Review Meeting
Grain Legumes Phase 1 and Extension Phase

Product line 2 – Heat tolerant chickpea, common bean, faba bean and lentil

Fouad Maalouf

Senior Scientist (Faba bean breeding)

ICARDA

F.maalouf@cgiar.org

5 October 2016

http://grainlegumes.cgiar.org

RESEARCH PROGRAM ON Grain Legumes

LED BY ICRISAT

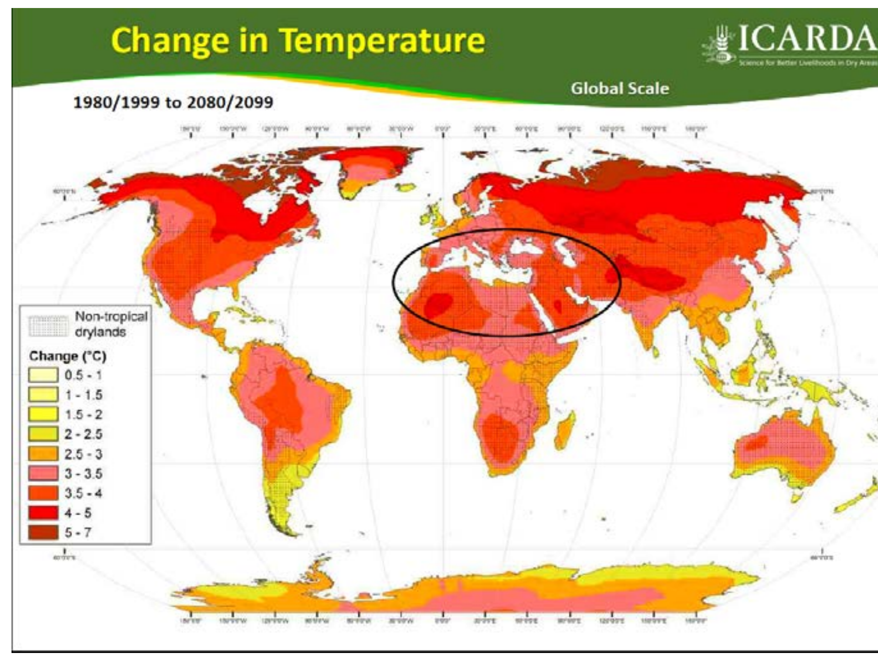
IN PARTNERSHIP WITH CIAT, ICARDA, IITA

and public and private institutes and organizations, governments, and farmers worldwide

Leveraging legumes to combat poverty, hunger, malnutrition and environmental degradation

Product Line Description

- Due to climate change, the target environments are becoming hotter, specially in dry areas
- Increase in temperature during the reproductive phase affects legumes productivity through: drop of flowers, drop of pods, seed number and seed size



Product Line Description *Cont…*

- Pollen viability is the most affected trait under heat stress.
- Heat tolerant varieties provide ample opportunities for adaptation of common bean, chickpea, faba bean and lentils to heat prone environments

Proposed outputs

Five-year outputs

- Understanding physiological mechanism of heat tolerance
- Protocols for heat tolerance screening developed for different crops.
- Development of breeding lines/varieties with tolerance to heat during reproductive phase

Ten-year outputs

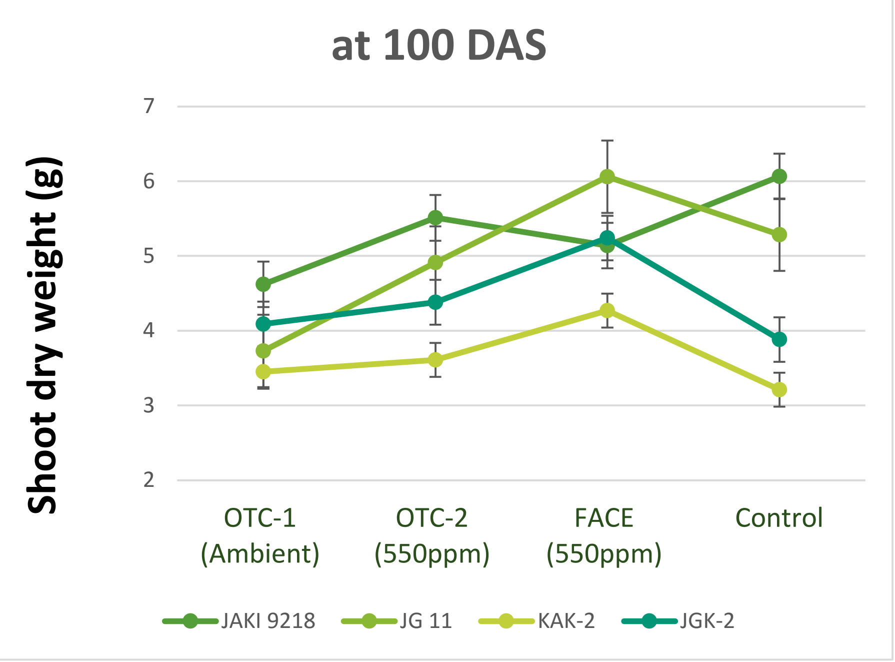
- Improved cultivars with heat tolerance developed and evaluated
- At least 10% of crop area in heat prone regions brought under the improved varieties

RESULTS

Managing productivity: Understanding physiological mechanisms of heat tolerance (FP 1)

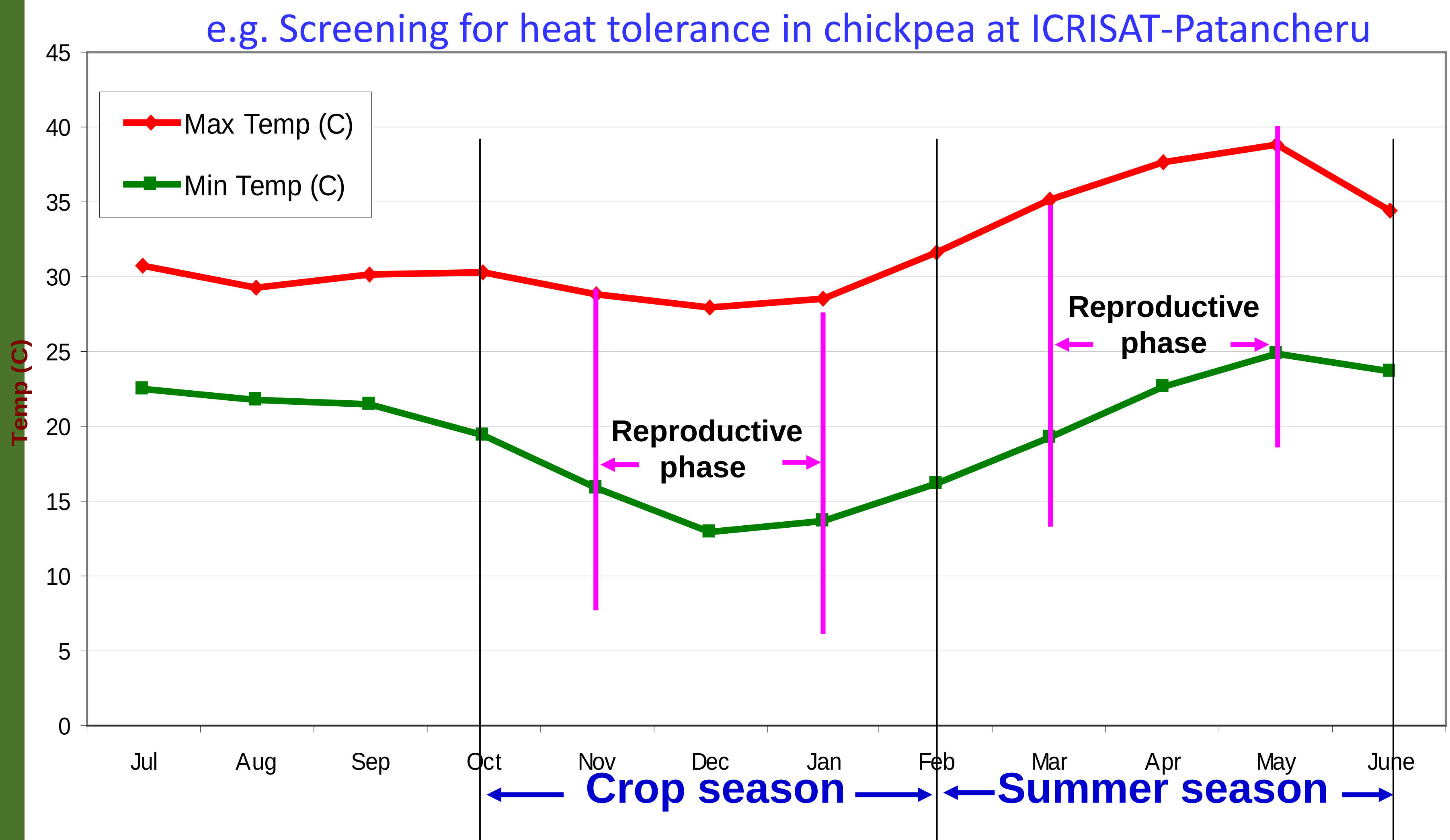
The elevated levels of CO_2 had positive effects on growth and yield of chickpea.

Significant yield improvement was observed in desi varieties compared to kabuli varieties due to increased CO_2.



RESEARCH PROGRAM ON Grain Legumes
CGIAR

Field screening for heat tolerance in Chickpea (FP1)



Long term weather data for Patancheru

RESEARCH PROGRAM ON Grain Legumes
CGIAR

Pollen viability under controlled environments in chickpea (FP1)

Genotypes: ICCV 92944 (heat-tolerant) and ICC 5912 (heat-sensitive)

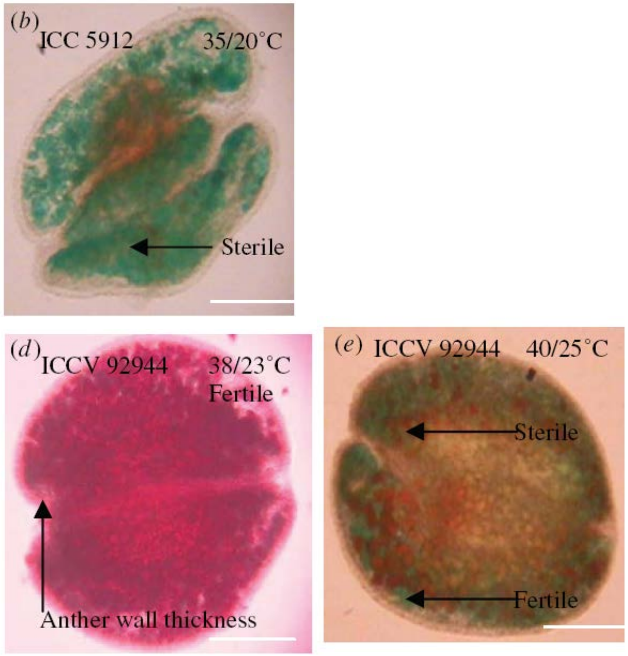
Treatments: High temperature stress (29/16^{0}C to 40/25^{0}C) and non-stress control (27/16^{0}C)

Results:

- ICCV 92944 pollens were viable at 35/20^{0}C (41% fertile) and at 40/25^{0}C (13% fertile), whereas ICC 5912 pollens were completely sterile at 35/20^{0}C.
- The stigma of ICC 5912 remained receptive at 35/20^{0}C and non-stressed pollen (27/16^{0}C) germinated on it during reciprocal crossing.

ICC 5912 (Sensitive)

ICCV 92944 (Tolerant)

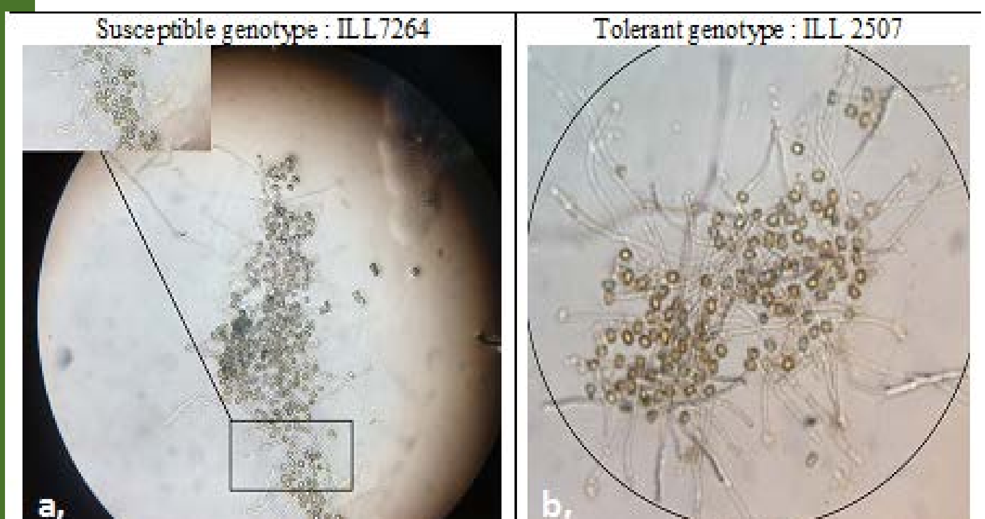


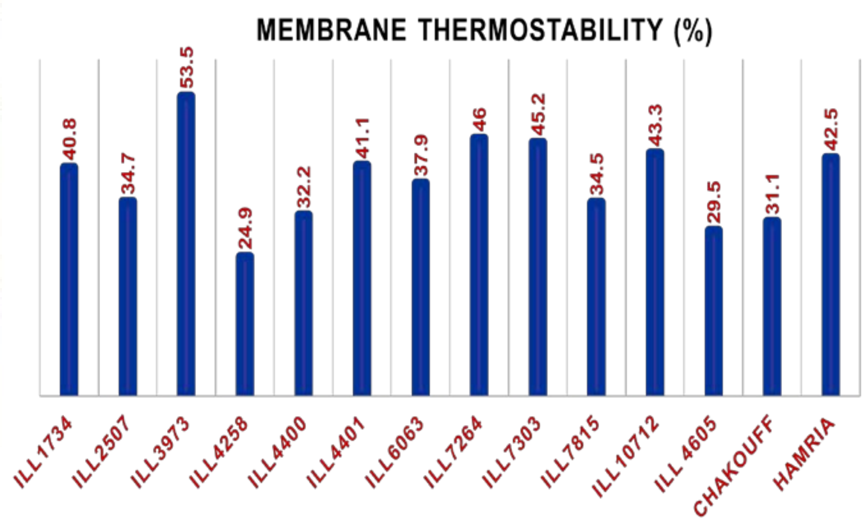
Anther-pollen fertility with Alexander's stain (fertile pollen grains are red; sterile pollen grains are green)

Devasirvatham et al. (2012). Functional Plant Biology 39:1009–1018

Response of Reproductive biology of lentil genotypes under high temperature (FP1)

- ILL1734, ILL4258 and ILL2507 showed pollen germination and pollen tube growth above 35°C & 40°C.
- ILL3973 and ILL7264 showed the maximum cell membrane thermostability (CT),
- No correlation between pollen germination and CT at high temperature.



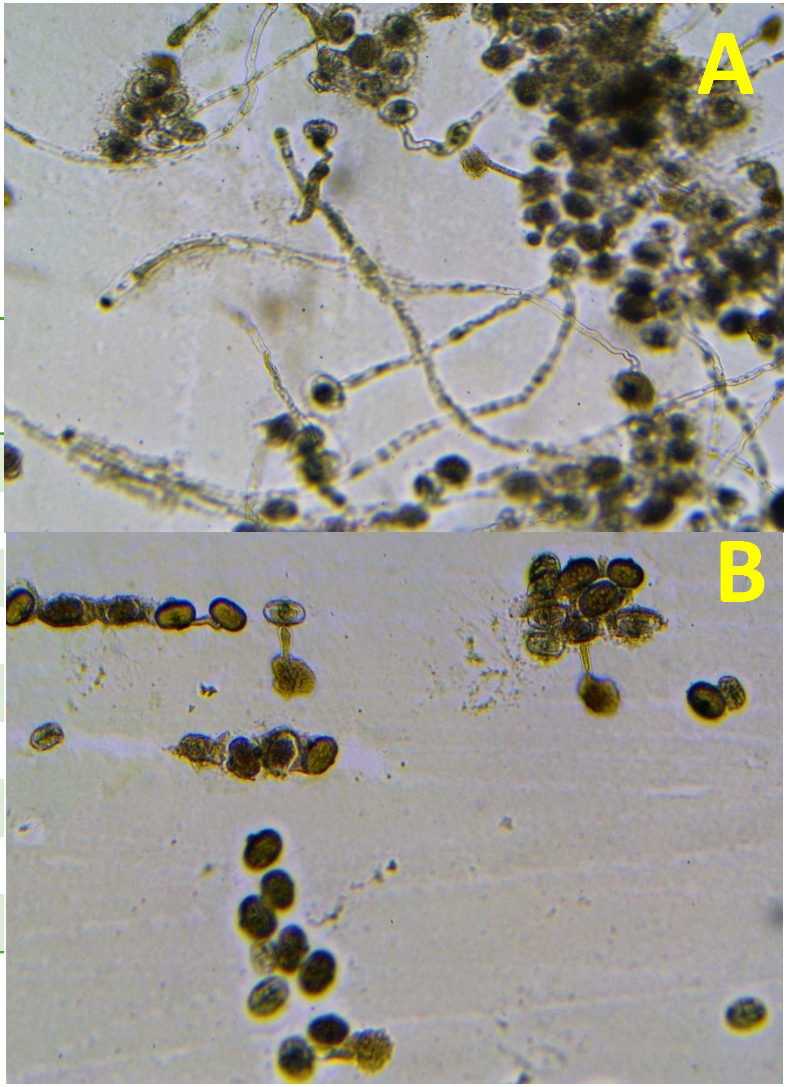


Pollen viability under heat stress in Faba bean (FP1)

Among 132 accessions 9 lines were the most heat tolerant with pollen viability under 35 degrees

Entry	Accessions	Origin	% Pollen Viability
1	Spanish420	Afghanistan	30.23
8	IG11843	Canada	30.14
49	IG104039	ICARDA	29.00
57	Spanish335	Russia	36.68
70	Spanish419	Ethiopia	41.33
86	Spanish522	Egypt	30.16
89	Spanish626	Sudan	29.90
102	INRA1197	United Kingdom	28.00
106	INRA1512	Sudan	38.72

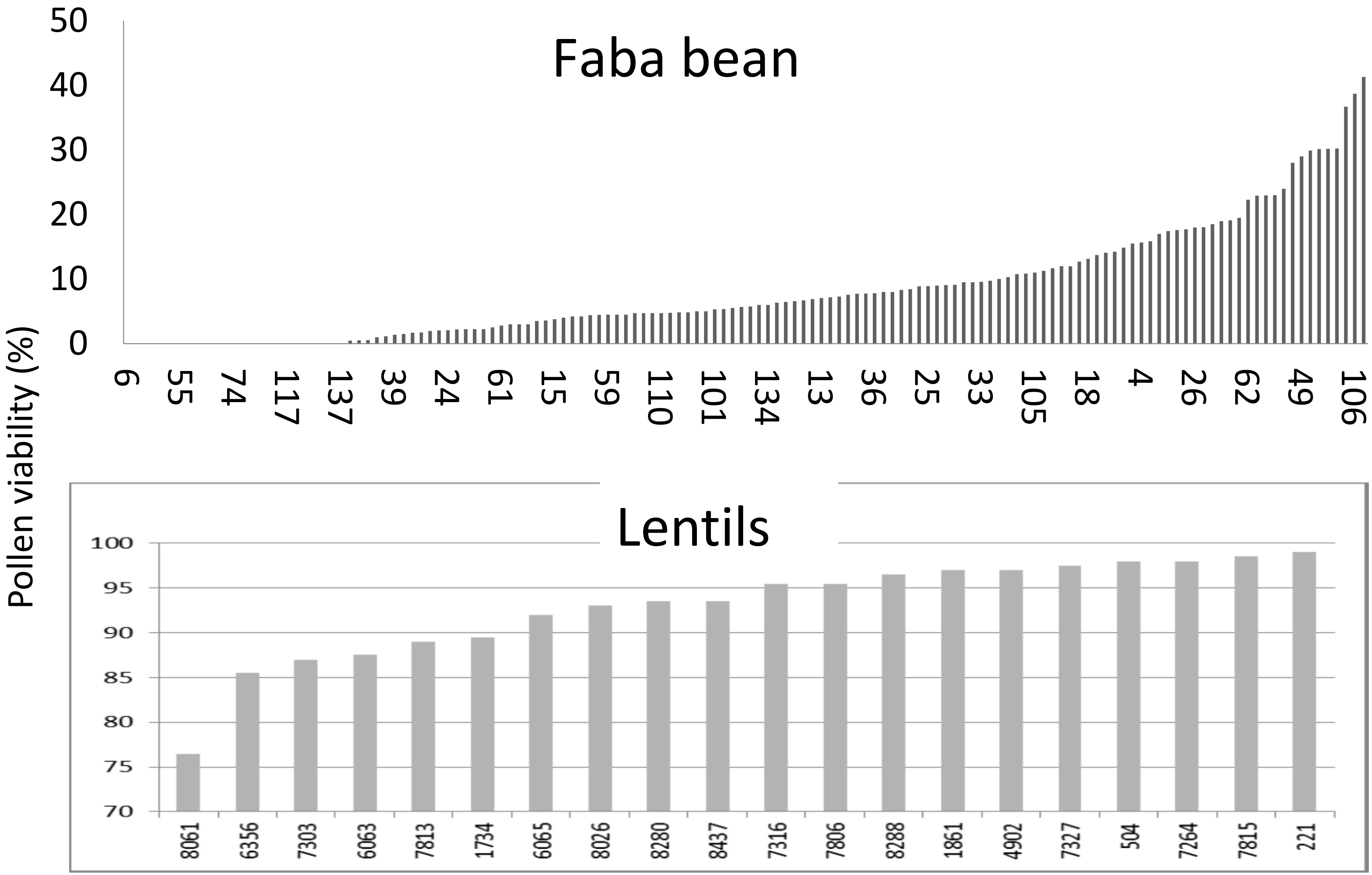
pollen viability of tolerant line



A: pollen viability of tolerant line
B: pollen viability of susceptible line

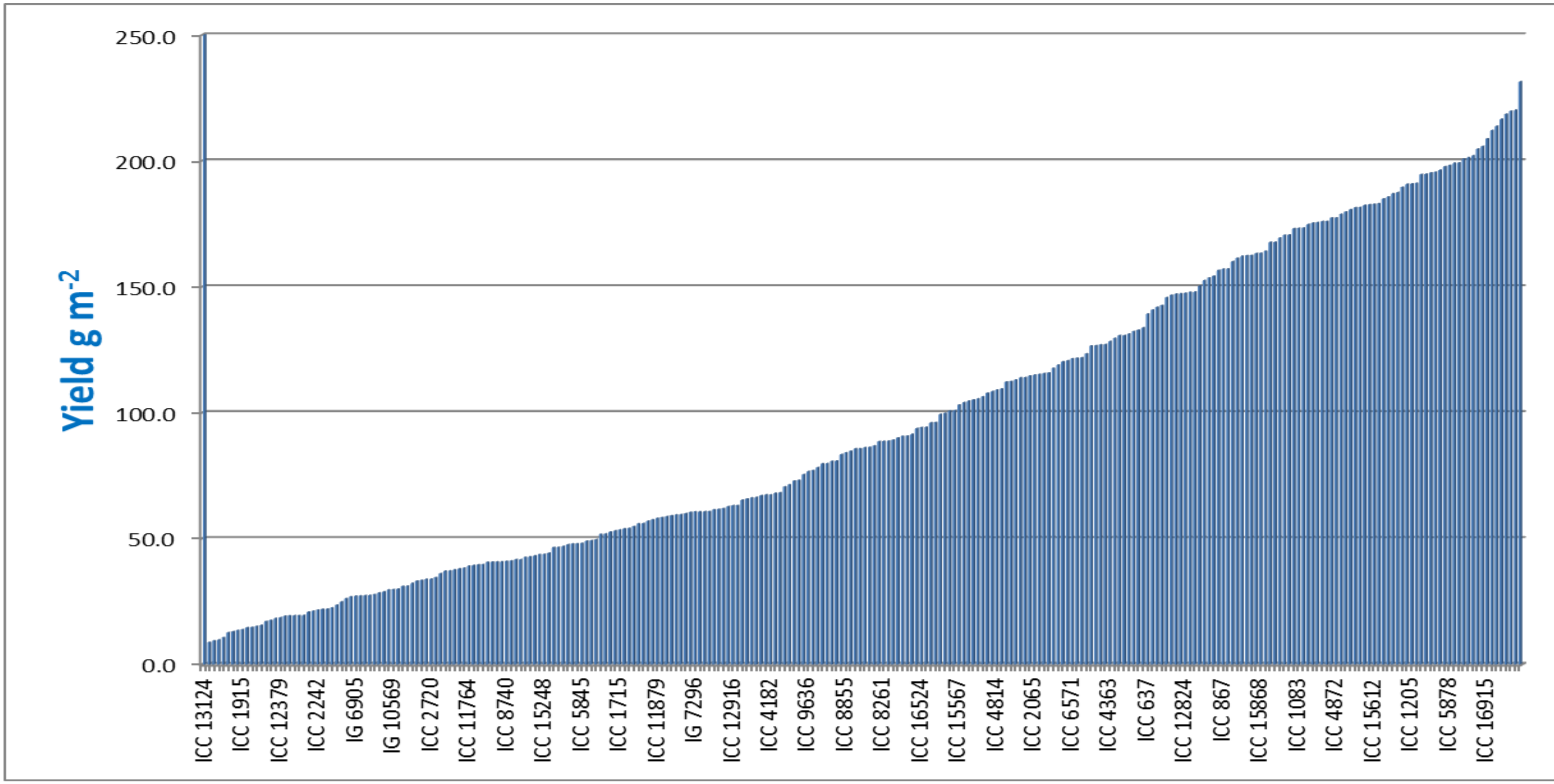
RESEARCH PROGRAM ON Grain Legumes
CGIAR

Wide range of Genetic variability of Pollen Viability under heat stress (35 degree Celsius) (FP1)



RESEARCH PROGRAM ON
Grain Legumes
CGIAR

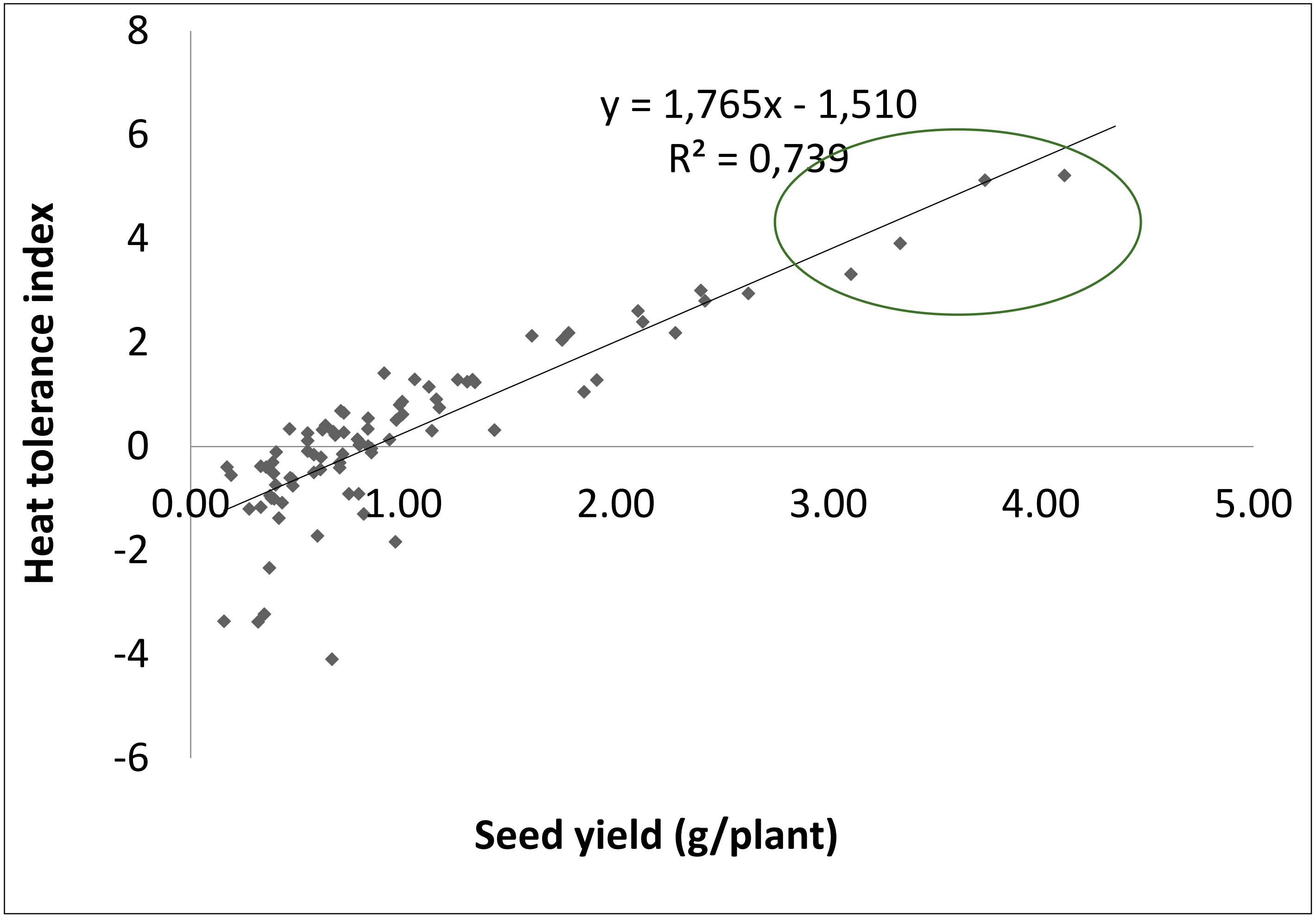
Large genetic variation for heat tolerance identified in chickpea (FP1)



The same was observed in Lentils and Faba beans

RESEARCH PROGRAM ON Grain Legumes
CGIAR

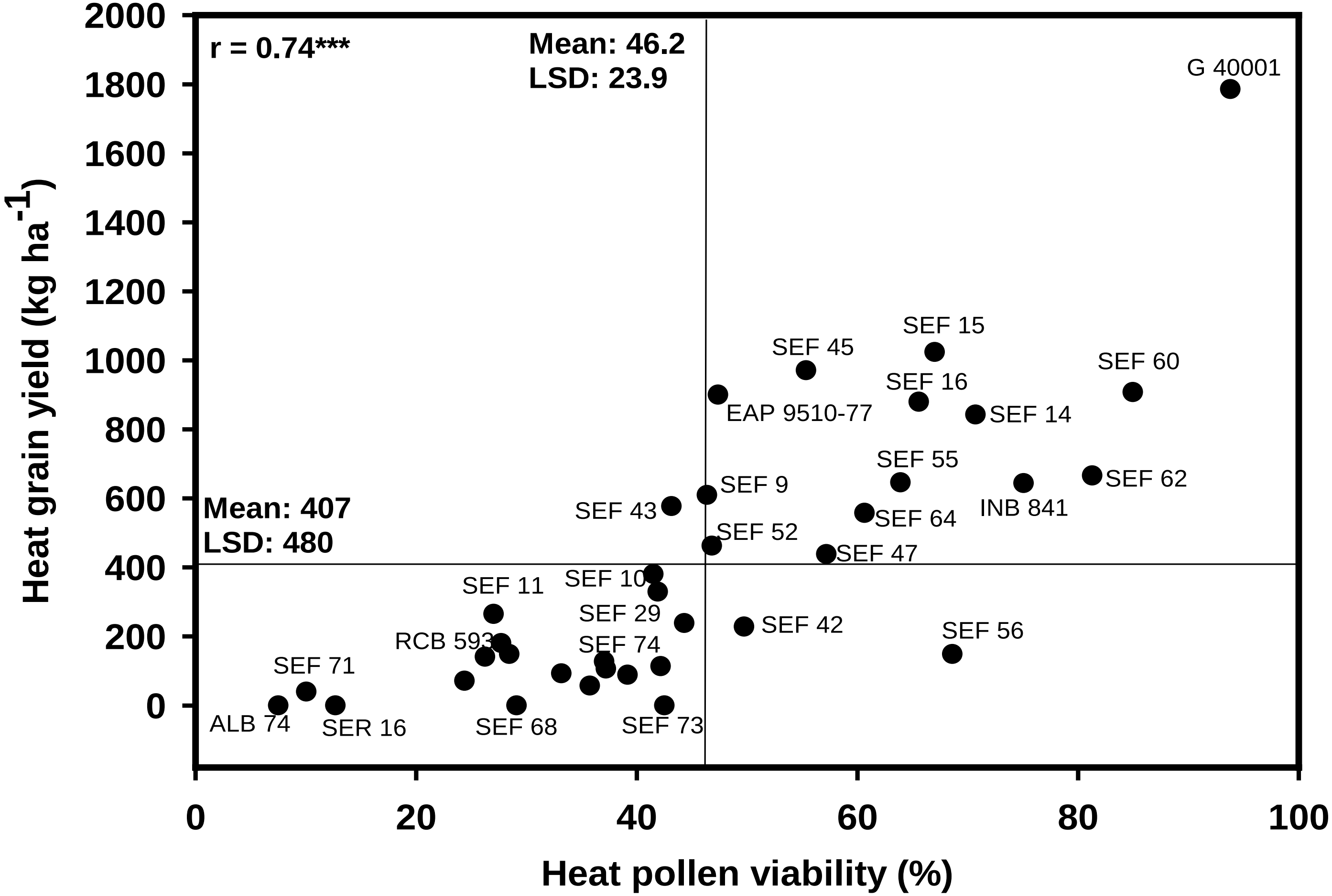
Correlation between Heat Tolerance Index (HTI) and seed yield in lentil (FP1)



ILL4902
ILL729
ILL7833
LL6338

RESEARCH PROGRAM ON Grain Legumes
CGIAR

Relationship of grain yield and pollen viability in common bean (FP1)



Effects of high temperatures on grain legumes (FP2)

- Reduction in germination percentage and increase in occurrence of abnormal seedlings.
- Reduction in plant biomass.
- Early flowering.
- Degeneration of nodules affecting the nitrogen fixation efficiency.
- Reduction in membrane stability
- Reduction in photosynthetic/mitochondrial activity.
- Reduction in pollen viability, pollen germination and pollen tube growth.
- Reduction in pod set.
- Reduction in harvest index and grain yield.

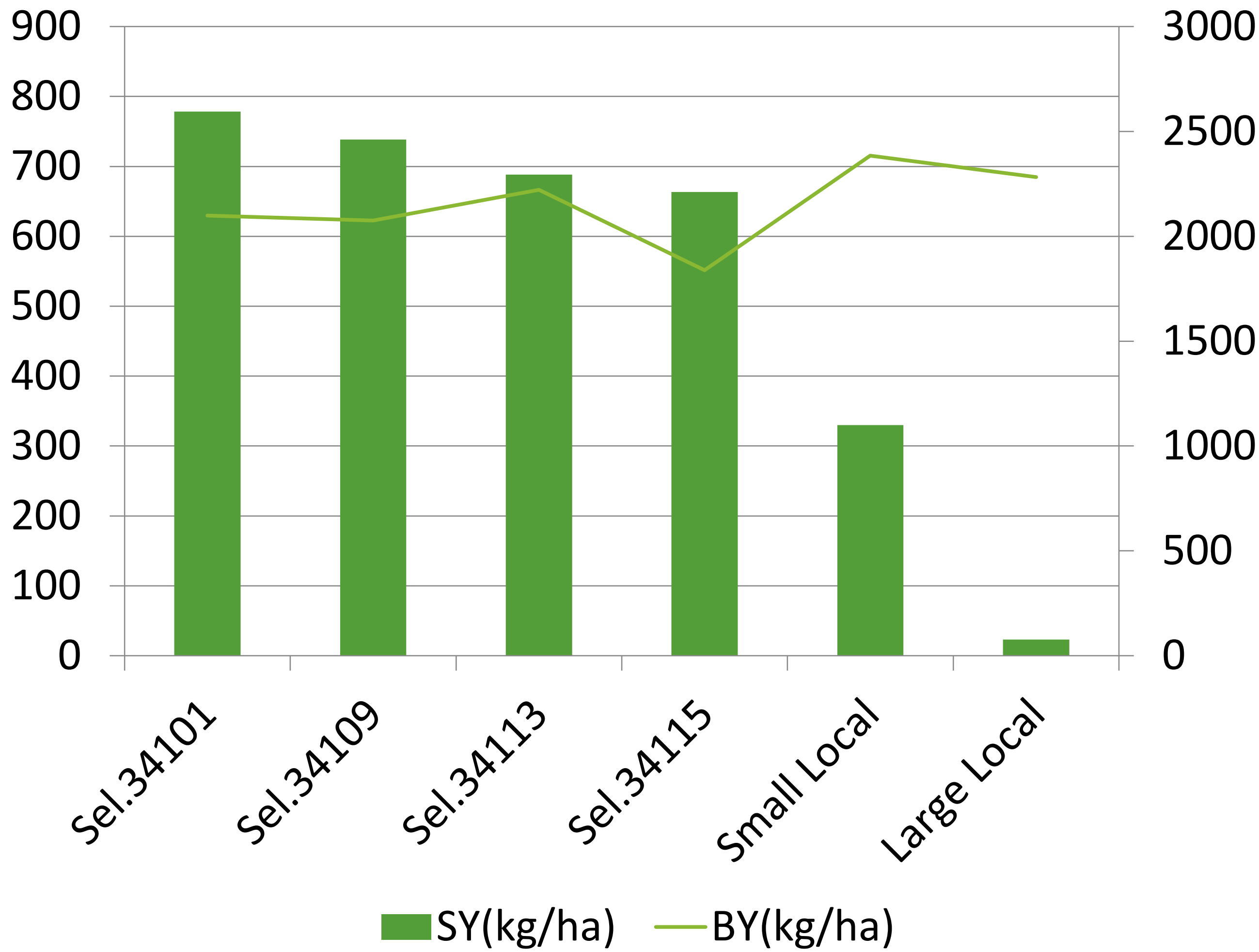
RESEARCH PROGRAM ON Grain Legumes
CGIAR

Identification of heat tolerant genotypes in chickpea (FP3)

Genotype	No of times in top 25%	No. of trials
ICCV 07102	11	13
ICCV 07110	11	13
JAKI 9218 (ICCV 93952)	11	13
JGK 2 (ICCV 95332)	11	13
JG 14 (ICCV 92944)	10	13
ICC 16181	10	13
ICCV 07109	10	13
ICCV 07118	10	13
JG 130 (ICCV 94954)	10	13
Vishal (ICCL 87207)	10	13
ICC 8474	9	13
ICCV 07117	9	12
GG 2	8	12
ICC 16216	8	11
ICC 4958	6	8
ICCL 81248	8	10
ICCV 07105	8	13
ICCV 07108	8	9
JG 16 (ICCV 96970)	8	8
ICC 14674	7	9

Sensitive **Tolerant**

Performance of Heat Tolerant Lentil Lines (FP3)



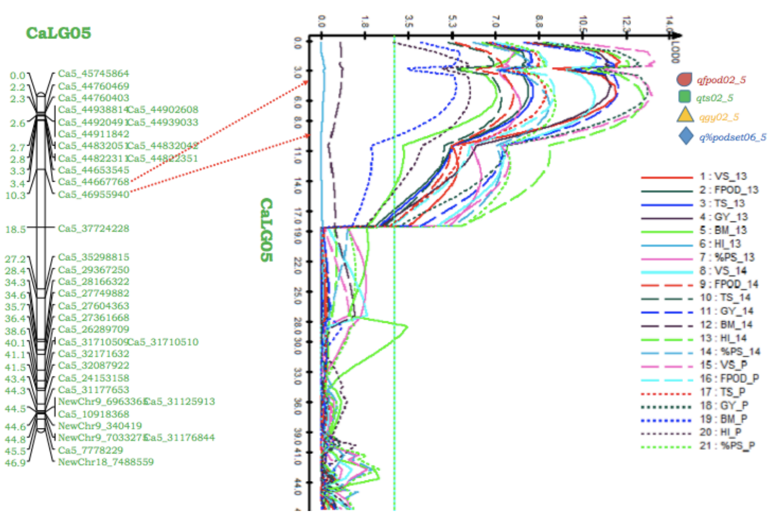
Improved lines for heat tolerance-Sudan (FP3)

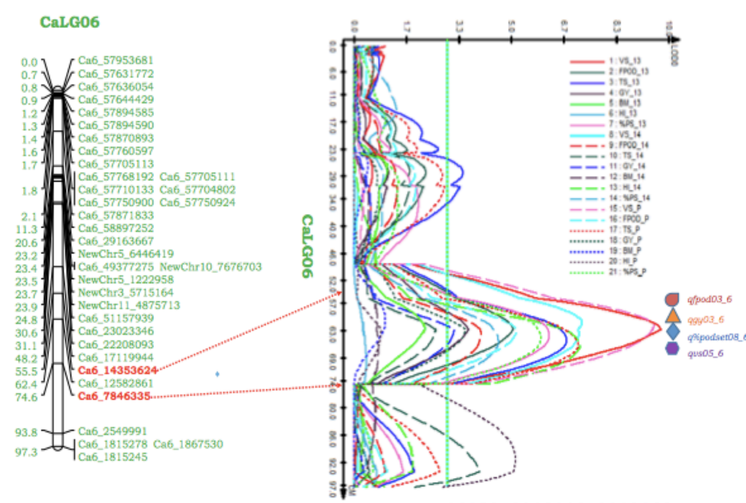
532 breeding lines screened and evaluated for 3 years 2013-2015, among them 8 were identified tolerant to heat

NO	Pedigree	DFLR	DMAT	SWP
3	Selection from BpL5061	39	114	163
4	S88094-8-1	43	113	127
5	S88134-3-1-1	41	113	117
11	Selection for heat from Shambat	41	108	107
12	Selection from Basabeer	41	114	245
14	Selection from Hudeiba	39	112	147
15	Selection for heat from Shambat	39	114	245
16	Selection from Hudeiba	40	113	148

Molecular mapping of genes/QTLs controlling heat tolerance (FP7)

Two key genomic regions harbouring several QTLs for heat tolerance associated traits identified on CaLG05 and CaLG06 based on ICC 4567 × ICC 15614 RILs



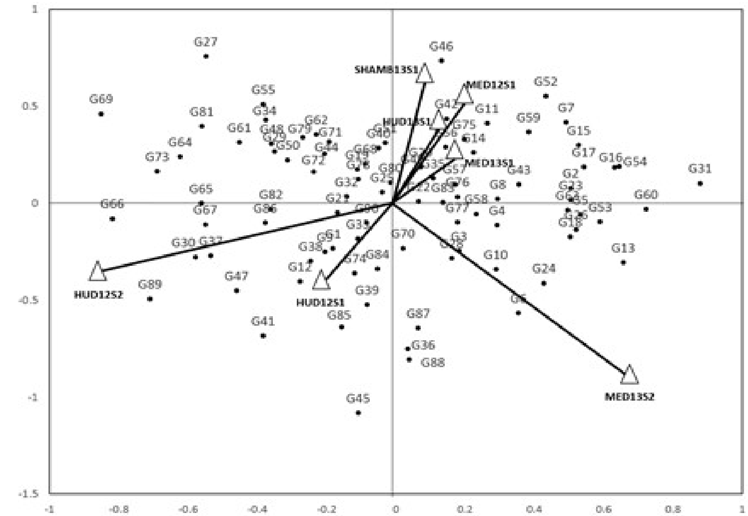


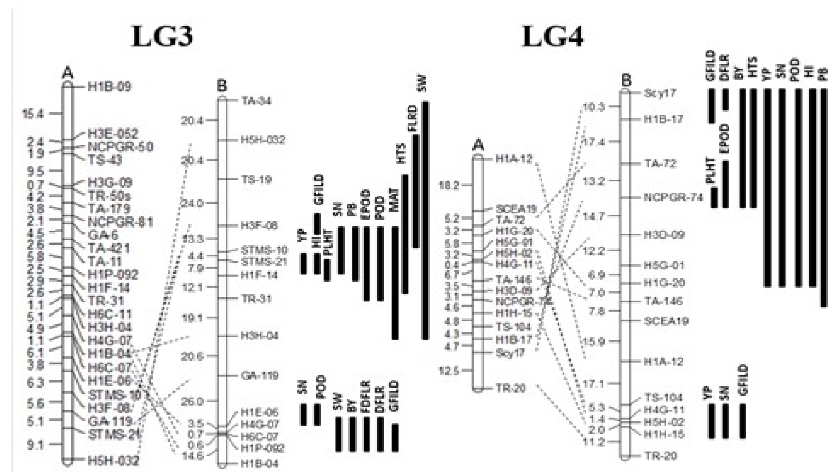
Molecular mapping of genes/QTLs controlling heat tolerance (FP7)

- **Two major QTLs for heat tolerance in chickpea identified**

- **Stressed environments conserved heat tolerance QTL**

- **These QTLs are located on linkage group 3 and 4.**





Tertiary gene pool in common bean: introgression by congruity BC (FP2)

(P.vulgaris x
P.acutifolius)

x

P.v.

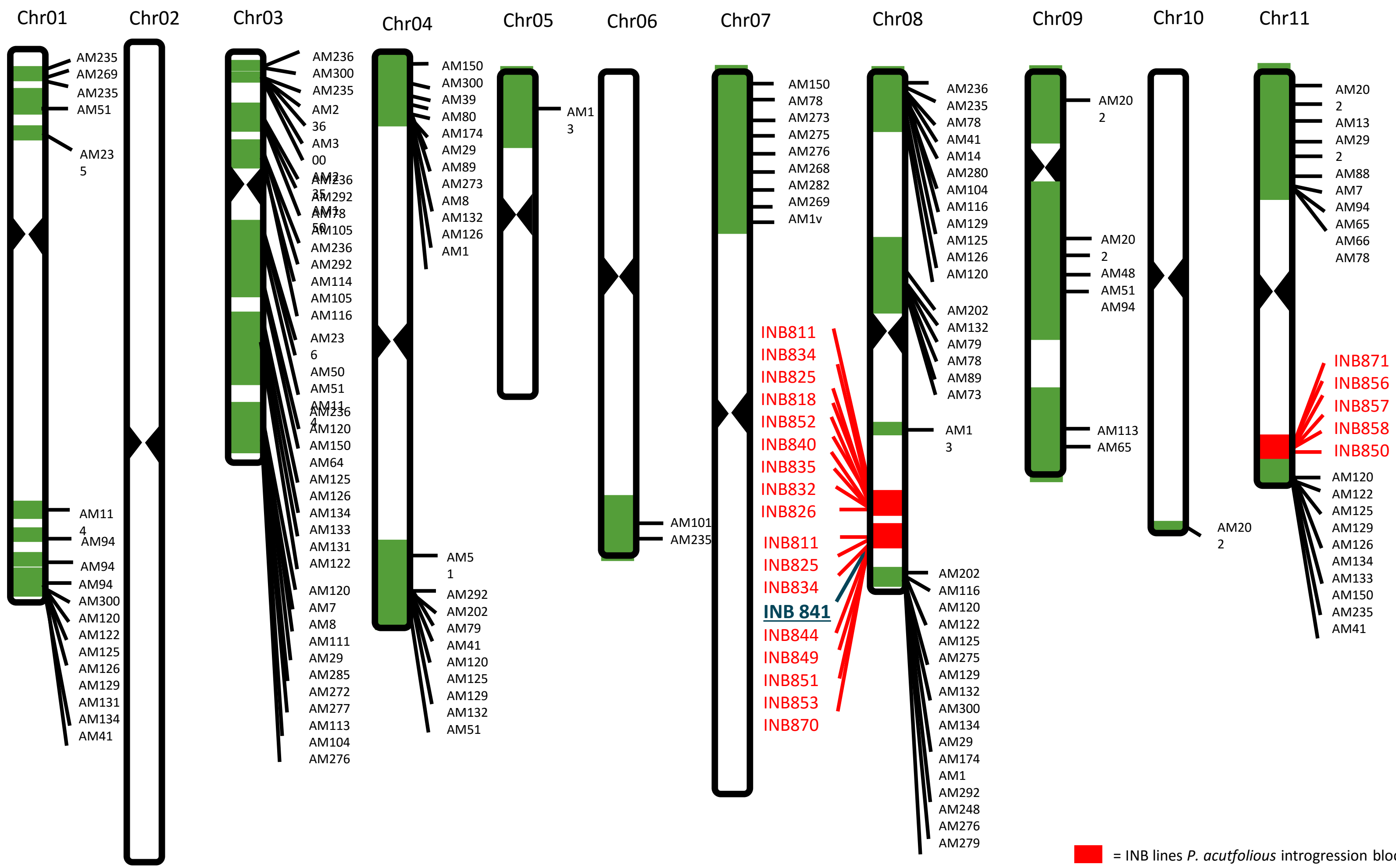
x P.a.

P.v.

x P.a.

Commercial
Check

Genes of *Phaseolus acutifolious* introduced into P. vulgaris (FP7)



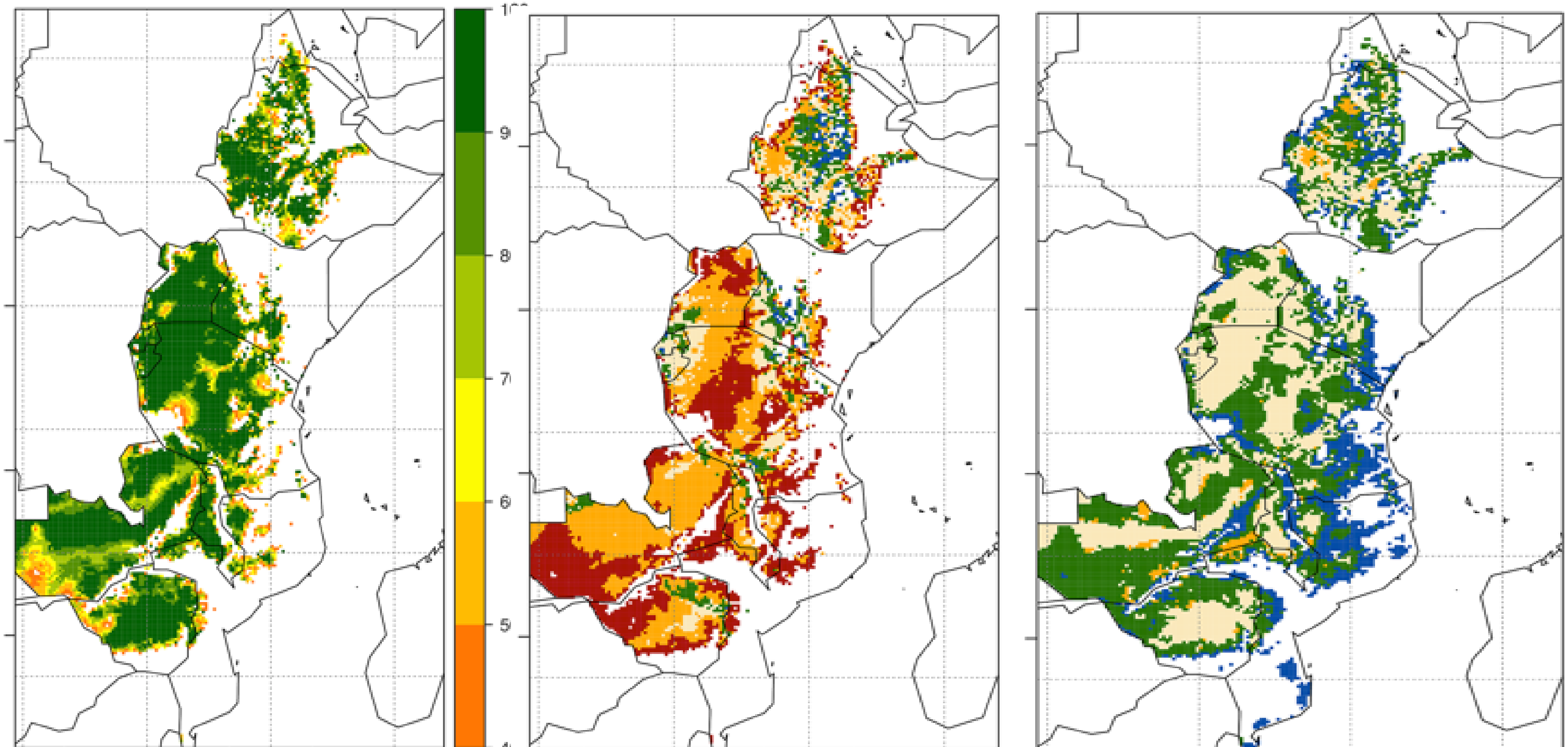
= INB lines *P. acutfolious* introgression blocks

= AM lines *P. acutfolious* introgression blocks

RESEARCH PROGRAM ON Grain Legumes

CGIAR

Estimates of Bean Adaptability with Heat Tolerant Beans with 3ºC advantage (FP7)



Current adaptability

The “do-nothing” scenario - 2050

Plus 3 degrees adaptation - 2050

(Julian Ramirez)

RESEARCH PROGRAM ON Grain Legumes

CGIAR

Performance of heat tolerant variety JG 14 at farmers' fields under late sown conditions in India (FP4)

State	No of demos	Local cultivar (kg/ha)	JG 14 (kg/ha)	% increase in yield
Uttar Pradesh	80	1145	1654	30.6
Madhya Pradesh	53	1376	1724	25.3

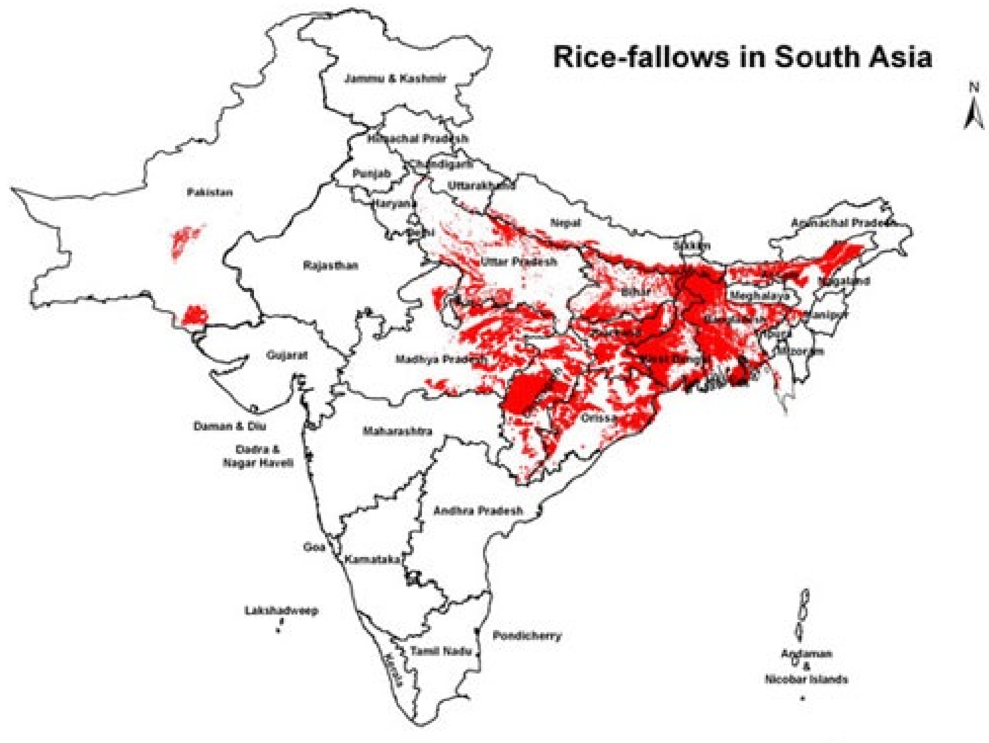
RESEARCH PROGRAM ON Grain Legumes
CGIAR
ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Adoption of heat tolerant variety ICCV 92944 (Yezin 6 in Myanmar and JG 14 in India) by farmers

Myanmar: Yezin 6 was grown in about 60,000 ha (about 19% of the chickpea area) in Myanmar during 2014-15.

India: JG 14 ranked 5th among 74 varieties for the Indian indent of chickpea breeder seed during 2015-16.

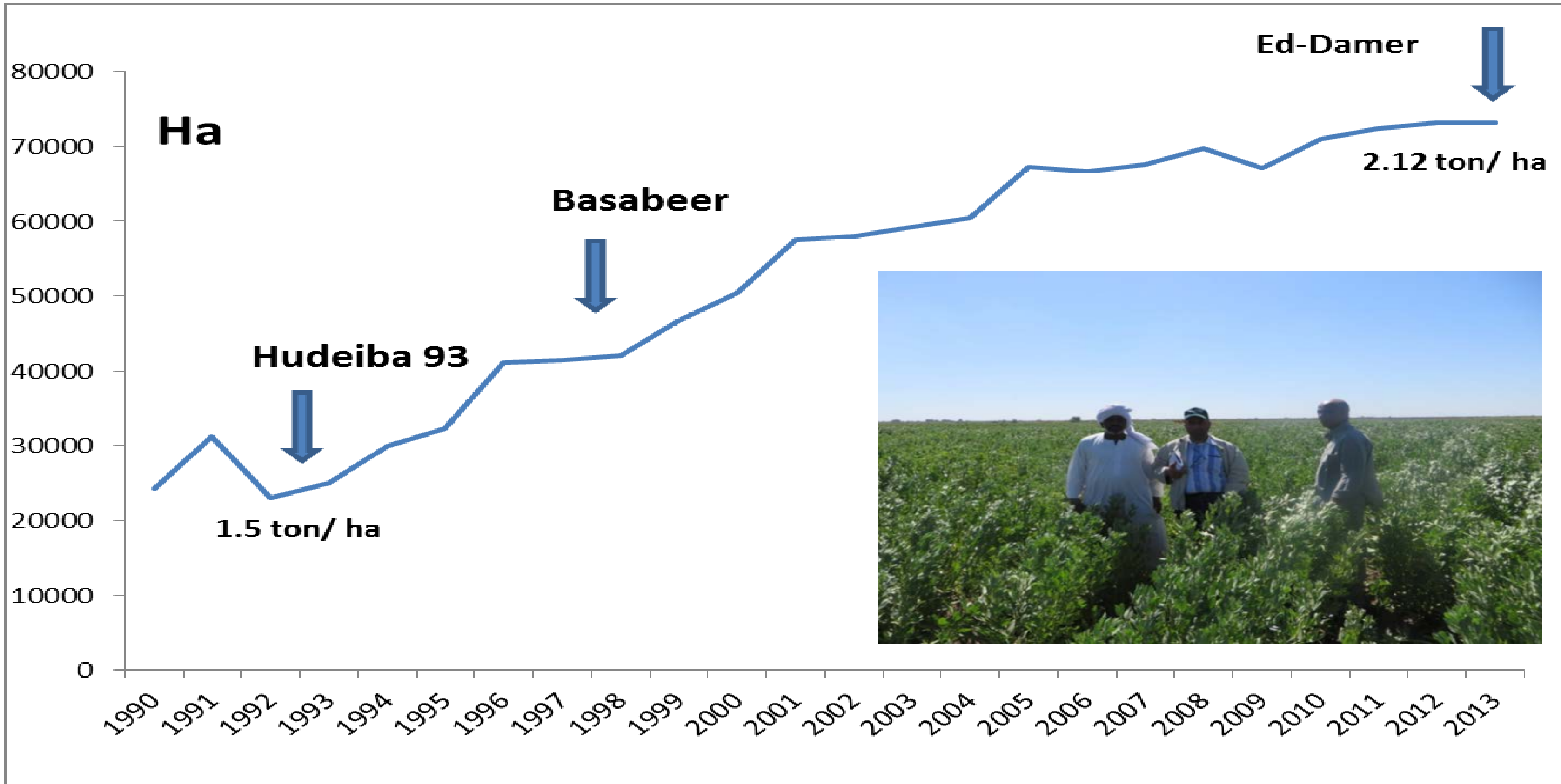
ICCV 92944 performed well in rice-fallows and other late-sown conditions of Eastern India (Bihar, Jharkhand, Eastern Madhya Pradesh, Chhattisgarh, and Orissa) and Bangladesh and its adoption by farmers is increasing rapidly.



RESEARCH PROGRAM ON Grain Legumes
CGIAR

Impacts of Faba bean heat tolerance in Sudan (FP4)

- **Faba bean production increased from ~40,000 t in nineties to 150,000 t at present.**
- **Increase in area (~20000 ha in nineties to ~70000 ha)**
- **Productivity from 1500 kg to 2120 kg per ha.**



RESEARCH PROGRAM ON
Grain Legumes
CGIAR

Capacity Building and Partnership(FP 5)

Students: Two students (PhD) at ICRISAT from India and six students (3 PhD and 3 MSc) at ICARDA from Syria, Sudan and Ethiopia conducted/conducting research relevant to this product line.

Training courses

- Pre-breeding and breeding of legumes at ICRISAT: 25 participants from Asia (India, Nepal, Bangladesh, Philippines, Laos and Myanmar) and Africa (Senegal, Ghana, Niger, Kenya, Tanzania, Malawi, Mozambique, Zambia and Uganda).
- Variety identification and variety maintenance at ICARDA: 26 participants from Algeria, Egypt, Jordan, Lebanon, Morocco, Sudan, Tunisia and Turkey.
- Training course on food legume improvement techniques in Lebanon: Participants from Algeria, Morocco, Tunisia, Turkey, Sudan, Lebanon, Morocco, Egypt and Jordan.
- Management of diseases and pests, pesticide uses and safety in Algeria: 20 participants from Algeria, Morocco, Tunisia, Turkey, Sudan, Lebanon, Egypt and Jordan

Field days

Areas suggested for continued R4D

- Dissection of heat tolerance into its components and their genetic mechanism
- Understanding the confounding effect of drought stress on heat stress
- Incorporating resistance to biotic, nutritional and grain quality traits in heat tolerant varieties
- Adaptation studies in different geographies and cropping systems
- Development of QTLs and their use in screening of the germplasm of cultivated and wild species for inducing/identifying enhanced levels of heat tolerance.
- Identify candidate genes and diagnostic markers for heat tolerance for use in breeding programs.

Summary.

- Screening protocols were established (related to reproductive development)
- Tools for screening for heat tolerance developed
- Sources for heat tolerance identified from naturally occurring genetic variability in the germplasm.
- Common bean crosses with *P. parvifolius* were advanced.
- Introgression of segment of *P. parvifolius* in common that are responsible for heat tolerance.
- Several QTLs associated with heat tolerance in chickpea were identified and mapped
- Capacity development enhanced

Contributing Bilateral Projects

- **Ministry of Agriculture and Farmer Welfare, Govt. of India**
- **Tropical Legumes II & III**
- **OCP-Morocco, India Project for food legumes**
- **EU-IFAD project**
- **ACIAR**
- **GRDC-Chickpea project**
- **USAID**

List of Posters

Breeding heat tolerant varieties of chickpea

Anita Babbar, Sushil K Chaturvedi, V. Jayalakshmi and Pooran M Gaur

Effects of heat stress on physiology and reproductive biology of chickpea and lentil"

Neeru Kaushal, Kalpna Bhandari, Rashmi Awasthi, P.Gaur, Vincent Vadez, Shiv Kumar, Neil Turner, Kadambot Siddique, and Harsh Nayyar

Heat tolerance in common bean derived from interspecific crosses

Jose Polania, Nestor Chaves, Juan Lobaton, Cesar Cajiao, Idupulapati Rao, Bodo Raatz, Stephen Beebe

Partners

- Agriculture Research Center, Sudan
- ANGAU Regional Agril. Res. Station, Nandyal, AP, India
- Department of Agricultural Research, Yezin, Nay Pyi Taw, Myanmar
- Ethiopian Agriculture Research Institute, Ethiopia
- ICAR-Indian Institute of Pulses Research (IIPR), Kanpur, India
- Panjab University, Chandigarh, India
- Punjab Agricultural University (PAU), Ludhiana, Punjab, India
- University of Sydney, Cobbitty, Australia.
- Washington State University, Pullman, USA

Thank you for your kind attention

Fouad Maalouf
Senior Scientist (Faba bean breeding)
ICARDA

Participating Centers: ICARDA, ICRISAT and CIAT

http://grainlegumes.cgiar.org

CGIAR RESEARCH PROGRAM ON Grain Legumes

LED BY ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

IN PARTNERSHIP WITH CIAT Centro Internacional de Agricultura Tropical International Center for Tropical Agriculture ICARDA Science for Better Livelihoods in Dry Areas IITA Research to Nourish Africa

and public and private institutes and organizations, governments, and farmers worldwide