Neglected and Under-utilized Crops for Food and Income Security in Marginal Environments

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Outline

- Marginal environments – characteristics
- Abiotic stresses – impact on crop productivity
- NUS for sustainable food and income security
- R & D work on NUS – Case studies
- Conclusions & Key messages

Marginal Environments

Characterized by one or more of the following abiotic stresses

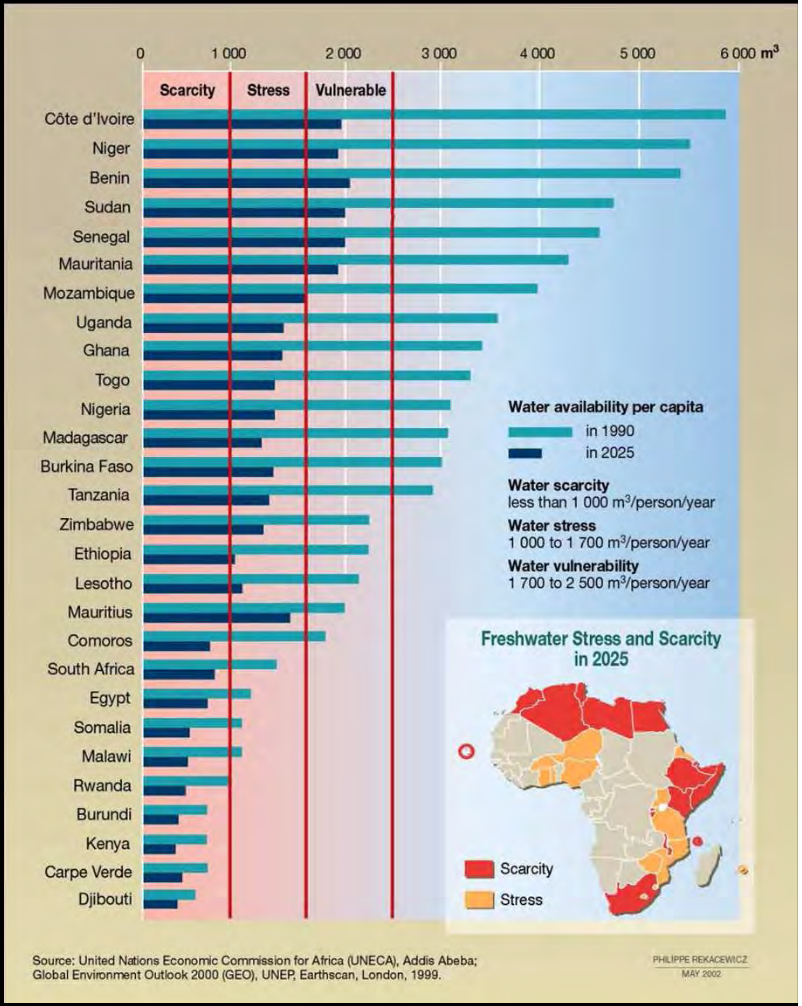
- Extreme levels of moisture (drought or water-logging)
- Extreme temperatures (heat or cold)
- Severe imbalances in soil fertility (absence of essential nutrients, salinity, sodicity)
- Unfavourable soil physical characteristics (steep slope)
- Meteorological conditions (heavy winds, hail) that cause physical damage to crops

Expanded definition of marginal environment includes:

- Biotic stresses - presence of high levels of diseases or pests
- Socioeconomic factors
  - ✓ farmers' resource limitations, non-availability of inputs
  - ✓ lack of access to information
  - ✓ absence of transportation and communication infrastructure

Abiotic stresses – Impact on productivity

- Agricultural productivity is particularly sensitive to temperature extremes and water scarcity
  - ✓ Dependence on rain-fed agriculture makes Africa particularly vulnerable
- Land degradation due to soil nutrient depletion and salinity also impacting productivity
- Soil salinity exacts major economic and environmental costs
  - ✓ Some10 million hectares (Mha) of arable land is lost due to salinity every year
  - ✓ In Africa, about 209 Mha of land is salt-affected
  - ✓ Secondary salinization accounts for nearly 5.9 Mha



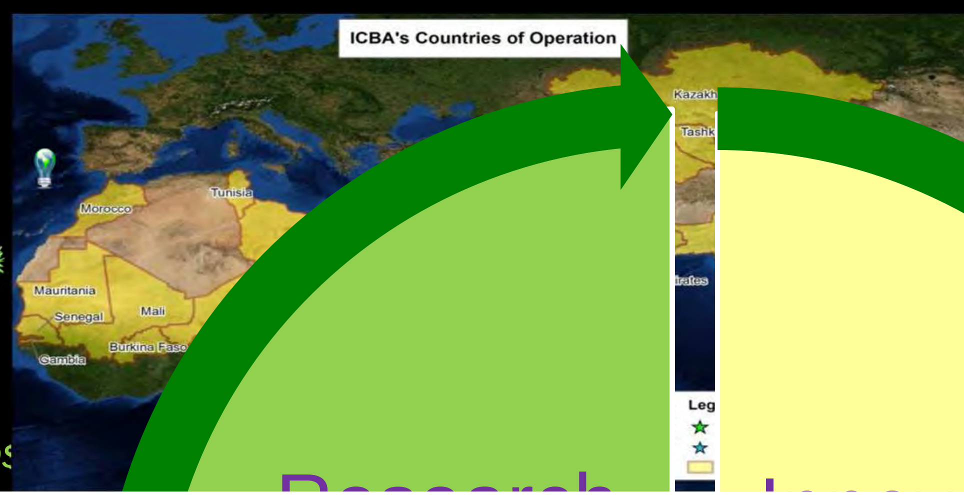
By 2025 most of the countries in Africa will be in a state of water stress or scarcity

Sustaining food & income security in marginal environments – Role of NUS

- One possible strategy is to look for alternative crops with special adaptation to hostile environments.
- Underutilized species offer major opportunities because of their comparative advantage over the staple food crops in terms of tolerance to harsh growing conditions
- The multiple uses of many of NUS offer greater opportunities to raise income of people through product diversification.
- Bringing the benefits of NUS requires focus on selected priority species, that have the highest potential value either for food and nutrition security, or as sources of income in harsh environments

International Center for Biosaline Agriculture (ICBA)

- Non-profit applied research and development centre, based in Dubai
- Mission: To work in partnership to deliver agricultural and water scarcity solutions in marginal environments
  - Focus on a wide array of crops, water qualities and themes
- Major donors: UAE - Ministry of Environ. & Water, Environment Agency Abu Dhabi and Islamic Development Bank, IFAD, OFID and USAID
- Member of the recently formed **Association of International Research and Development Centers for Agriculture** (AIRCA) that also includes (CABI, CATIE, AVRDC, ICIMOD, ICIPE, IFDC, INBAR and CFF)

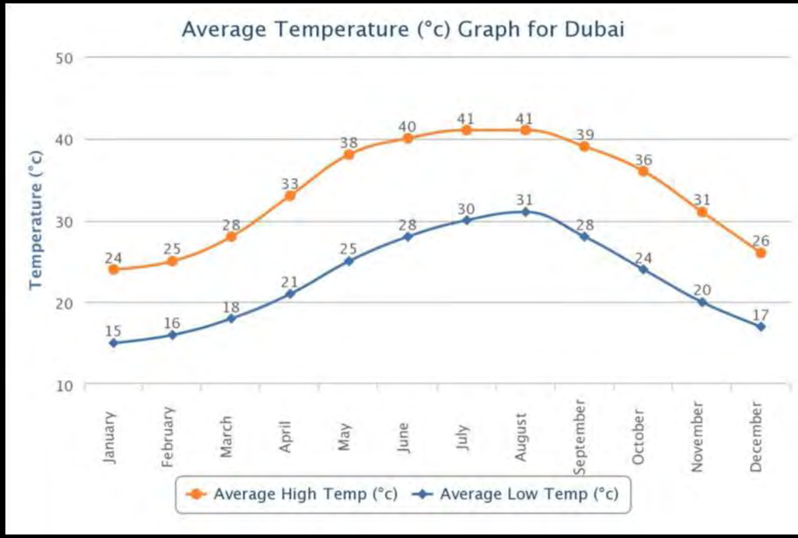


NUS for diversification of production systems – R & D at ICBA

- Diversification of production systems based on alternative crops has been ICBA's main strategy to sustain agricultural and economic growth in marginal areas
- ICBA seed genebank – over 12,000 accessions of 225 species assembled to provide source of genetic diversity for R & D in marginal areas – initial focus on forages and salinity
- Several under-utilized forage species were studied for biomass and seed yield potential
  - ✓ Salt-tolerant genotypes of pearl millet, triticale, buffel grass, etc. were identified and successfully introduced to several countries of WANA and CA
- Recent focus on species for food and bioenergy production in marginal areas

Climate, soil and water characteristics at ICBA research station

- Daily mean temperatures range between 19° (January) and 35°C (August)
- Rainfall: 94 mm, occurs during winter months, very erratic
- The soils are sandy (sand 98%, silt 1%, and clay 1%), poor with very low organic matter (<1%), calcareous (50–60% $CaCO_3$ equivalents), and moderately alkaline (pH 8.22)
- Ground water highly saline – about 15-25 dS/m (9000-15,000 ppm)



NUS currently under investigation at ICBA

- ✓ Mustard (*Brassica juncea*) – Food, Edible oil
- ✓ Quinoa (*Chenopodium quinoa*) – Food, Forage
- ✓ Guar (*Cyamopsis tetragonoloba*) – Food, Industrial
- ✓ Glasswort *(Salicornia bigelovii)* – Food, Bioenergy
- ✓ Safflower (*Carthamus tinctorius*) – Edible oil, Ornamental
- Amaranth *(Amaranthus spp.)* – Food , Forage
- Castor (*Ricinus communis*) – Bioenergy, Industrial
- Wild melon *(Citrullus colocynthis)* – Bioenergy, Pharmaceutical
- New Zealand spinach (*Tetragonia tetragonioides*) - Food
- Purslane (*Portulaca oleraceae*) – Food

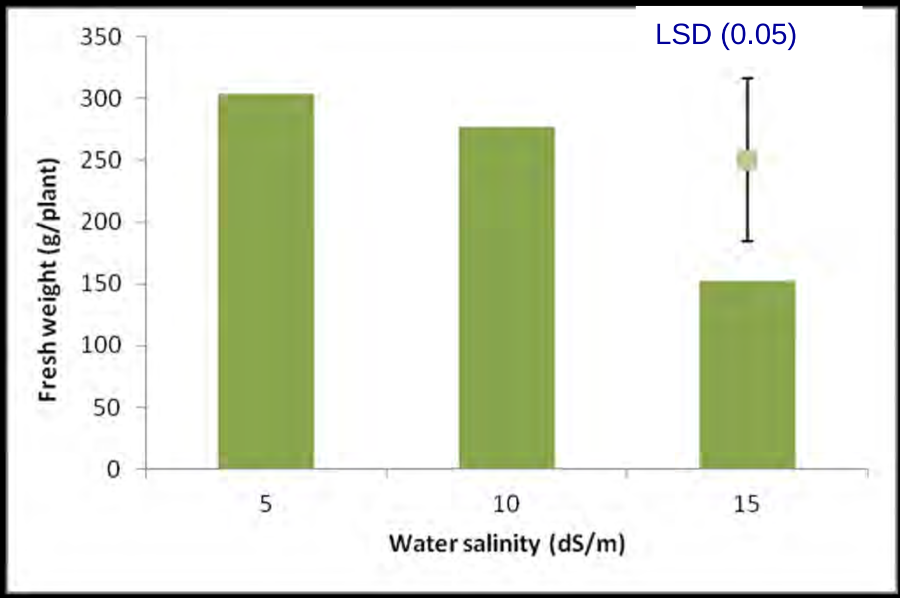
Mustard Green (*Brassica juncea* (L.) Czernj & Cosson)

- Winter crop native to the Himalayan region of India – belongs to Brassicaceae
- Cultivated for young tender green leaves and edible oil from seeds
- Excellent source of vitamins K (497 µg), C (70 µg), A (10,500 IU) and folic acid (187 µg) (all per 100 g)
- Second only to Brussels sprouts in terms of total glucosinolate content that has cancer-preventive properties
- More salt tolerant than the commonly grown leafy vegetables lettuce and spinach, water requirement being very similar

Leafy mustard - salinity trial

- 100 accessions from Australian Tropical Crops and Forages Germplasm Center (ATCFGC) – Agromorphological characterization
- 12 accessions selected for leafiness further evaluated
- Six top-performing accessions were studied for salinity tolerance using 5, 10 & 15 dS/m irrigation water.
- Average green biomass decreased by about 9% and 50% by increase in salinity from 5 to 10 and 15 dS/m (respectively)
- In terms of relative tolerance to salinity at 15 dS/m, ATC 93471 and ATC 93569 were outstanding

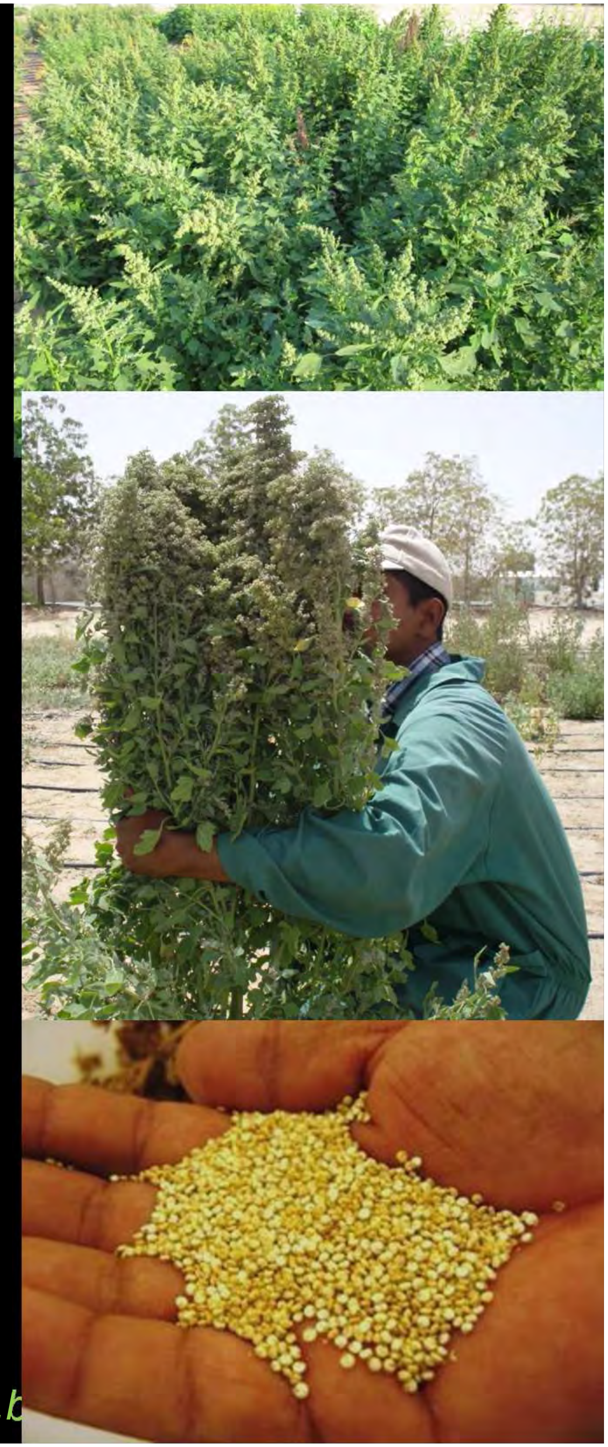
ATC 90333-1	Moderately tolerant
ATC 93569	Highly tolerant
ATC 93471	Highly tolerant



Effect of salinity on green biomass (mean of 6 genotypes)

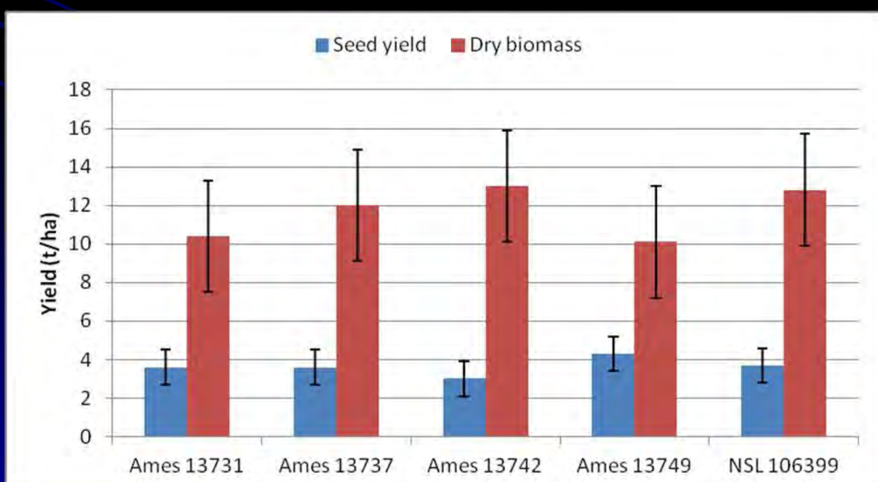
Quinoa (*Chenopodium quinoa* L.)

- Facultative halophyte with unusually high salt tolerance – Native to the Andes region and member of the family Chenopodiaceae
- Seeds used as breakfast cereal, to make soup, for brewing beer and also as animal feed
- Leaves used as vegetable and green biomass as animal fodder
- Wide adaptation to a range of climates and growing interest in organic farming
- Highly nutritious seeds with 12-16% protein and well balanced amino acid contents
- FAO has named 2013 "the international year of quinoa".



Quinoa…

- 5 top-ranking accessions (selected from 60 accessions received from USDA) were studied for grain and biomass yield potential in 2009-10
- Mean grain (456.6 g/m^2) and dry matter (1,464 g/m^2) yields obtained were much higher than the average yields (2 and 8.8 t/ha, respectively) from the Andes (Rao & Shahid, 2012)



Quinoa performed well when planted in salt-affected farms in the Western Region, Abu Dhabi emirate and also in Yemen

Guar (*Cyamopsis tetragonoloba* (L.) Taub.

- Guar (also known as clusterbean) is a summer annual legume known for its drought tolerance
- High level of salt tolerance and low water requirement
- Many economic uses – guarbeans (pods) are used as vegetable
- Guar gum has many industrial applications
  - ✓ Stiffener in ice cream, instant puddings and as a meat binder, in cloth and paper manufacture, explosives, ore flotation, etc.
- Guar is also grown for cattle feed and as a green manure crop

Guar…

- 100 accessions received from USDA studied for adaptation and yield potential in 2008-09.
- Ten top-performing accessions further evaluated for pod, seed and forage yields in summer 2010.
- Seed yields obtained were close (2,730 kg/ha) to the highest reported from the USA (Rao and Shahid, 2011)

Growth performance and yield of 10 selected guar accessions

Trait	Range	Mean ± SEM
Plant height (cm)	79.3–112.9	92.5±7.4
Pods/plant	**113–164.4**	**149.4±28.6**
Pod length (cm)	5.4–7.0	5.8±0.4
Pod width (mm)	6.3–7.3	6.6±0.2
Seeds per pod	6.9– 8.0	7.5±0.4
100 seed weight (g)	3.1–3.6	3.2±0.2
Seed yield (kg/m2)	**0.19–0.27**	**0.22±0.05**
Green Biomass (kg/m2)	3.4–3.9	2.8 ± 0.07

Some promising guar accessions
PI 263991
PI 263896
PI 323083
PI 158123
PI 158129

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Safflower (*Carthamus tinctorius* L.)

- Moderately salt-tolerant crop of the family Asteraceae, originated in the Middle East
- Survives long spells of drought due to strong and profound root systems
- Flowers have horticultural value, petals used as substitute for saffron
- Seeds contain 25-35% oil, nutritionally closer to olive oil
- Phenotypic diversity for quantitative and qualitative traits in 631 accessions from 11 countries was assessed
- Multivariate selection criteria for high biological and seed yield, long rosette period and no-few spines identified five accessions for subsistence farming systems in marginal areas (Jaradat and Shahid, 2006).

Safflower….

Safflower - Salinity tolerance studies

- 52 genotypes were studied over two seasons using saline irrigation with ECw of 10 and 15 dS/m.
- Salinity reduced grain yields by 75% and flower number by 25%
- Stability analysis identified 10 accessions adapted to high salinity (Fraj et al. 2013)

<u>Promising accessions for marginal areas</u>

PI 181866

PI 251262

PI 251985

PI 237550

PI 251285

Salicornia (*Salicornia bigelovii* Torr.)

- Halophyte from family Chenopodiaceae, grows wild in coastal areas of Mexico and the USA
- Young stem tips are edible – eaten raw, fried, pickled or as garnish in fresh salads
- Seeds contain 30% oil of high quality - great potential for edible oil and bioenergy feedstock production
- Grown on commercial scale in Mexico and Eritrea
- Encouraging results at ICBA in field trials with seawater
    - ✓ Number of spikes/plant : 70 and 152
    - ✓ Green biomass yield: 3.3 kg/m^2 to 4.6 kg/m^2
    - ✓ Maximum seed yield:1 t/ha
- ICBA collaborating with MASDAR Institute (USA) to evaluate the potential for biodiesel production

(Source: Jaradat and Shahid, 2012; Shahid et al. 2013)

Conclusions

- NUS have a crucial role to meet the food and nutritional security and improve the livelihoods (through income generation) in marginal environments
  - ✓ Greater resilience compared to staple crops contributes to reducing the risks against unpredictable environment
  - ✓ Present alternatives and opportunities to farmers and markets
- ICBA is working on several NUS as part of its strategy to mitigate the affects of salinity, heat and water stress in production systems
- Selection of appropriate species/genotypes to match the growing environment, adaptive and developmental research are very crucial to derive economic benefits from NUS
- Partnerships and sharing of resources, including germplasm, data, knowledge and experience can maximize the contribution of NUS to global food security and improved livelihoods of the poor farmers from marginal areas

Key messages

- Dedicated R & D program(s) and resource allocation by NARS – Integration into climate change adaptation research?
- Crop/agro-climatic suitability maps and simple models to evaluate the suitability of a species for a given geographic region and changing climates
  - ✓ Need database with geographic distribution of NUS, soil properties (soil texture, soil pH, and soil drainage) and climate variables (daily maximum and minimum temperatures, precipitation and growing days)
- Global knowledge platform for sharing/dissemination of information, including good and bad examples, cultivation/marketing/use, case studies, lessons learned from experience, on a variety of scales from local to international.

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Thank you