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The role of germplasm for adaptation to climate change

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AVRDC – The World Vegetable Center

34th International Vegetable Training Course
Module 1: Vegetables: From Seed to Table and Beyond
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AVRDC Research and Training Station ESEA
Kamphaeng Saen, Nakhon Pathom, Thailand

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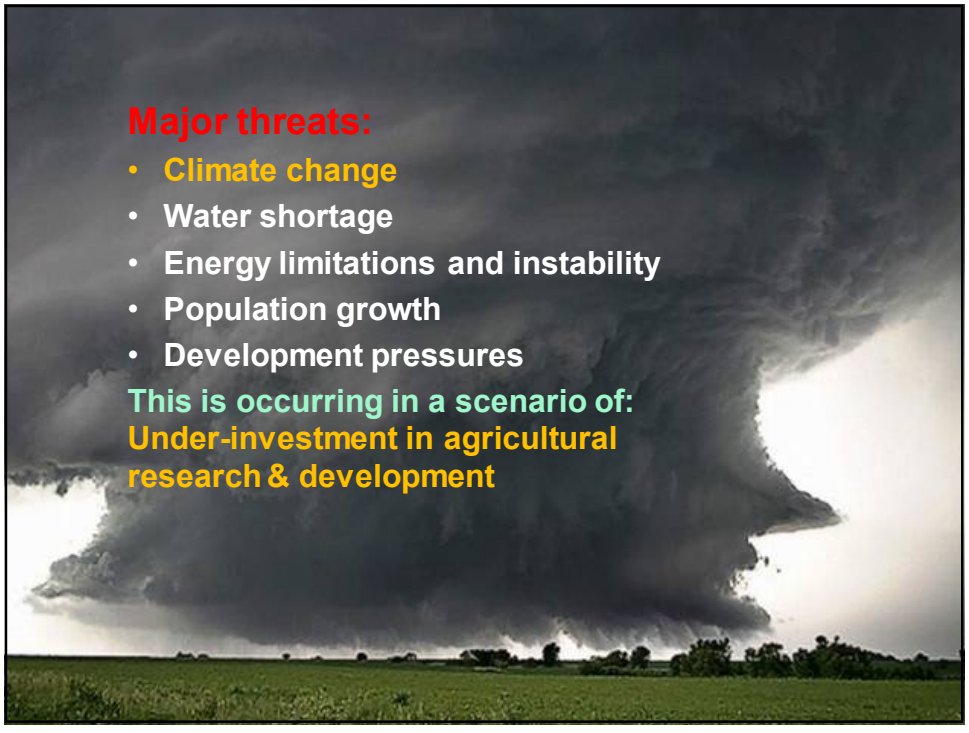

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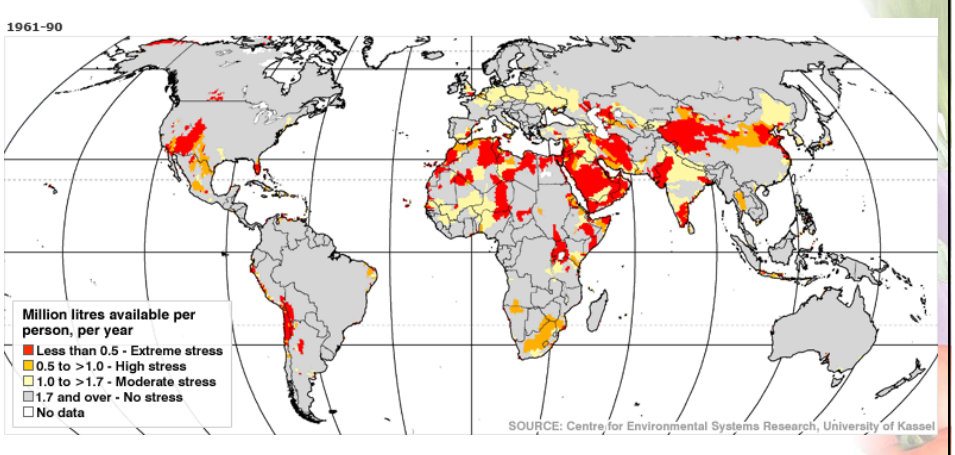
Change in Water Availability

under climate change, population growth and industrialization

1961-1990



Source: BBC, Tuesday, 8 December 2009. The key effects of climate change.
http://news.bbc.co.uk/2/hi/science/nature/7821082.stm

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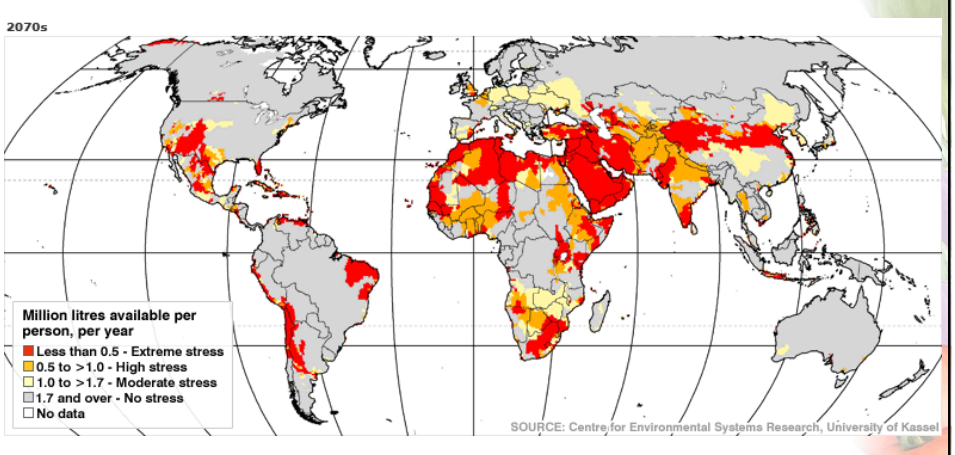
Change in Water Availability

under climate change, population growth and industrialization

2070s



Source: BBC, Tuesday, 8 December 2009. The key effects of climate change.
http://news.bbc.co.uk/2/hi/science/nature/7821082.stm

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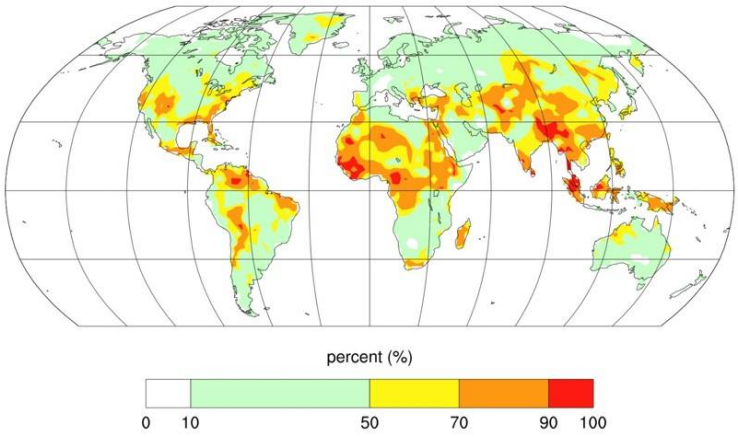
Change in Temperature

Likelihood (in percent) that the summer average temperature in 2050 will exceed the highest summer temperature ever observed (1900-2006).

Summers in 2040-2060 Warmer than Warmest on Record



Source: Battisti, D.S., and R.L. Naylor. 2009. Historical warnings of future food insecurity with unprecedented seasonal heat. *Science*, 323, 240-244.

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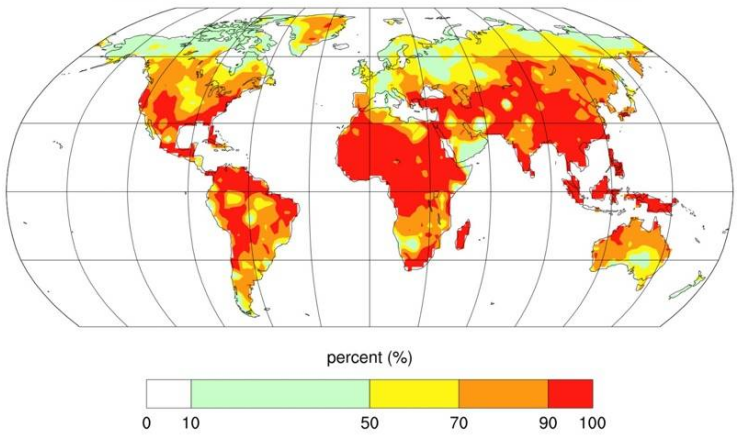
Change in Temperature

Likelihood (in percent) that the summer average temperature in 2090 will exceed the highest summer temperature ever observed (1900-2006).

Summers in 2080-2100 Warmer than Warmest on Record



Source: Battisti, D.S., and R.L. Naylor. 2009. Historical warnings of future food insecurity with unprecedented seasonal heat. *Science*, 323, 240-244.

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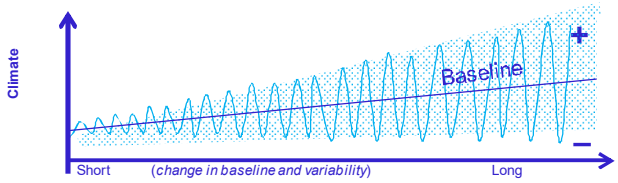
Principal climatic risks

- **30% novel climates (Williams et al. 2007) – combinations of climatic factors never before experienced on earth**
- **Changes in averages, and increases in variability**



- **Increased maximum temperatures above and beyond what is experienced today (Battisti & Naylor 2009)**

Battisti DS, Naylor RL. (2009) Historical warnings of future food insecurity with unprecedented seasonal heat. Science 323: 240–244.

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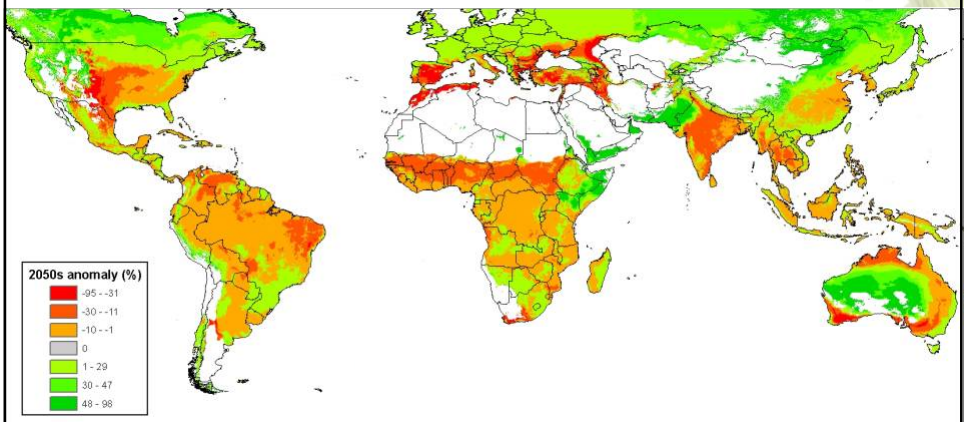
Crop suitability is changing



Average projected % change in suitability for 50 crops, to 2050

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Climate change and biological interactions

- The complex biological interactions are differentially affected by accelerated climate change causing changes difficult to predict.
- Crop yield and quality are affected by climate change directly/and indirectly, through abiotic and biotic (insect pests and diseases) stresses.
- Specific predictions will be difficult because of the complex multi-trophic relationships between many microbial organisms including pathogens, their vectors and their respective host plants.

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Effects of climate change on crop diseases

- Components of climate change (temperature, greenhouse gases, water) will have different effects based on their specific interactions with pests and diseases.
- The consequences of climate change on pests and diseases are complex and still not perfectly understood.
  - Some pests will be able to invade new areas and become increasingly problematic e.g. rusts,
  - Some pests that currently occur in small areas, or at low densities, may be able to spread more widely and reach damaging population densities. e.g. aphids.

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Climate change & vegetable production in Taiwan

- **Temperature**
  - Trends of elevated night air temperature
    - Respiration will rise as a result of higher temperatures during night
    - Quality and yield will decrease
- **Precipitation**
  - Days with light rain (daily rainfall < 1 mm) decreased.
    - Most light rain occurred during winter
    - Production season of most leafy vegetables is in winter
- **Heavy precipitation events**
  - Days with torrential rain (daily rainfall ≧ 200 mm) in Taiwan show a significant increasing trend in the last 50 years
    - Vegetable production during rainy season becoming difficult

Germplasm: How to prepare for the storm?

- Collect remaining diversity from the field
- Conserve it – securely and permanently
- Screen it for traits essential to meet climate change, water, energy and food security challenges – and also help mitigate climate change (pre-breeding)!
- Supply enhanced germplasm for breeding new climate-ready crop varieties

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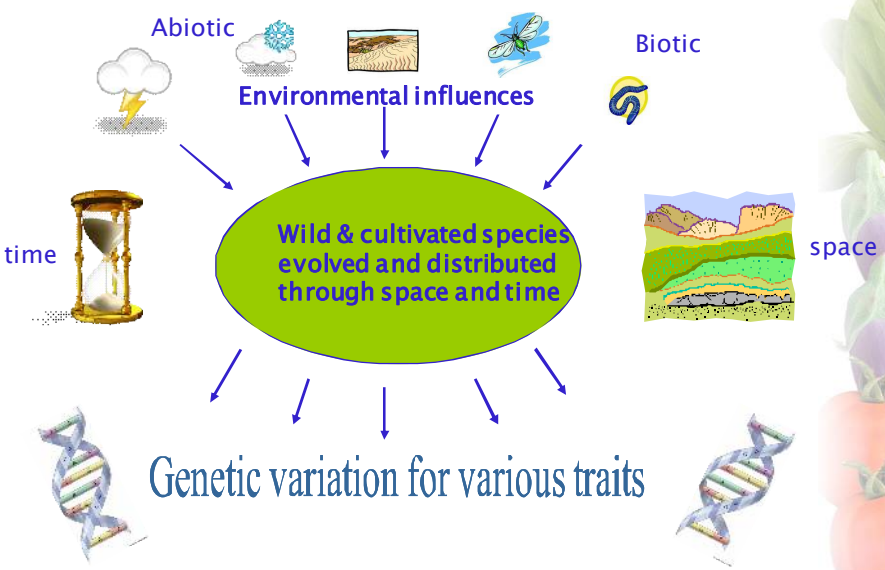
Reason for genetic variation



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Deployment of resilience sources for climate change adaptation

- Diversity to build spatial and temporal heterogeneity into the cropping system, will enhance resilience to both abiotic and biotic stress challenges.
- More robust genetic resistance and biochemical response mechanisms are needed
  - Breeders should have access and select parental germplasm proven to be resilient under likely climate change scenarios including extreme events.
  - Polygenic resistance (non-race specific) for effective and durable resistance should be used instead of major genes.
- The biodiversity produced should be deployed at spatially heterogeneous scales to maximize its efficacy and protect its longevity.

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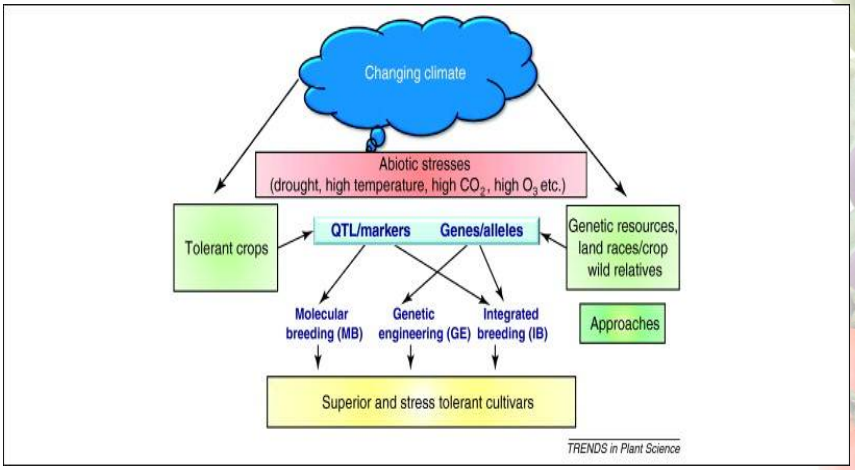
Genetic diversity for adaptation to abiotic and biotic stresses



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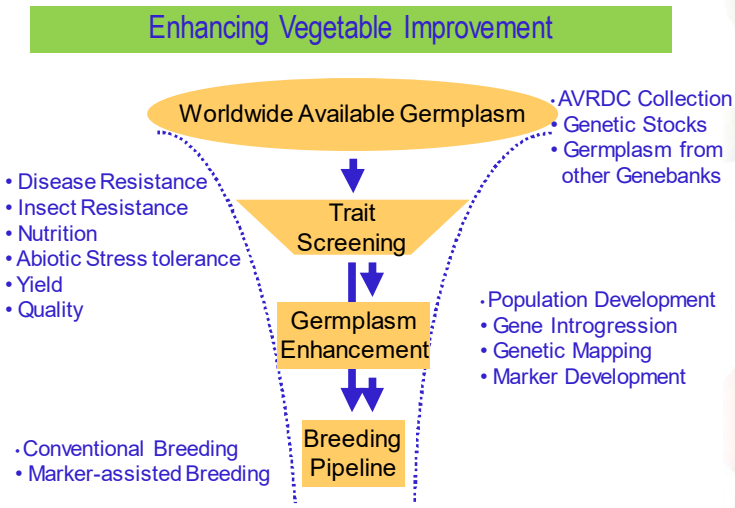
The role of Global Theme - Germplasm



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Probably the world's largest public sector collection of vegetable germplasm: AVRDC Genetic Resources and Seed Unit Genebank

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Traditional vegetable crops can thrive in marginal areas. They are also good candidates for crop diversification

Momordica charantia: **An option for crop diversification**

Traditional vegetables such as kangkong can grow in saline soils

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Crop Wild Relatives (CWR) and landraces for climate change adaptation

CWR: Wild species that are closely related to our crops – often the species from which our crops have been domesticated

TI1

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Crop Wild Relatives (CWR)

- **CWR are often found growing in the wild and as weeds in disturbed habitats (road sides, field margins)**
- **50,000-60,000 CWR can be found in the wild (Maxted & Kell, 2009); more than 10,000 of these are important genetic resources for food and agriculture**
- **CWR are often associated with the centers of crop origin and crop diversity**

- CWR are used to improve yield and nutritional quality of crops
- Genes of CWR are being introgressed into cultivated lines to enhance resistance against pests and diseases and to improve tolerance to abiotic (environmental) stresses
- CWR sustain agroecosystems and provide ecosystem services

Slide 20

TI1 I have added a screenshot of the portal to the next slide. You could use the second slide on CWR for the project and portal
Thormann, Imke (Bioversity), 7/16/2010

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Crop Wild Relatives (and landraces) are presently poorly conserved

- Insufficient and dispersed information on CWR
- Lack of coordination between actors to conserve CWR
- Lack of awareness and use of CWR
- Decision making/priority setting procedures needed
- Conservation strategies often do not target CWR

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Impacts on wild PGRFA

- **16-22% (depending on migration scenario) of these species predicted to go extinct (Jarvis et al. 2008)**
- **Wild peanuts were the most affected group, with 24 to 31 of 51 species projected to go extinct**
- **For wild potato, 7 to 13 of 108 species were predicted to go extinct**
- ***Vigna* was the least affected of the three groups, losing 0 to 2 of the 48 species in the genus**

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Use of tomato germplasm for breeding at AVRDC

Initial crop focus of AVRDC: Brassicas, tomato and *Vigna*; initial collection size: 590 accessions;

Tomato program: adaptation to tropical environments with high temperature and high disease pressure; need to expand initial collection for large-scale screening of desired traits;

Heat tolerance: optimum mean temperature for fruit set: 21-24 ºC ; above 25 ºC, fruit set declines. After screening thousands of accessions, tomato lines were identified that reached up to 70% of normal fruit set at 29-31 ºC night temperature.

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Tomato collection maintained by AVRDC

Category	Accs.
Wild species	812
Unidentified accessions	585
S. lycopersicum	6,144
S. lycopersicum var. *cerasiforme*	125
Sub-total	**6,854**
Genetic stocks (IL, RIL, hybrids)	595
Total	**8,261**

Major contributing countries to cultivated tomato collection:

- US (1197 accs.)
- China (453)
- El Salvador (411)
- Taiwan (394)
- Peru (305)
- Guatemala (231)
- Philippines (217)

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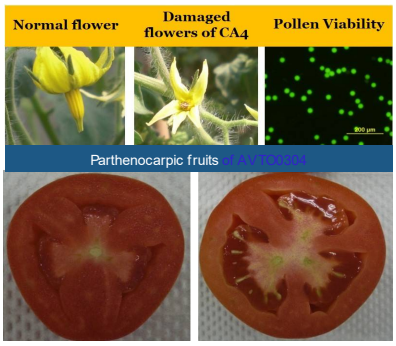
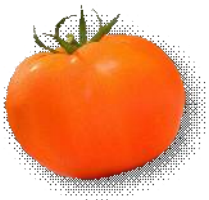
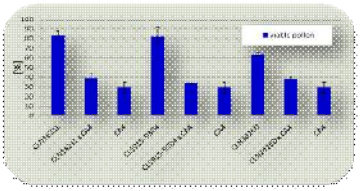
Searching for heat tolerance in tomato





No fruit set in VI059364 (CA4)



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Heat tolerance in pepper

Orange Bell
0537-7032
X
SW-HP
9848-4840

F1 COA 779

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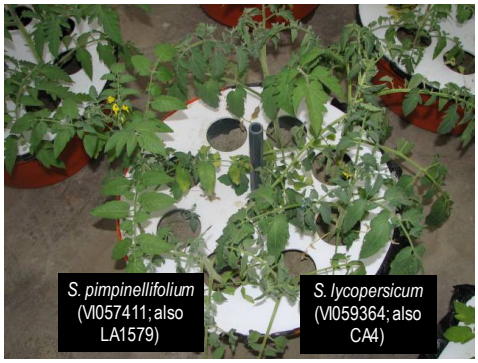
Screening for Drought Tolerance

Drought Pool Assay



Gravimetric Assay

Measurements: Chlorophyll content and chlorophyll fluorescence, time to wilting and soil moisture content, height and final biomass

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Introgression of drought tolerance from wild species

S. lycopersicum x S. pennellii

S. lycopersicum x S. pimpinellifolium

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Screening of *S. pimpinellifolium* accessions for salinity tolerance

Susceptible

Tolerant

Control 150mM NaCl

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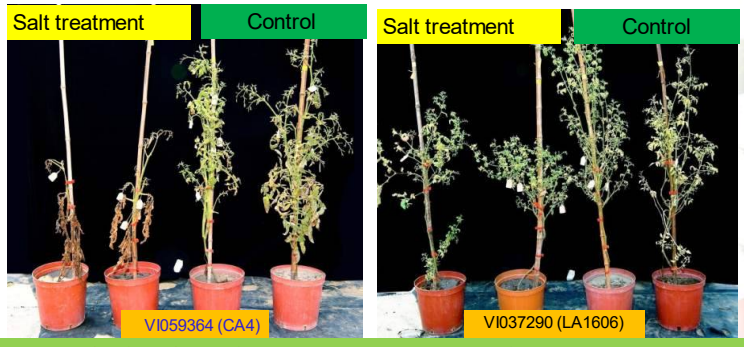
Screening for salinity tolerance under progressive stress (500 ml of 200 mM NaCl every 2nd day; final EC of 40 dS/m)



5 genotypes (4 of core) identified with good survival traits; 7 for yield traits; 2 with combined good survival and yield traits under salt stress

Rao et al. (2013) Relationship between survival and yield related traits in *Solanum pimpinellifolium* under salt stress. Euphytica 190(2): 215-228 (DOI 10.1007/s10681-012-0801-2)

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Usefulness of *S. pimpinellifolium* core collection (75 acc.)

Genotype No.	Accession No.	Other code	Country of origin	Remarks
8	VI006037	PI126432	Peru	High yield under salt stress
25	VI007001	PI212408	Peru	High yield under salt stress
26	VI007002	PI212409	Venezuela	High survival score under salt stress
42	VI007519	PI270448	Mexico	High survival score under salt stress
72	VI037280	LA1547	Ecuador	High survival score under salt stress
75	VI037290	LA1606	Peru	High survival score under salt stress
86	VI009628	LA1384	Peru	High yield under salt stress
39	VI007514	PI270443	Mexico	LB resistance*

* Merk et al. (2012) Selective genotyping to identify late blight resistance genes in an accession of the tomato wild species *Solanum pimpinellifolium*. Euphytica DOI 10.1007/s10681-012-0729-6

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Screening for salinity tolerance of *Solanum pimpinellifolium*

- 172 accessions of *Solanum pimpinellifolium*
- Irrigated with 200 mM NaCl solution every second day
- Salt susceptible check: *S. lycopersicum* (CLN2498E and CA4)
- Salt tolerant check: CLN2498E and CA4 grafted onto salt tolerant eggplant (*S. melongena*) rootstock (VI039523 and VI041752)

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Sources of Tomato Yellow Leaf Curl Resistance (Ty) Genes

Species	Gene/Alleles / QTLs	Chromosome	Reference
Solanum chilense	Ty-1	6	Zamir et al., 1994
S. chilense	Ty-3, Ty-3a, Ty-3b	6	Ji et al., 2007
S. chilense	Ty-4	3	Ji et al., 2008
S. chilense	TYLCV1, TYLCV2	6	Agrama and Scott, 2006
S. chilense	qTY4.1, qTY6.1, qTY10.1, qTY11.1	4,6,10,11	Kadirvel et al., 2013
S. habrochaites	Ty-2	11	Hanson et al., 2000, 2006
S. peruvianum	Ty-5	4	Anbinder et al., 2009
S. peruvianum	5 recessive genes		Pilowsky and Cohen 1990
S. lycopersicum 'TyKing'	ty-5 (recessive)	4	Hutton et al., 2012
S. pimpinellifolium	Major gene/QTL	6	Scott, 2007
S. cheesmanii	Recessive gene		Hassan et al., 1984

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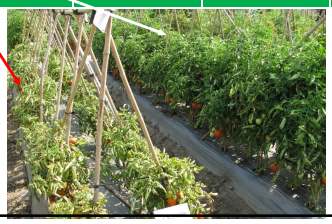
Multiple TYLCV resistance in tomatoes

Code	Pedigree	BW	TY-1	TY-2	TY-3	F-2
AVTO01080	CLN3022E	90	S	S	S	
AVTO0601	CLN2585D		S	R	S	S
FLA595	FLA595-2-2-13-26-31	16	R	S	R	R
AVTO1001	CLN3125F2-21-27-15-0	58	R	R	R	R
AVTO1032	CLN3079F1-3-34-25-12-8	33	S	S	R	R
AVTO1021	CLN3125F2-21-15-7-12	23	R	R	R	R
AVTO1025	CLN3125F2-21-15-7-16-9	23	R	R	R	R
AVTO1077	CLN3022F2-154-45-8-18-21	100	R	S	R	R



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Search for new resistance sources for late blight from wild tomatoes (*Solanum habrochaites*)

- **Tomato lines: 17 *Solanum habrochaites* accessions**
- **Pathogen isolate: Pi-411 (T1,2,3,4) and Pi-858 (T1,2,3,4,5)**
- **Segregation was observed, and 22 resistant plants were selected for producing S1 lines.**



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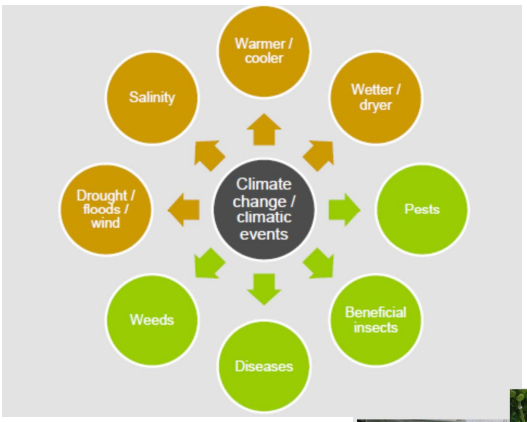
Resilient production systems to adapt to climate change



New varieties
Cropping systems
Grafting
Irrigation
Drainage
Rain shelters

Protected cultivation – nursery and production
Hydroponics and fertigation
Post-harvest

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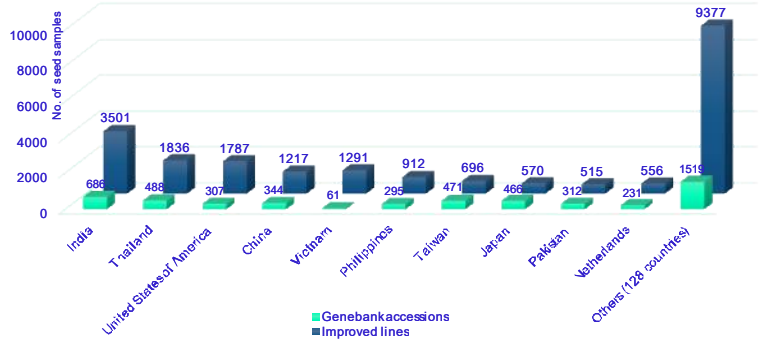
Worldwide tomato germplasm distribution by AVRDC 2001-2013

Total No. samples: 27,438 (5,180 genebank accessions – 18.9%)



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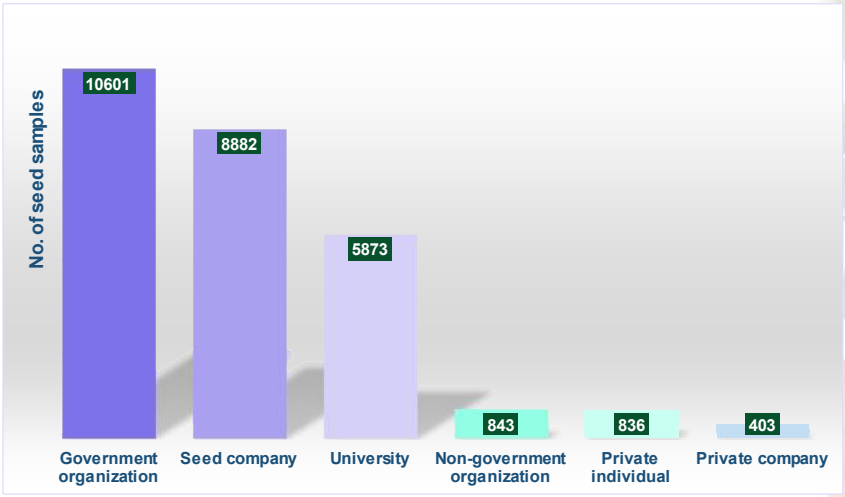
Worldwide tomato germplasm distribution by AVRDC 2001-2013, by recipient category



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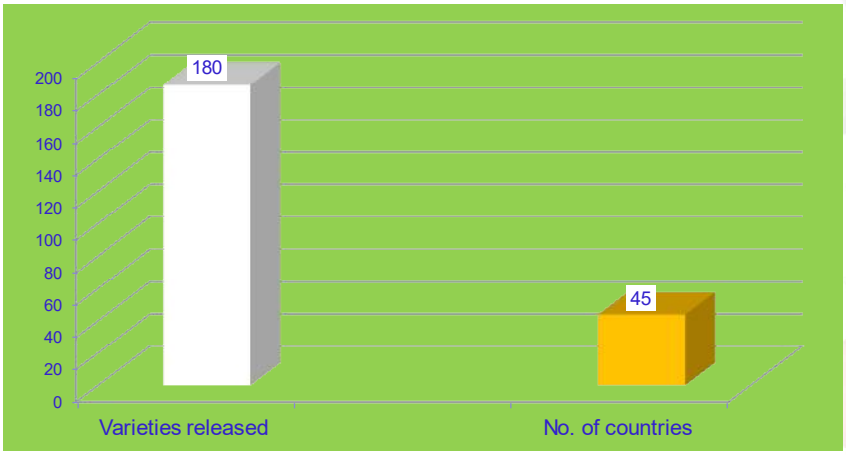
AVRDC-developed tomato varieties released worldwide since 1978



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Origin and Importance of *Capsicum*

- ✓ *Capsicum* is a highly diverse complex of domesticated and wild species that originated in the Americas
- ✓ *Capsicum* is a crop of global importance for the diet and income of many farmers worldwide
- ✓ Capsicum is promising as ingredient in a wide range of products
- ✓ The center of diversity corresponds to areas of poverty, offering options for improvement of livelihoods
- ✓ *Capsicum* has been identified by the regional plant genetic resources network as a priority research species for the Americas
- ✓ CWR of *Capsicum* have potential for resistance breeding to biotic stress as well as for tolerance to environmental stress, but have not yet been widely used for this purpose

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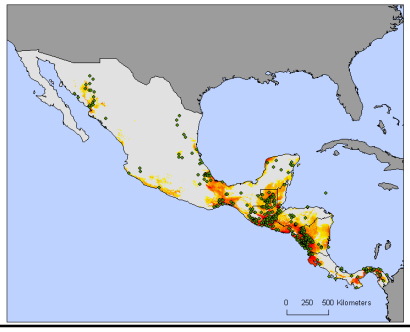
Wild *Capsicum* species: *C. annuum* var. *glabriusculum*

- Found from US to Bolivia; origin: Central Mexico
- Ancestor of most cultivated hot peppers
  C. annuum, C. frutescens, C. chinense?
- In Mesoamerica known as: *chiltepín*, *piquin*
- Taxonomical characteristics: white flower, whitish seeds

http://www.infernochili.tk/



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Differential reactions of breeding line 'PP0538-8525' to two anthracnose (*Colletotricum acutatum)* pathotypes

Pathotype CA1
(Coll-153)

Pathotype CA2
(Coll-524)

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Single plant selection in greenhouse for pepper anthracnose resistance confirmation and seed saving

New source of resistance:
VI044352 -
Capsicum baccatum

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Germplasm Evaluation for Disease Resistance

Resistance to powdery mildew (*Sphaerotheca fuliginea*) in cucumber
2/41 accessions resistant:
VI033568
VI056347

Resistance to downy mildew (*Pseudoperonospora cubensis*) in cucumber
10/41 accessions resistant:
VI034670, VI040917, VI033558, VI036273, VI040934, VI033568 VI040105, VI040910, VI040116, VI047765

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Screening cucurbits for PRSV-W* resistance

*PRSV-W = Papaya ringspot virus – watermelon strain

- 104 cucurbit lines from GRSU have been screened (up to 24 plants per line)
- Absence of virus infection was confirmed by DAS-ELISA

Cucurbit species	Number of Lines tested	Number of Lines					
		Resistant (0% infection)	1-20% infection	20-40% infection	40-60% infection	60-80% infection	80-100% infection (Susceptible)
Cucurbita moschata	94	4	8	13	18	19	32
Cucurbita maxima	5	0	0	1	2	2	0
Cucurbita pepo	5	0	0	1	1	0	3

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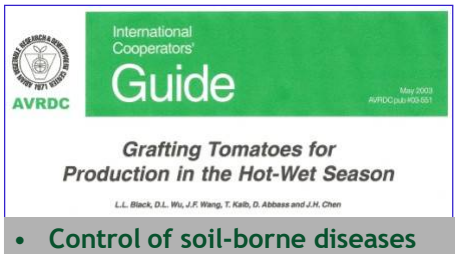
Flooding - Asia
Typhoon Morakot - August 2009

Flooding tolerance of *Capsicum baccatum* var. *pendulum* (PBC1422-B) – a typhoon 'Morakot' selection

- AVRDC-GRSU No. TC06898-B
- Cultivar name – Aji Yellow
- Source: Peru
- Susceptible parent line of intraspecific population for anthracnose resistance

Observation noted August 25, 2009
Hayde Flandez Galvez & Allen Hsu

Grafting



- Control of soil-borne diseases
- Enhancing ability to tolerate salinity and water logging of flood-sensitive vegetable crops
- Improved water / nutrient uptake ability
- Improved fruit quality
- Extending the growing season
- Less pesticide applications

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AVRDC Recommended Rootstocks

- **For tomato grafting**


TS03 ●●


EG190 ●●●●


EG195 ●●

Resistant to:
- ● Bacterial wilt
- ● Fusarium wilt
- ● Root-knot nematode
- ● Flooding


EG203 ●●●●


EG219 ●●●●


HW7996 ●●

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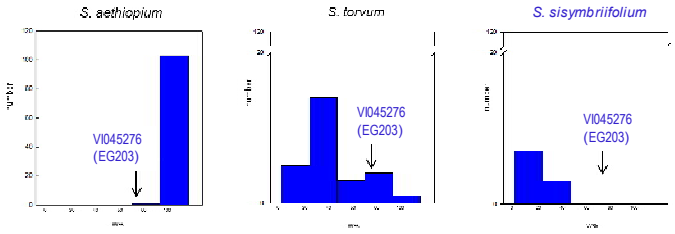
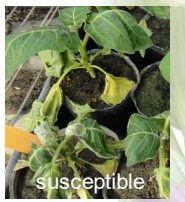
Screening of wild eggplant for bacterial wilt resistance




susceptible


resistant

5 out of 30 *S. torvum* & 7 out of 10 *S. sisymbriifolium* accessions with high bacterial wilt resistance (Pss97 - phylotype I, biovar 3 - isolate; soil drench/root wounding) identified as potential rootstock for tomato; all 108 *S. aethiopicum* accessions highly susceptible.

Courtesy: AVRDC Phytopathology group

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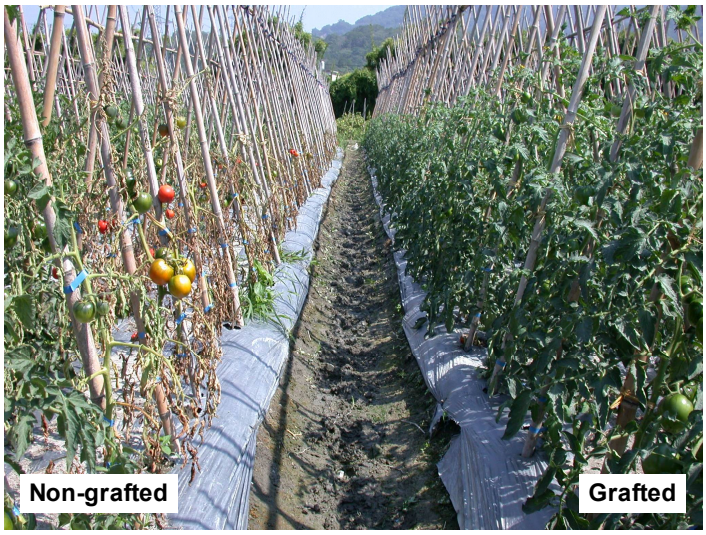

On-farm trial of integrated management of tomato bacterial wilt

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Production of Grafted Tomato Seedlings

Seedling production (14-16 days)

Under AVRDC HQ (Taiwan) condition

Grafting

Healing (4-7 days)

Hardening (2-3 days)

Further hardening (7-8 days)

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Plant Material for Current Grafting Experiment at GRSU

- **Scion:**
  - Cherry tomato 'Yu-Nu' (Known-You Seed Co. Ltd., Taiwan)
  - Green shoulder tomato FMTT1728 (AVRDC)
- **Rootstock:**
  - Control (non-grafted tomato)
  - Self-grafted tomato
  - VI047335 (EG195) *Solanum melongena*
  - VI045276 (EG-203) *S. melongena*
  - VI043614 (Hawaii 7996) *S. lycopersicum*
  - VI007002 *S. pimpinellifolium* (high survival score)
  - VI008107 *S. pimpinellifolium* (high survival score and low Na content)
  - VI034876 *S. quitoense* (highly resistant to *Ralstonia solanacearum*)
  - VI039590 *S. sisymbriifolium* (highly resistant to *Ralstonia solanacearum*)

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Healing and Hardening

- **Scion/rootstock combinations will be grown in pots in the screenhouse under standard conditions and under salinity stress (4.0 dS m^{-1}), in 3 replicates and with 3 plants per replicate.**
- **Grafting survival rate, plant growth/performance, fruit quality and phytonutrient composition data will be collected for further analysis.**

Grafted seedlings in the healing room

Grafted seedlings are moved to plastic house for hardening

Grafted seedlings will be transplanted to pots for treatments

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Grafting

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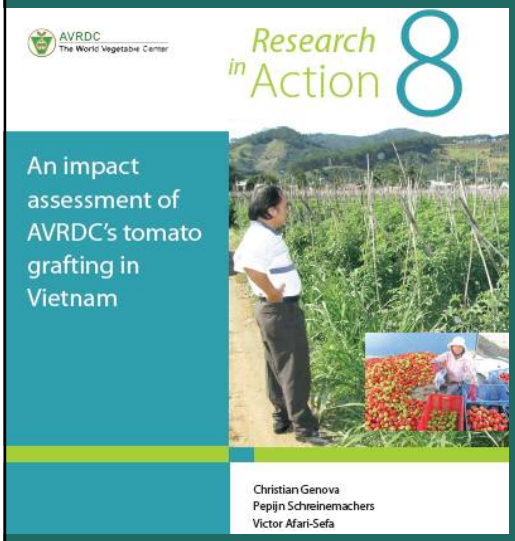

Quang Vinh, IVTC trainee

2007 Lam Dong Province 4000 ha cultivated with grafted seedlings

2012:
Full adoption in Lam Dong and increasing in Red River Delta

Yield increased by 18 t ha^{-1}

Increased profit in Lam Dong of US$7.7 million

Agronomic practices

Tomato bacterial wilt caused by *Ralstonia solanacearum* (soil-borne, vascular bacterial disease)		
Control principle	Specific measures	Efficacy
Pathogen exclusion	Use a plot without disease history Use clean seedlings No contact with contaminated water	***
Pathogen reduction	Practice rotation Remove diseased plants Apply chemical or organic amendments	**
Host resistance	Use locally effective resistant cultivars	***
Direct protection	Use sterilized pruning tools	*

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Agronomic practices

Tomato leaf curl virus caused by begomoviruses (insect-transmitted viral disease)		
Control principle	Specific measures	Efficacy
Pathogen exclusion	Raise healthy seedlings by protection with 60-mesh net	***
Pathogen reduction	Control whitefly, with pesticide, trap crops, pheromone traps Remove and destroy infected plants	*
Host resistance	Use locally effective resistant cultivars	***
Direct protection	Apply summer oil on leaves	*





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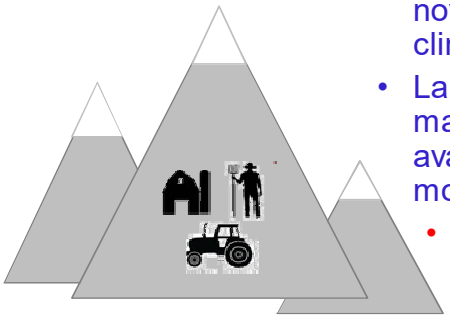
Geographic transferal of agricultural practices and technologies



- Whilst we will need to deal with some novel climates, majority of future climates are not novel (70%)
- Large pool of PGRFA and associated management practices already available to adapt. They just need to move geographically:
  - Locally (e.g. germplasm and technologies move up a mountain)
  - Regionally
  - Globally

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Increased climatic interdependence in 2050: a numerical study

- 98% of countries more similar to others in 2050 than they currently are
- 30% increase in climatic interdependence between countries
- Greatest increases for bananas, barley, beans, coffee, groundnuts, maize, millets, potatoes, rice, sorghum and wheat, least for cassava
- Asia and Africa experience greatest increases in climatic interdependence

Jarvis et al. (2011). Climate change and plant genetic resources for food and agriculture. FAO July 2011.

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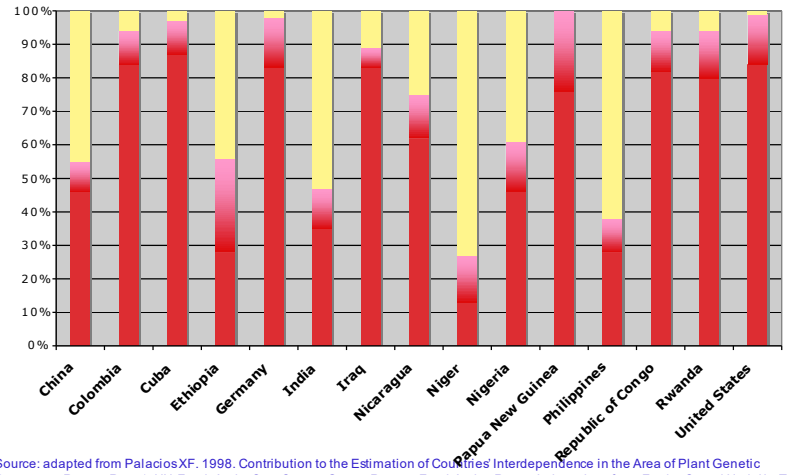
Global interdependence

Food Energy Supply (calories/day)

= % genetic resources of crops not indigenous to country

= % genetic resources of crops indigenous to country



Source: adapted from Palacios XF. 1998. Contribution to the Estimation of Countries' Interdependence in the Area of Plant Genetic Resources. Rep. 7, Rev. 1, UN Food. Agric. Org. Comm. Genet. Resour. Food Agric., Rome, Italy. taken from Fowler C. and Hodgkin T. 2004. Plant Genetic Resources for Food and Agriculture: Assessing Global Availability. Annu Rev Environ Resour 29: 10.1-10.37.

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Conclusions

- Climate change is threatening centuries of site-specific agricultural development
- Hotter (everywhere), changed rainfall patterns (most places), and novel (30%) climates to be experienced
- Climate projections indicate increased climatic interdependence between countries and regions
- Many adaptation options, many coming from PGRFA
- Resulting in likely increase in PGRFA demand, and increased genetic resource interdependence
- AVRDC's genebank is a rich source of genetic variability for crop adaptation to climate change and to develop new varieties with multiple resistance against an increasing number of diseases and insect pests faced by vegetable producers worldwide (used in-house & by scientists in public & private sector)

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Conclusions (2)

- Intensive trait screening is on-going at AVRDC for abiotic (drought, heat, salt) and biotic stresses (diseases and insect pests), both in cultivated and wild germplasm to facilitate germplasm use in breeding programs
- AVRDC is also working on germplasm enhancement (population development, gene introgression from wild species, mapping & marker development) to fast-track vegetable improvement for better adaptation and stable yields.


Thank you for your attention!
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