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LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

Sweet sorghum: a multiple-purpose crop for water-limited and low-input systems

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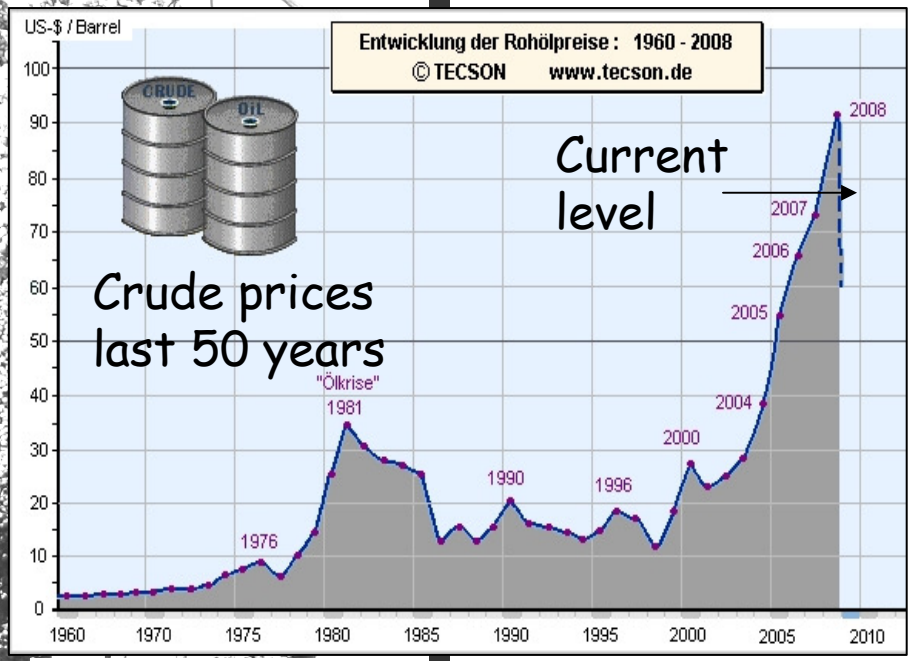
Sweet Fuel

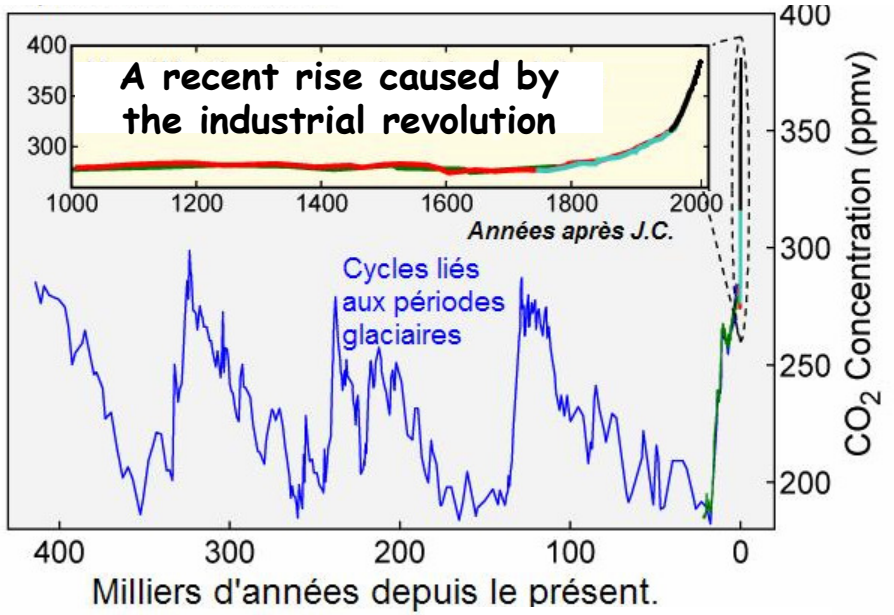
Context (1)

The world needs to diversify its energy sources:



http://inflation.free.fr

Atmospheric CO_2 last 400 000 years



(source: http://wikipedia.org)

➡ Biofuels will be in demand

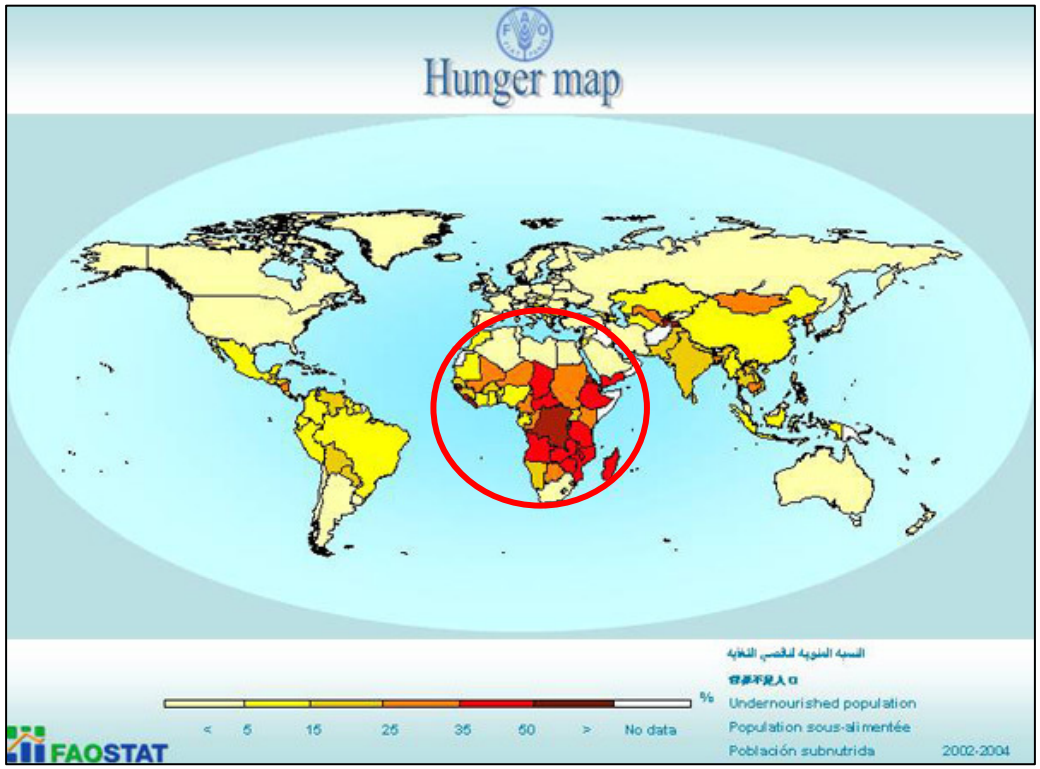
➡ An agricultural revolution is on its way

Context (2)

Energy prices force poorest countries to grow biofuel crops

- Less arable surfaces available for food production
- Increasing staple food world market prices (good for producers, bad for urban consumers)

→ → **Food security in peril**



Which plants ?

Candidate crops for bio-fuel production in the tropics

Sugar Cane
- No.1 Bio-EtOH
- C4
- Brazil
- Intensive crop
- Irrigation !

Jatropha
- Africa's current bet
- Bio-Diesel
- +/- dry environments

Oil Palm
- Bio-Diesel
- SE Asia
- Intensive crop

Sweet Sorghum
- Annual crop
- Grains (staple food crop of savannahs)
- Sugars in stems (=> Bio-EtOH)
- C4 : semi-arid zones, poor soils

+ maize, rape seed, cassava…
(almost any staple food crop)

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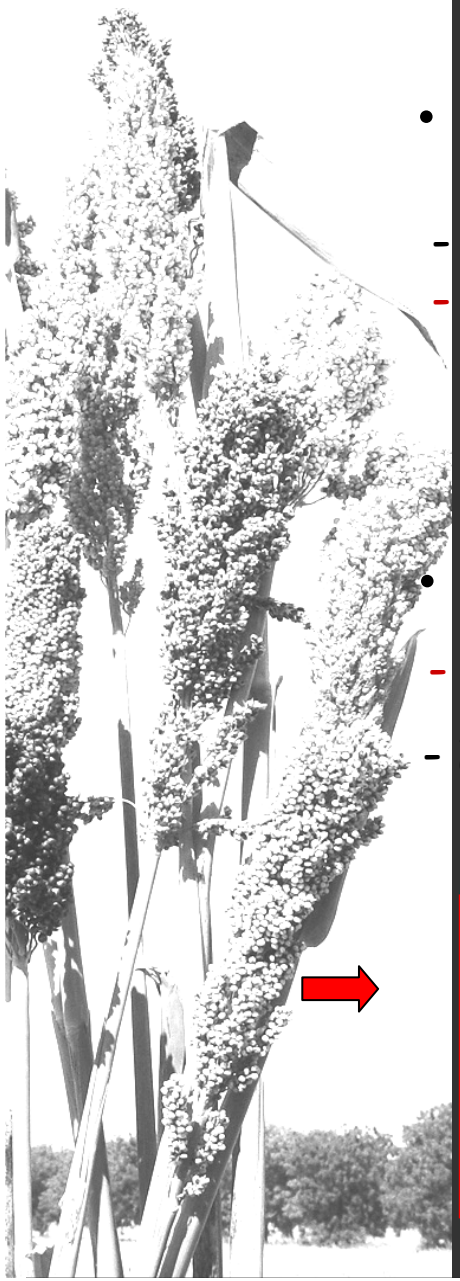

For what type of bio-fuel ?

- Bioethanol *vs.* Biodiesel

- Biodiesel : Triglycerids stored in fruits (oil palm, Jatropha…)
- EtOH : Alcoholic fermentation of sugars
  - Grains: hydrolysis of starch
  - Stems: soluble sugars in extractable juice

- 1st vs. 2nd generation of bioethanol

- 1st : soluble sugars & starch (available technology)
- 2nd : all biomass incl. ligno-cellulosics (future technology)

Promising path for the tropics:

Sweet sorghum for the combined production of grain for food and 1st generation Bio-EtOH

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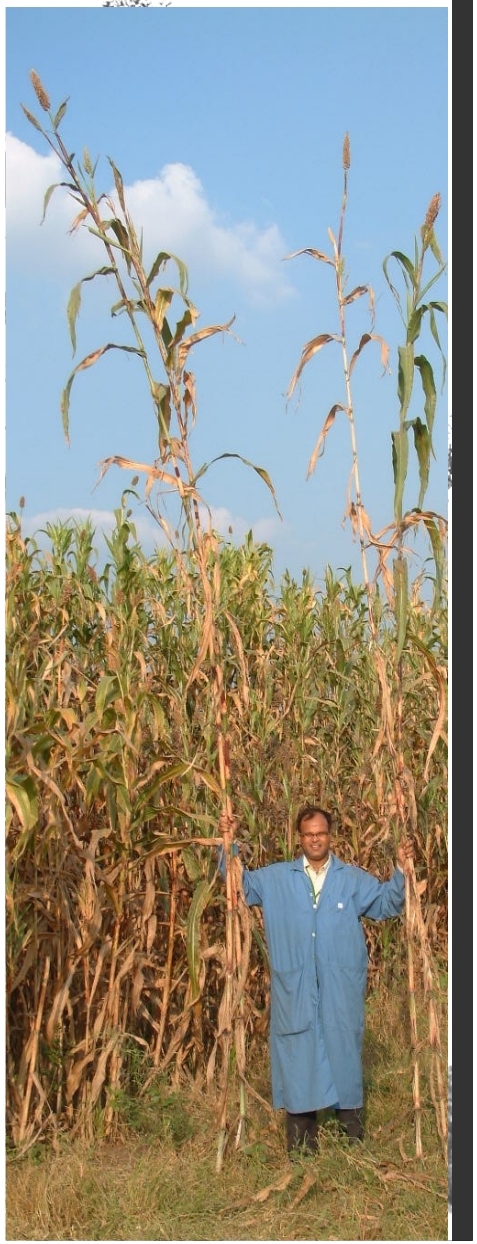


Sweet sorghum

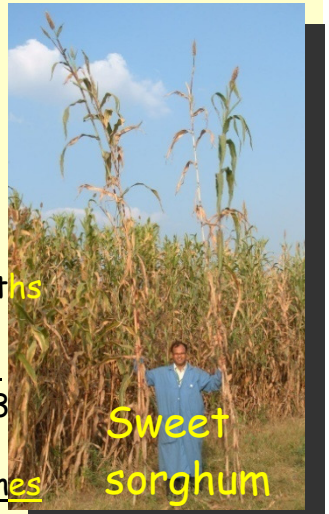
A 'sugar cane' that produces grain, is drought tolerant, and…

- 20-40 t/ha dry matter (stress free conditions)
- 2-6 t/ha grains
- Soluble sugars (80% sucrose) in stems
  - 16-23 % Brix at dough stage (similar to sugar cane)
  - 12-18 % Brix at grain maturity
- Excellent forage quality
- Tolerant of poor soils and drought
- Produces ethanol at lower price compare with corn in temperate zone

Why producing ethanol from sorghum ?

Tropical zone

VS



Propagation
Cuttings seeds

Length of cycle
12-16 months 4-5 months

Water requirements
36 000 m3 8000 m3

Adaptation to dry zones
Irrigation yes

Adaptation to marginal soils
Cane << sorghum

Grain production
0 >> up to 6T / ha

Ethanol production (l ha-1)
6500 5600

Uses
Fuel Food, Feed, Fu

ADVANTAGE SORGHUM

Temperate zone

VS

Intrant needs
orghum << maize

WUE (kg H2O kg-1 DM)
310 | 370

Nitrogen Use Efficiency
sorghum >> maize

Adaptation to dry environments
sorghum >> maize

Adaptation to marginal soils
sorghum >> maize

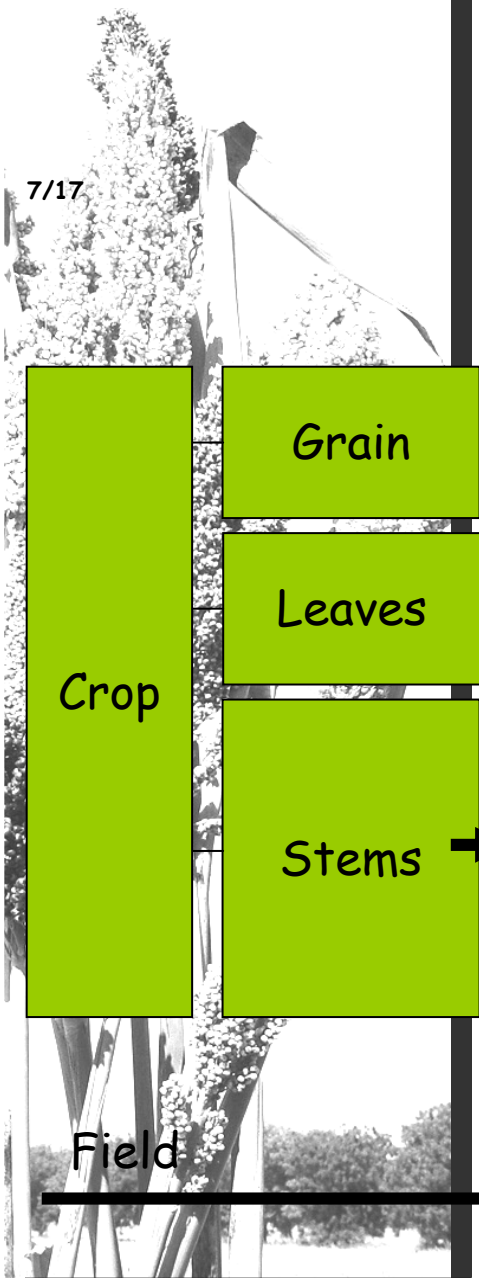
Hudge potential of improvement
Respect of environment
Development of rural zones
Low competition with food crop
Better sustainability of the production system

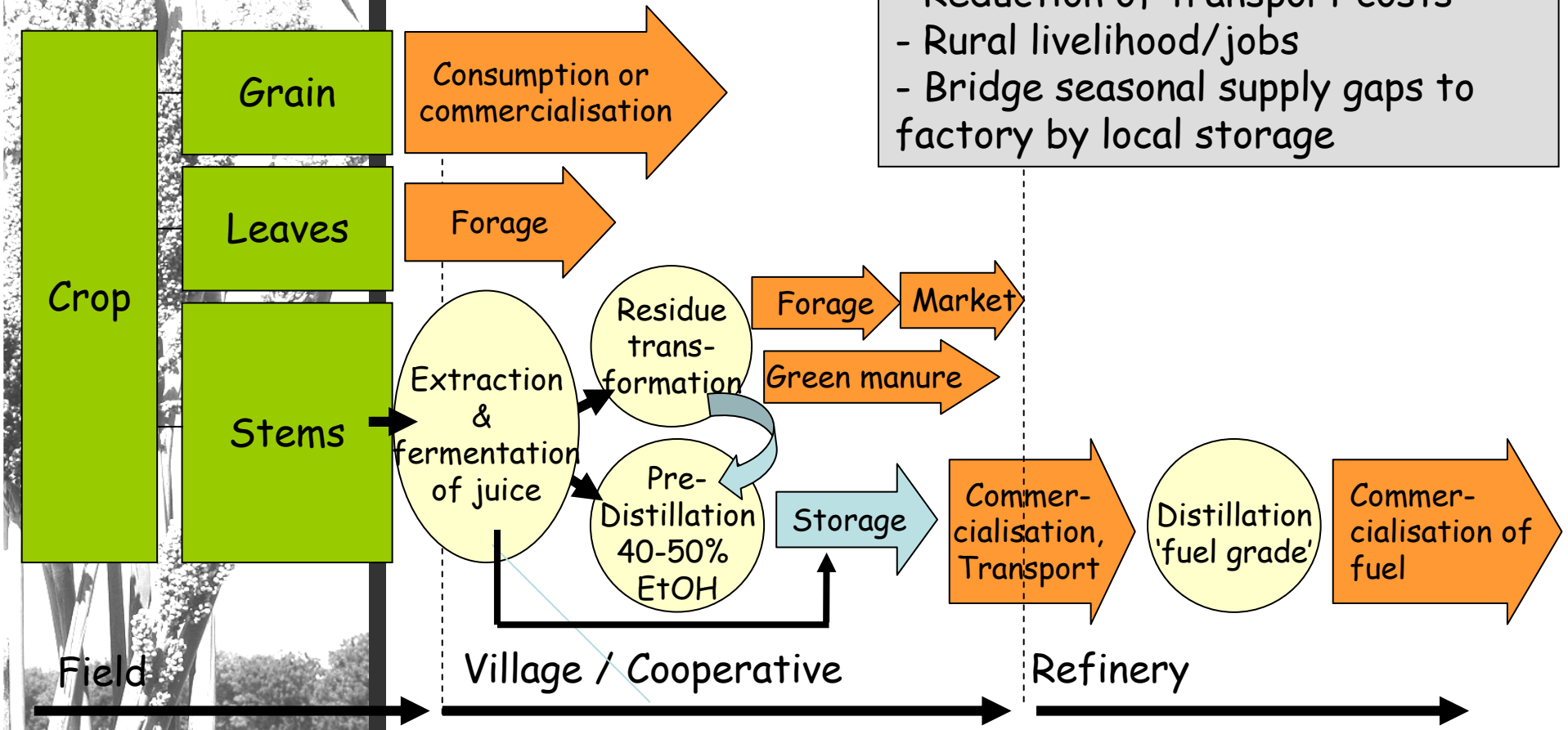
Biomass
ım ⇔ maize
40TDM ha-1)

ADVANTAGE SORGHUM

A multi-purpose crop:

Concepts for a decentralized production and processing system





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A Food-Feed-Fuel crop

Characteristics of proposed ideotype

-Modest **grain** yield (1,5-3,0 t/ha)

- High **sugar** concentration in stems (level of sugar cane)
- Thick and **juicy** internodes
- High **biomasse** due to relatively late maturity (30-40 t/ha)
- Good **digestibility** of residues for forage (bmr gene)
- « **Stay-green** » for:
    - maintainance of stem juiciness until maturity
    - tolerance to terminal drought
- Different genotypic levels of **photoperiod sensitivity** for:
    - fit into local cropping calendars and diversified cropping systems
    - fit to local climate and latitude

Genetic diversity of sorghum (CIRAD)

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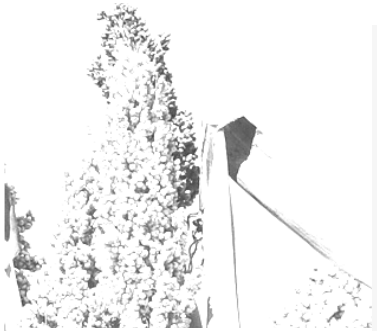
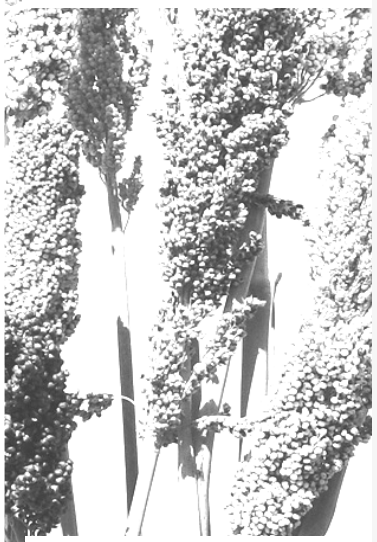
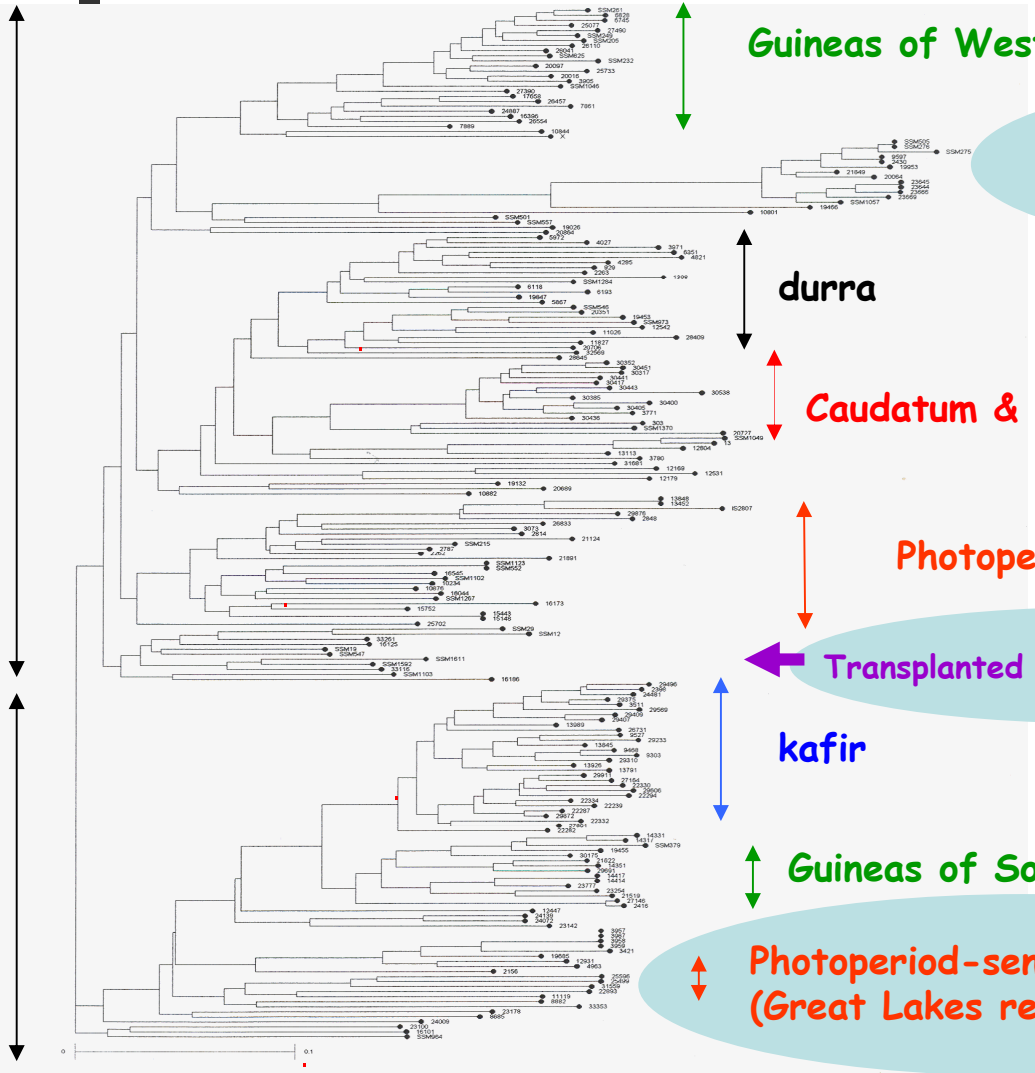


Hemisphere N



Hemisphere S



Guineas of West Africa

Margaritiferum guinea ('sorghum-rice')

durra

Caudatum & bicolor of China

Photoperiod insensitive caudatums

Transplanted sorghums (durra x guinea)

kafir

Guineas of South & East Africa

Photoperiod-sensitive caudatums (Great Lakes region)

10% of West African sorghums are sweet (bicolor and mixt forms)

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Biodiversity of sweet sorghums

(Study of Icrisat on 9000 accessions of the world collection)

Bicolor

Sweet sorghum genotypes are abundant in all genetic groups except kafir

Guinea

Durra

Caudatum

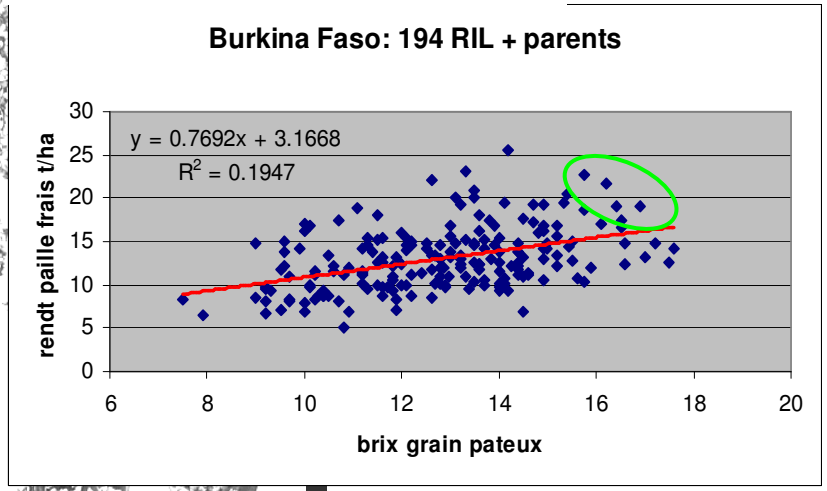
Kafir

Genetic diversity of useful traits

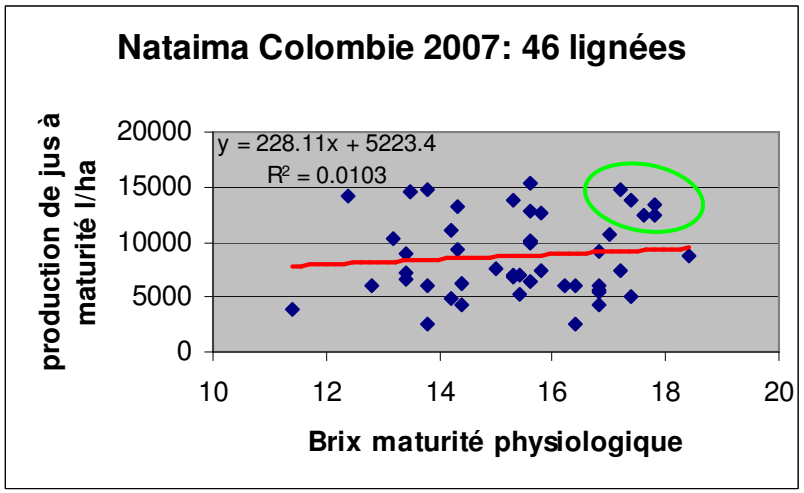
Sugar concentration vs. Biomass and Juice yield

(Sources : CORPOICA-CIRAD / MADR et CIRAD-INERA)

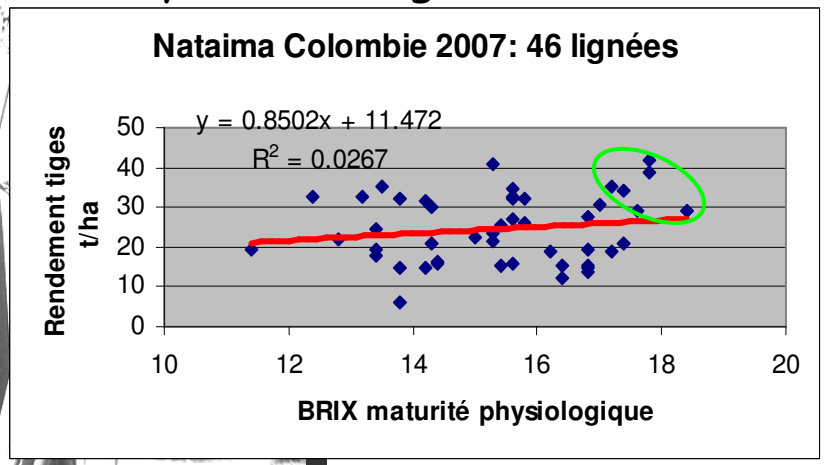
Biomass vs. Sugar conc.



Juice yield vs. Sugar conc.



Stem yield vs. Sugar conc.



No trade-offs between…

- Biomass & sugar concentration
- Stem yield and sugar concentration
- Juice yield and sugar concentration

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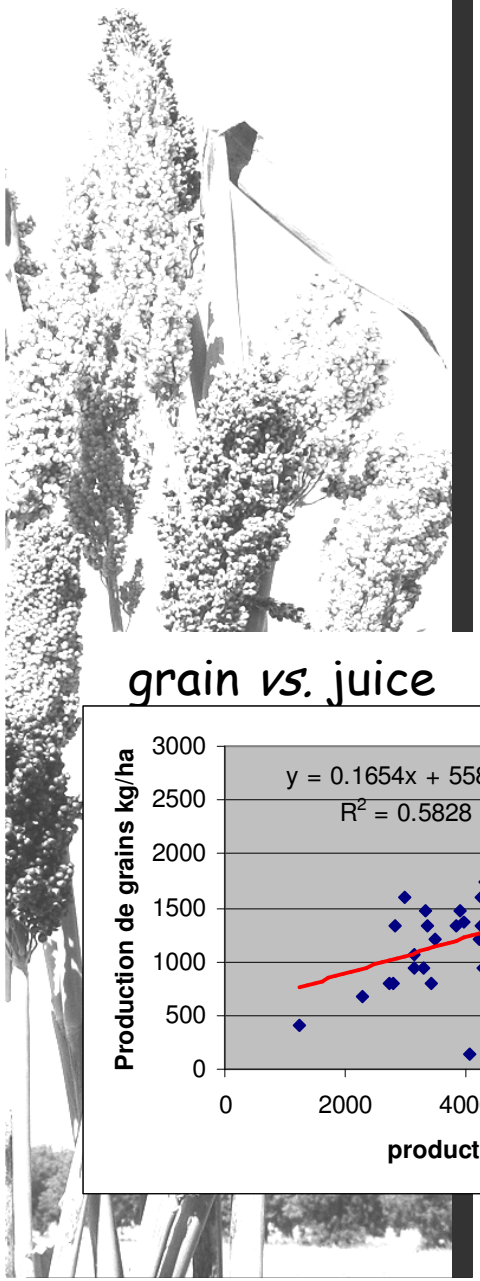
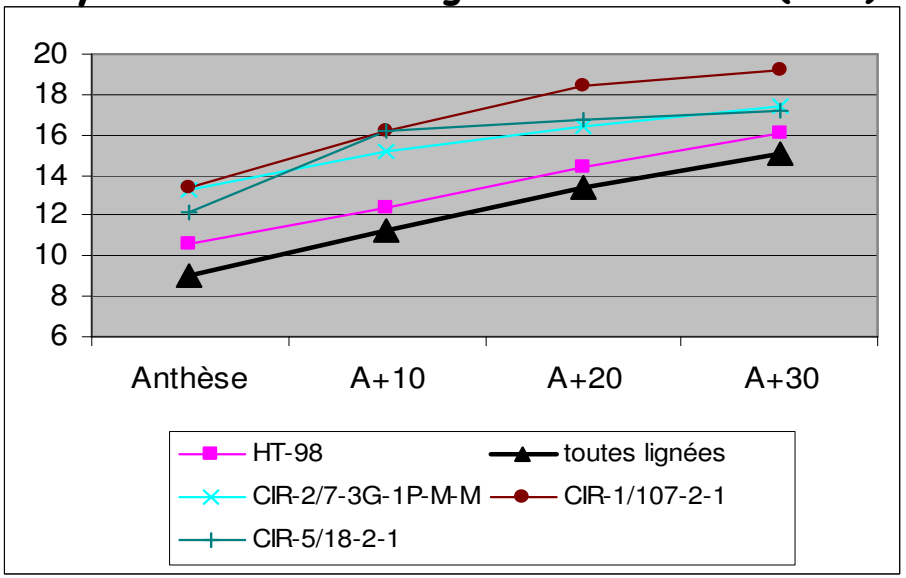


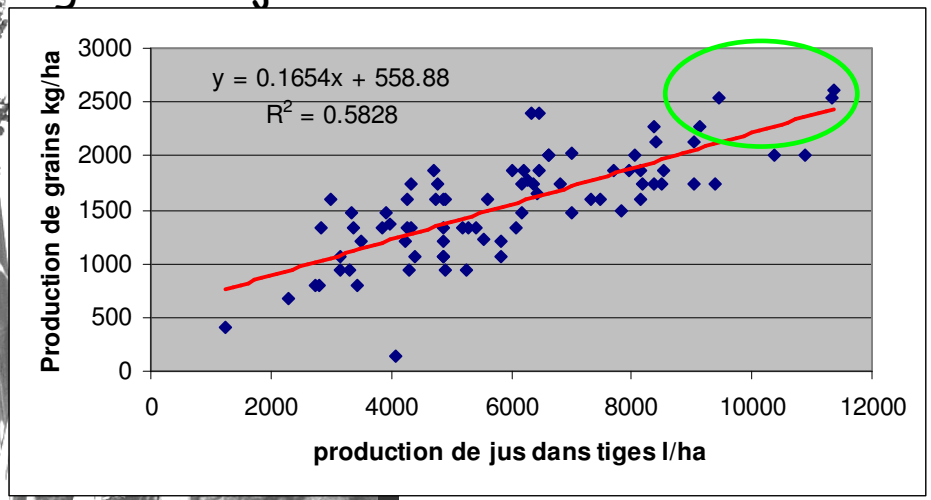
Genetic diversity of useful traits

(source: CIRAD/Nataima, Colombia 2007)

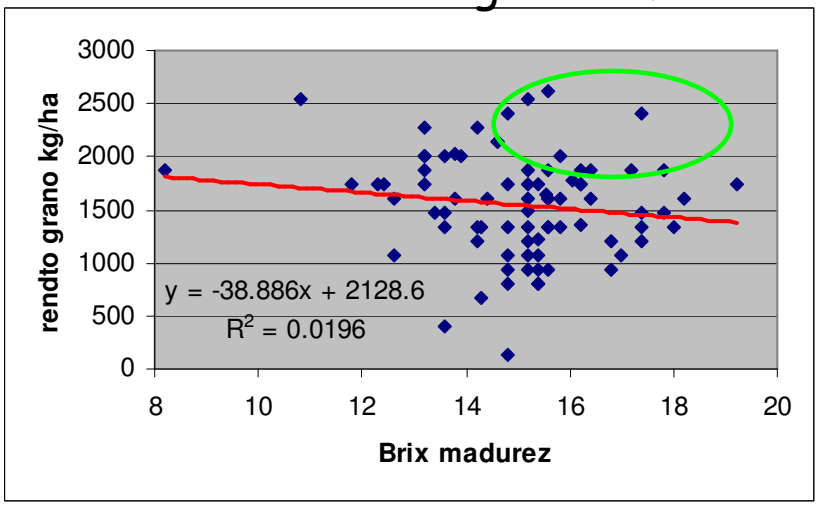
Dynamics of stem sugar concentration (Brix)



grain vs. juice

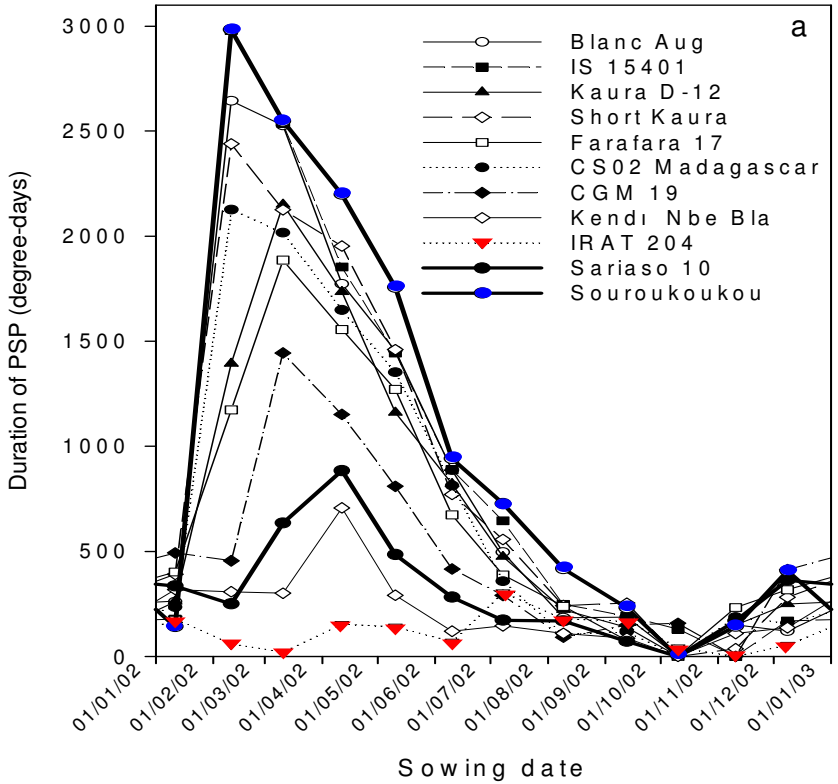


grain vs. Brix



Genetic diversity of useful traits

Flowering response to photoperiod



Source:
CIRAD/IER
Mali, 2002

Potential advantages:

- **drought adaptation through timing of flowering at end of rainy season**
- **greater biomass through longer crop duration**

Genetic diversity of useful traits

Donor materials for stay-green

- **Temperate regions**
  - **BTx 642** (=B35): Line derived from IS 12555 (Ethiopian durra landrace), USA
  - **KS 19:** Line derived from a Nigerian durra-caudatum landrace, Australia
- **Tropical regions**
  - **E 36-1** (Ethiopian caudatum landrace)
  - **IS 22380** (Sudan?)
  - **Kokologho** and **Pisnu** (caudatum landraces from Burkina)
  - …and more

Stay-green and sweetness are frequently associated

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Conclusion

- FFF (Food-Feed-Fuel) concept compatible with diversified, low-input systems
- Ideotypes and an «Ideosystem» were identified: decentralized processing
- Abundant genetic diversity available for ideotype traits (sweetness, juiciness, stay-green, photoperiod response)
- No or little physiological trade-offs among useful traits
- Introduction of new trait combinations (e.g., grain yield x bmr x sugar).

Thank you
Sweet Fuel
www.sweetfuel-project.eu