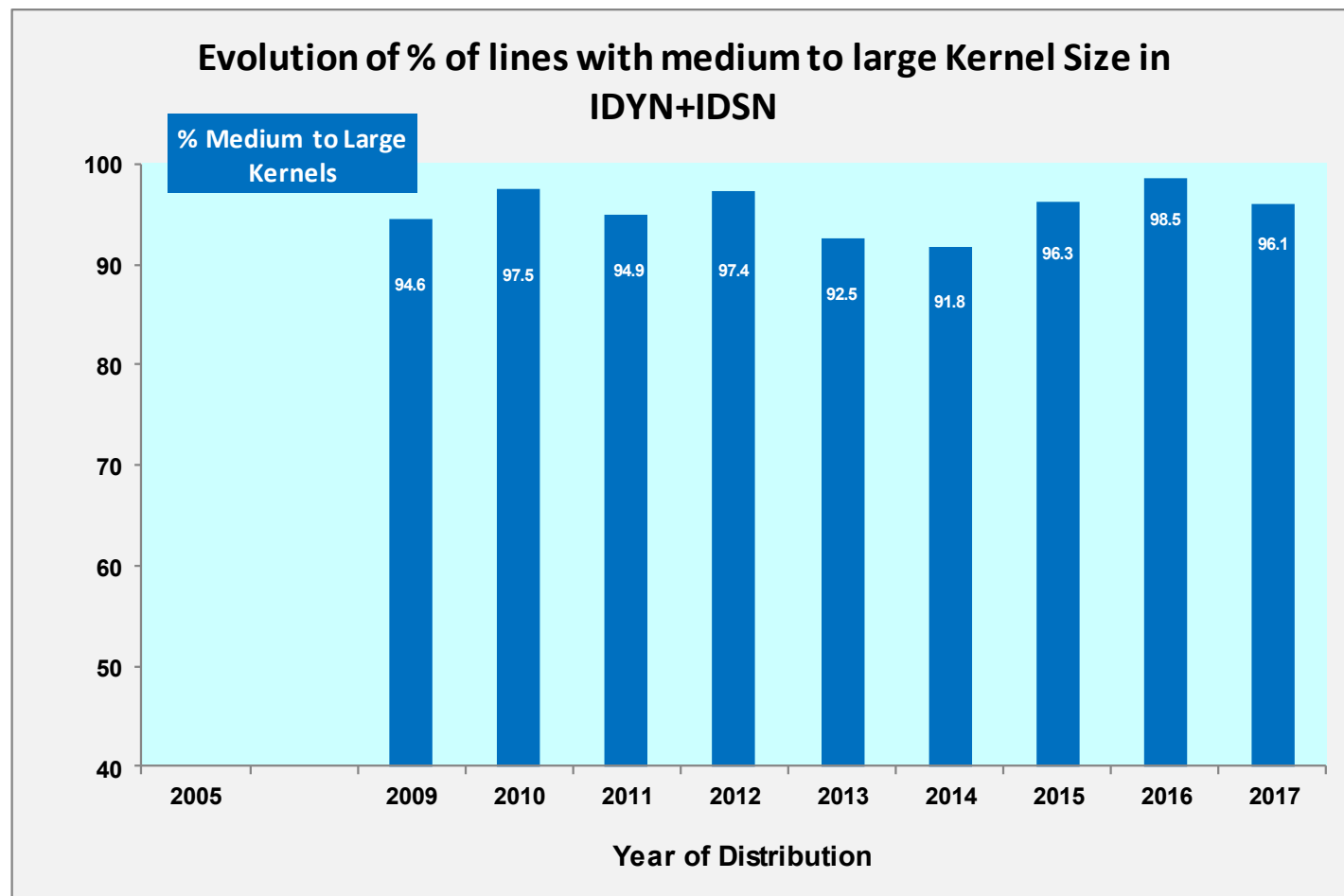
- ▶ **Test weight (hectoliter weight, specific weight)**
 - Used by industry as measure of grain “soundness”
 - Relates to milling yield
 - **Genetic component: moderate**
 - **Environmental component: high**
 - Used in late evaluations of elite material, not used in routine selection

- ▶ **Kernel size**
 - Relates to milling yield
 - **Genetic component: moderate to high**
 - **Environmental component: moderate to high**
 - Used from the first yield testing (PYT) evaluations, used heavily in selection
 - Also related to drought and heat tolerance



Breeding Results: Enhanced Industrial Quality

Germplasm distributed globally 2009 – 2017: KERNEL WEIGHT



**Medium to Large Kernels:
>90% of Large-Kernel Check Jupare C2001**

2-4 years YT average – Obregon Full Irrigation

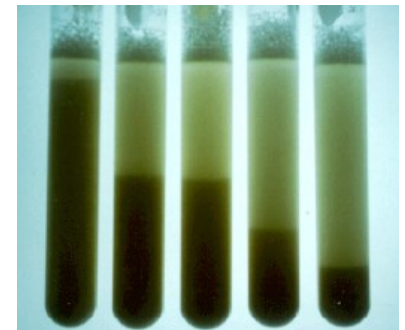
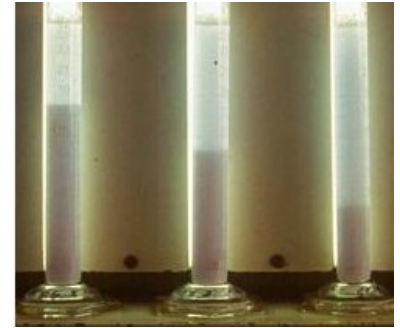


Breeding Industrial Quality

GLUTEN STRENGTH: How it is best measured for breeding durum?

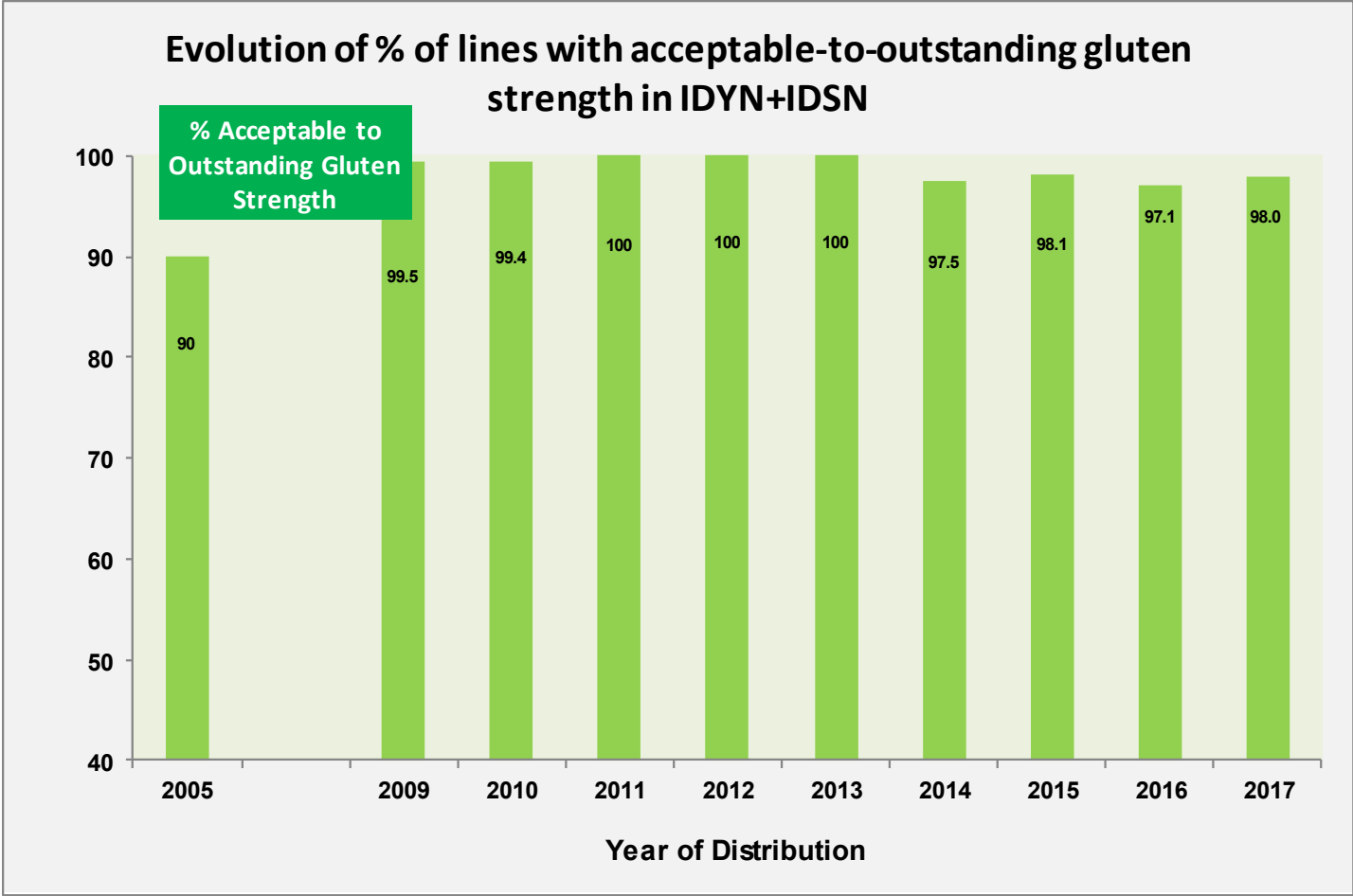
► Micro-SDS-Sedimentation Test

- Fast (100s/day)
 - Cheap (SDS + lactic acid), no major equipment
 - With 1 gr. of ground wheat
 - Provide good differentiation
 - Based on precipitation of polymer
-
- Highly inherited, early generation selection possible
 - **Genetic component: Very high**
 - **Environmental component: Very low**
 - Used in all yield trials and parent characterization in DW program



Breeding Results: Enhanced Industrial Quality

Germplasm distributed globally 2009 - 2017: GLUTEN STRENGTH



Acceptable-to-Outstanding gluten strength:
>80% of strong gluten Check Jupare C2001

2-4 years YT average – Obregon Full Irrigation



Breeding Industrial Quality

YELLOW COLOR: Biochemical & Genetic Basis

- ▶ **Mostly LUTEIN in durum wheat**

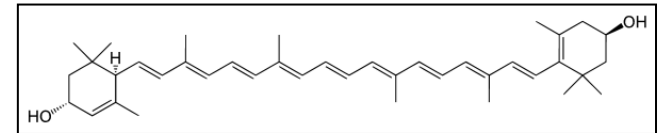
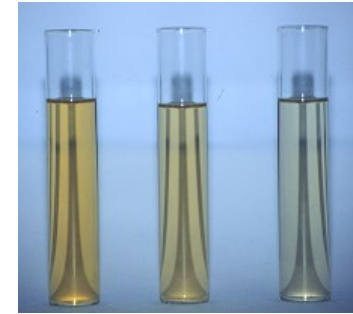
- Carotenoid, Xantophyll

- ▶ **No nutritional value, just aesthetic**

- Degraded upon processing, cooking

- ▶ **Several loci identified**

- *Psy-1*, *Psy-2*, other...
- Chromosomes group 7, others...
- Multi-allelic
- Highly inherited, selection in early generation possible
- **Genetic component: high**
- **Environmental component: moderate**
- Used in all yield trials and parent characterization

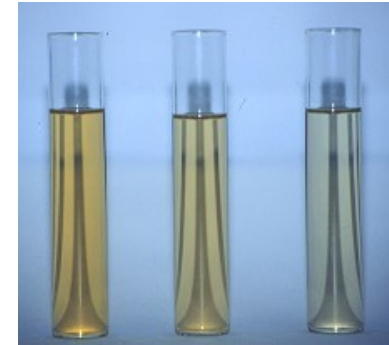


Breeding for Industrial Quality

YELLOW COLOR: How is it best measured?

► **Pigment extraction in butanol**

- Butanol is toxic
- Relatively time consuming
- Not high-throughput, can be medium



► **Colorimeter (Minolta)**

- On ground wheat, b-value (yellow index)
- Very fast, 100s of samples/day
- Best for breeding

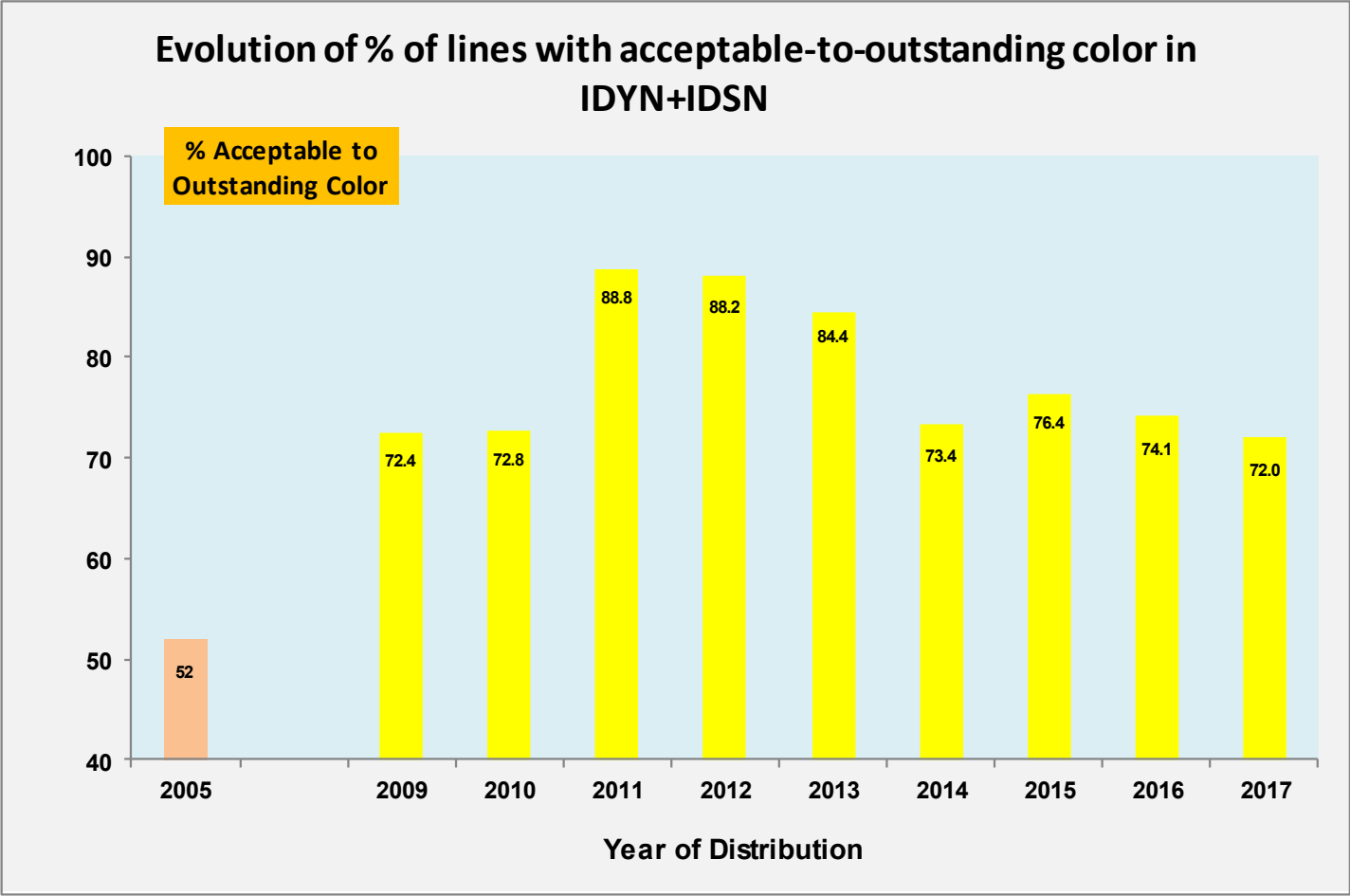


- **Either method is Highly correlated with semolina or pasta color**



Breeding Results: Enhanced Industrial Quality

Germplasm distributed globally 2009 - 2017: YELLOW COLOR



Acceptable-to-Outstanding yellow color:
> +1 colorimeter point of Check Jupare C2001

2-4 years YT average – Obregon Full Irrigation



Conclusions I

Breeding strategy and current achievements

- ▶ **Increase in yield potential tended to be accompanied with decreased protein**
 - Since 1993, capacity of plants to extract and translocate N increased as yield increased
 - All levels of protein within the reach of targeted crop management (N, irrigation) program

- ▶ **Yellow color increased by 4% annually**
 - By 2000, the average yellow color of nurseries were above acceptability threshold

- ▶ **Gluten strength (Sedimentation Index) progressed by 0.5% annually**
 - Weak LMWG-1 types (*Glu-B3*) selected against and disappeared since 1996
 - Alleles at *Glu-B1* generally linked to weaker gluten, HMWG-20 and HMWG-6+8 drastically decreased in frequency to the benefit of HMWG-7+17 and HMWG-7+8



Conclusions II

Evolution of globally distributed CIMMYT germplasm (post “Green Revolution”)

► **Quality is a center-piece of CIMMYT’s breeding goals**

- In all crosses
- For all target environments

► **Quality attributes selected for**

- Kernel appearance (free of yellow-berries and black point)
- Kernel weight
- Gluten strength: Sedimentation test (volume + Index) on ground wheat
- Yellow Color: Colorimeter on ground wheat

► **Continuous progress in the overall quality profile of globally distributed germplasm**

- Kernel weight: maintained at medium to large size
- Gluten strength: virtually fixed at medium to extra strong levels
- Yellow color: More of a struggle, progress is being made towards increasing the frequency of lines with acceptable to outstanding levels of color



**BILL &
MELINDA
GATES
foundation**

**“Delivering Genetics
Gains in Wheat”**

DFID Department for
International
Development

Funding & Support for Durum Wheat Breeding at CIMMYT – 2017-18



India

Sonora - Mexico



Spain



Australia



Canada - Saskatchewan



CIMMYT – coordinated initiatives



CRP - WHEAT



Foundations:



CIMMYT



Durum Wheat Mosaic, Oudhna-Tunisia
Courtesy of M.S. Gharbi - INRAT

Thank You...
... Any questions?

