

REDEFINING R&D PROGRAMMES FOR A SUGARCANE INDUSTRY

MAY 2005

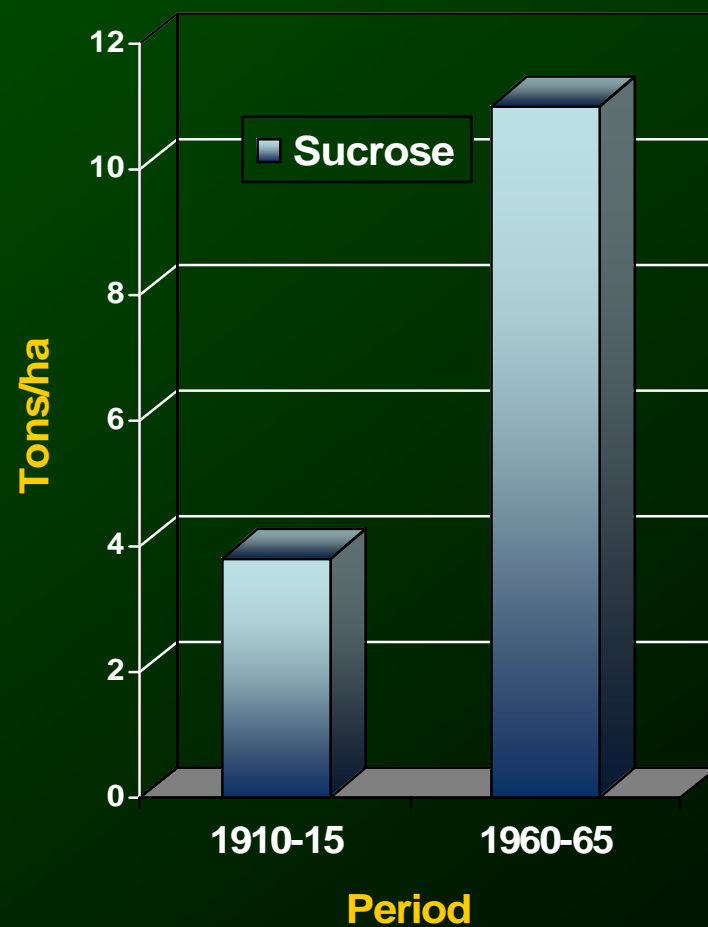
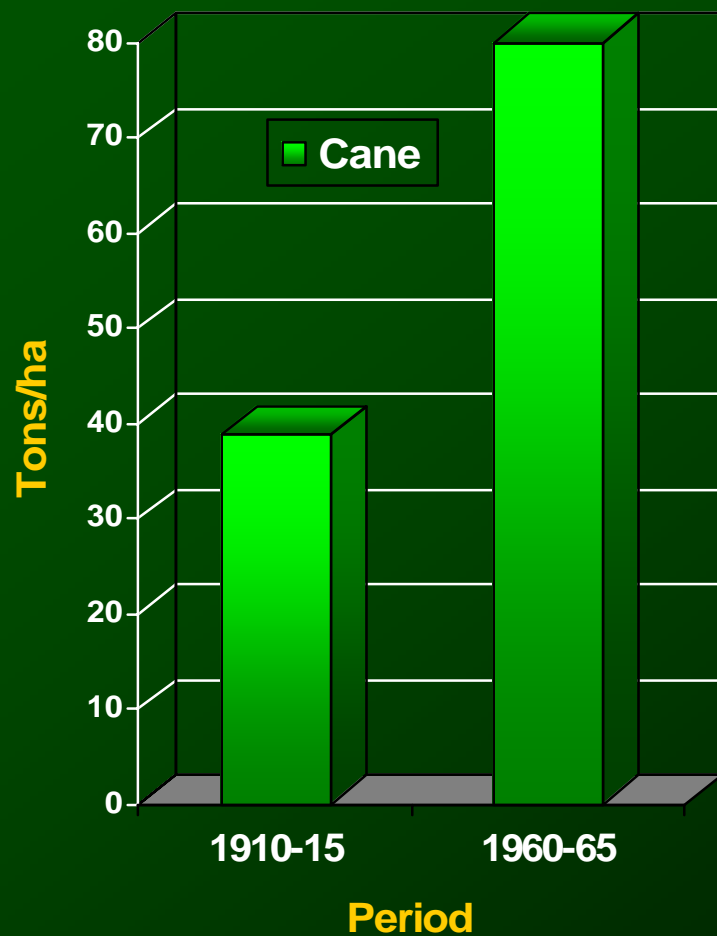


SOUTH AFRICAN SUGARCANE RESEARCH INSTITUTE

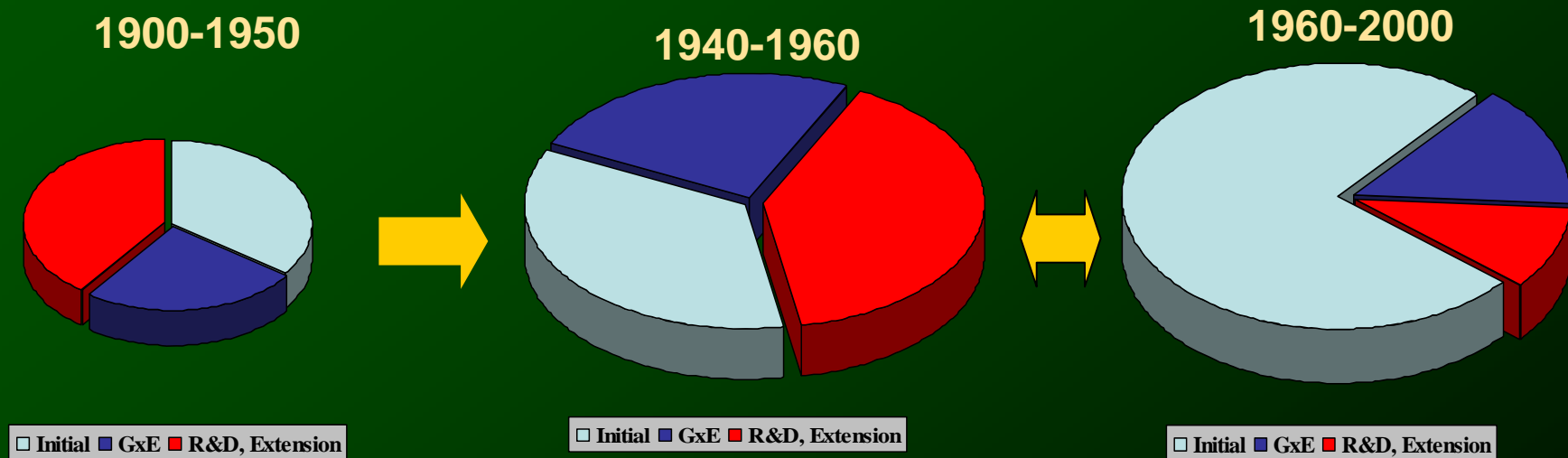
OUTLINE

- **The Sugar Industry**
- **Options for a Mature Industry**
- **What are the Opportunities**
- **Is Sugarcane a Good Option?**
- **Conclusions**

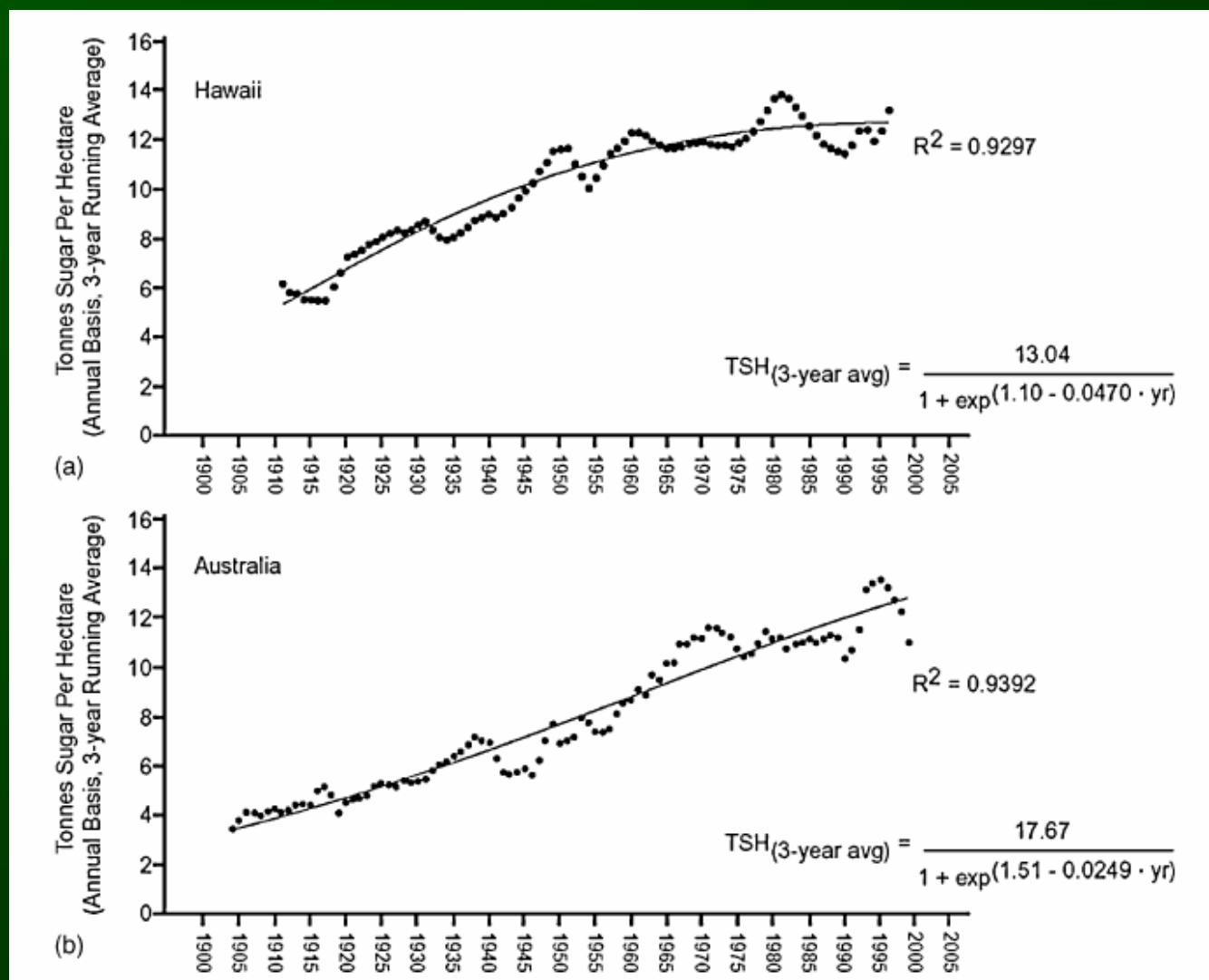
Sugarcane's Green Revolution



Does R&D still contribute?

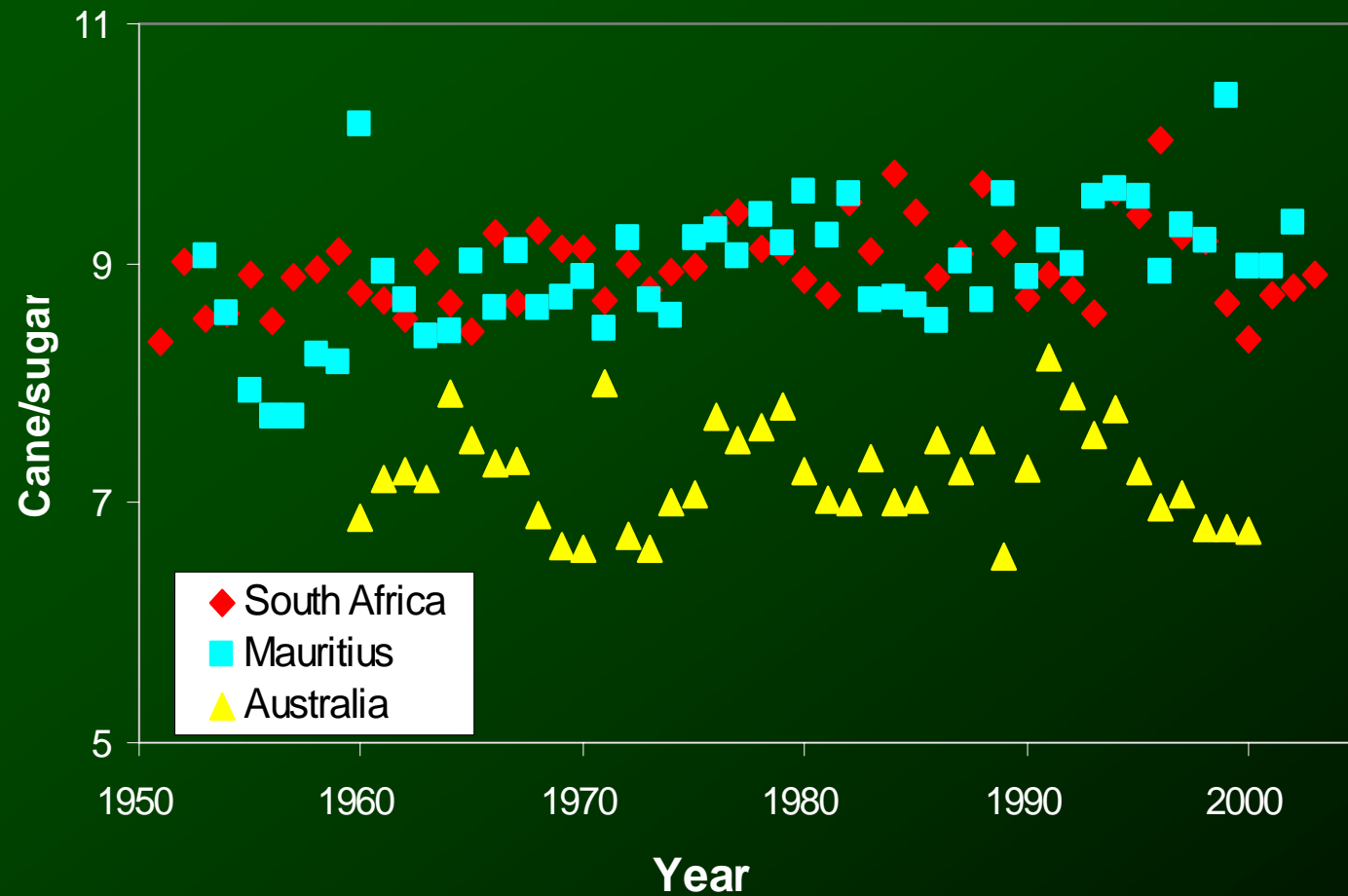


Historic Yield Data: Sugarcane

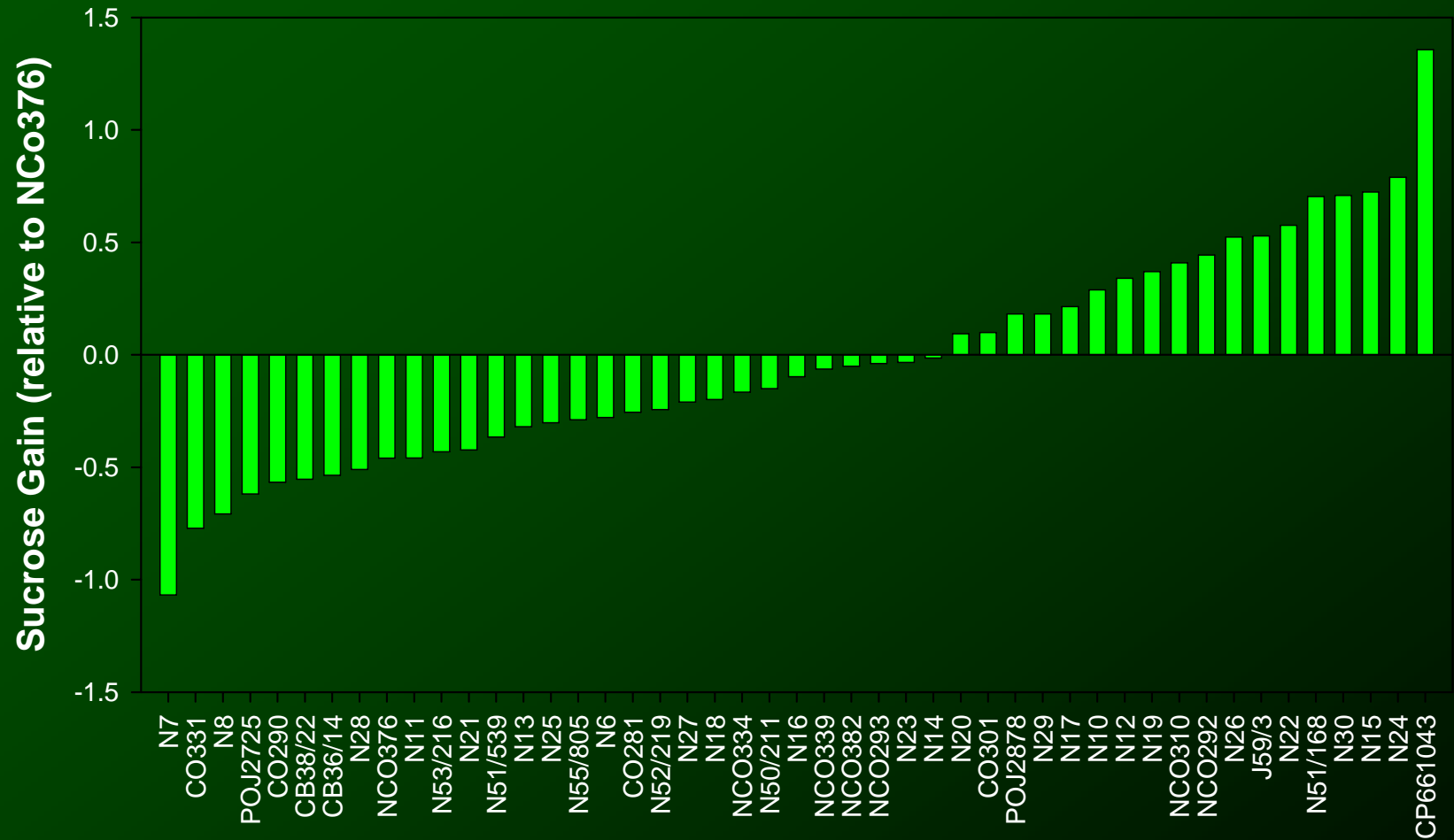


(From Moore 2005)

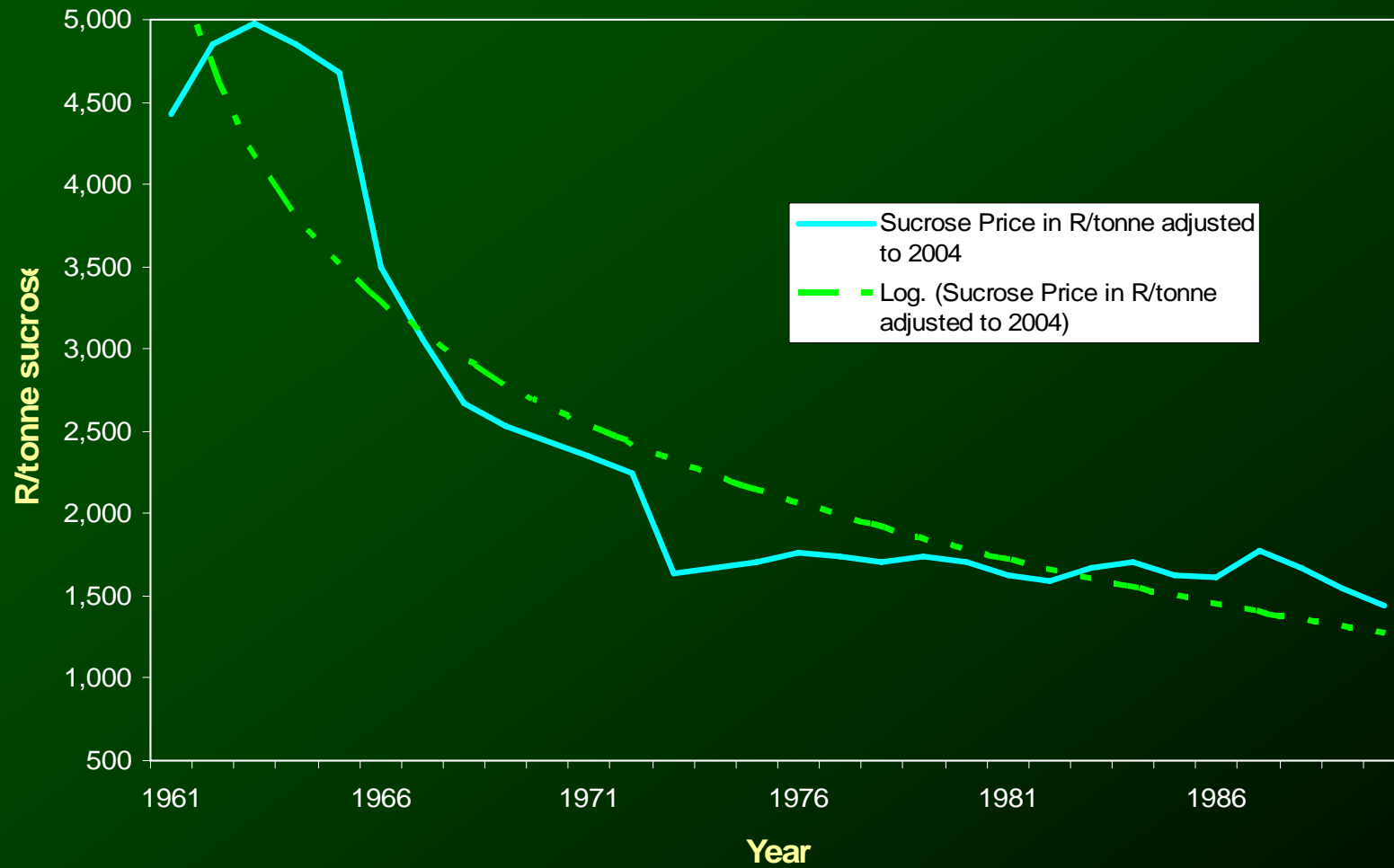
Sucrose Production from Cane



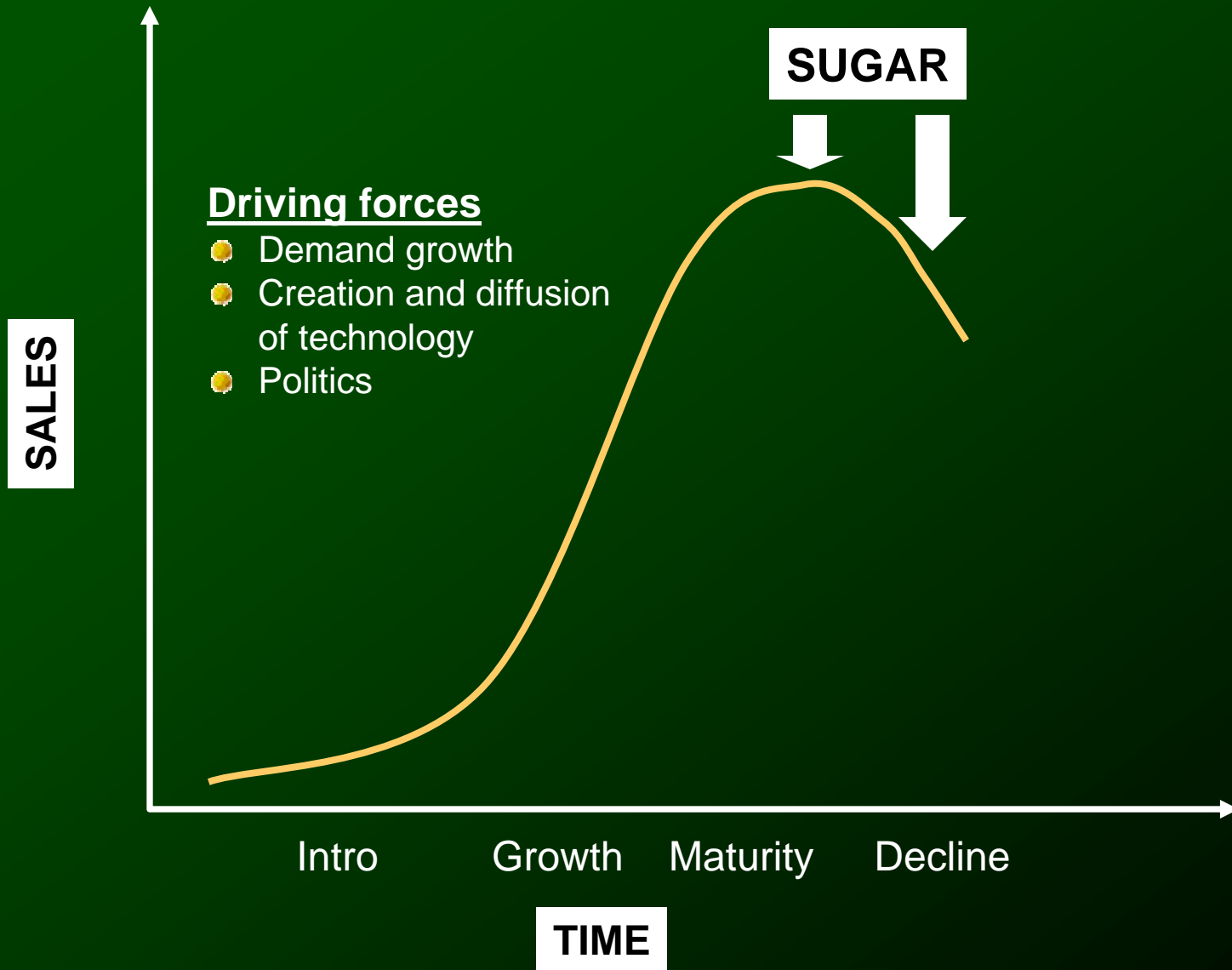
Sucrose – post ‘green revolution’ era



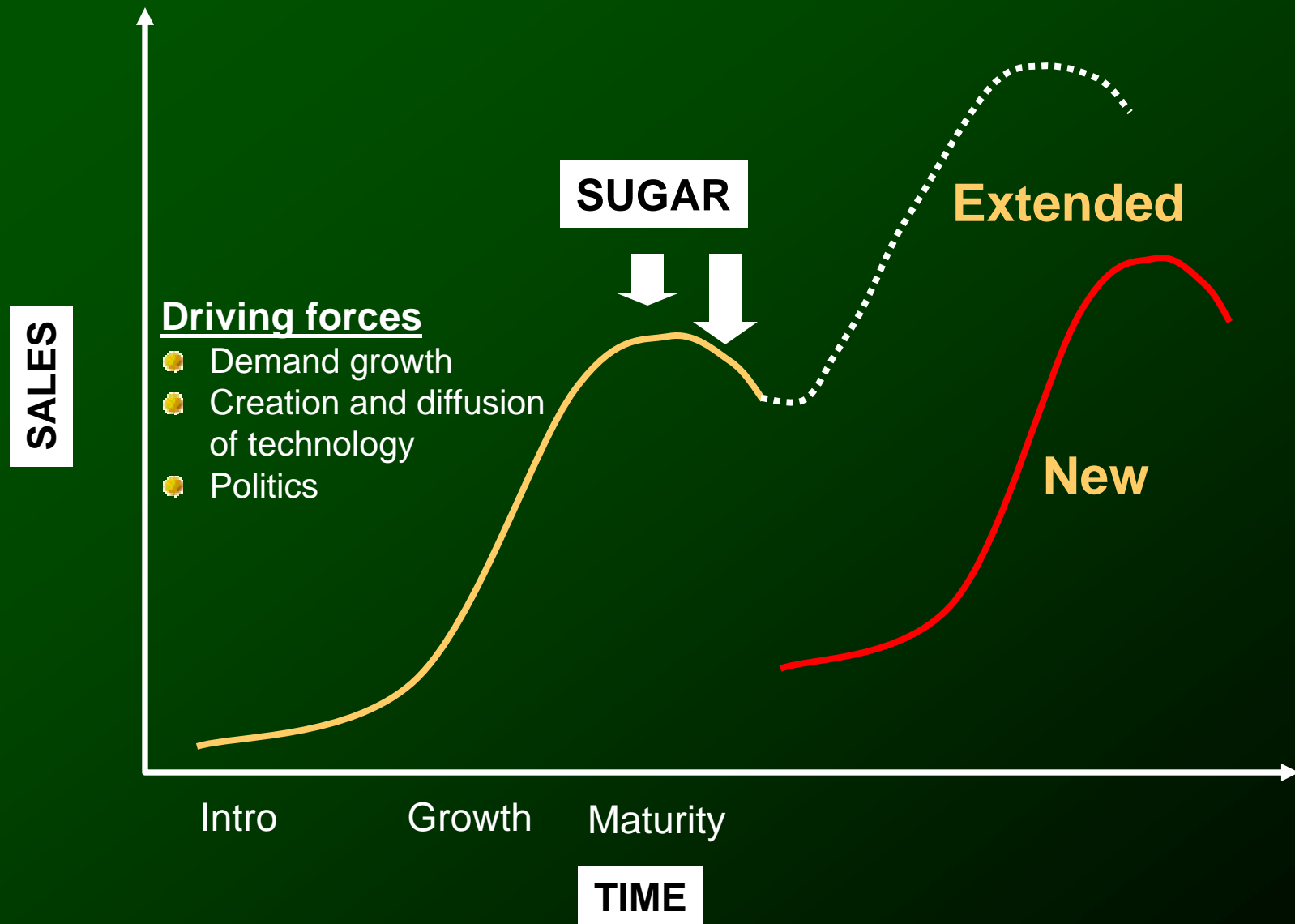
The International Sucrose Price



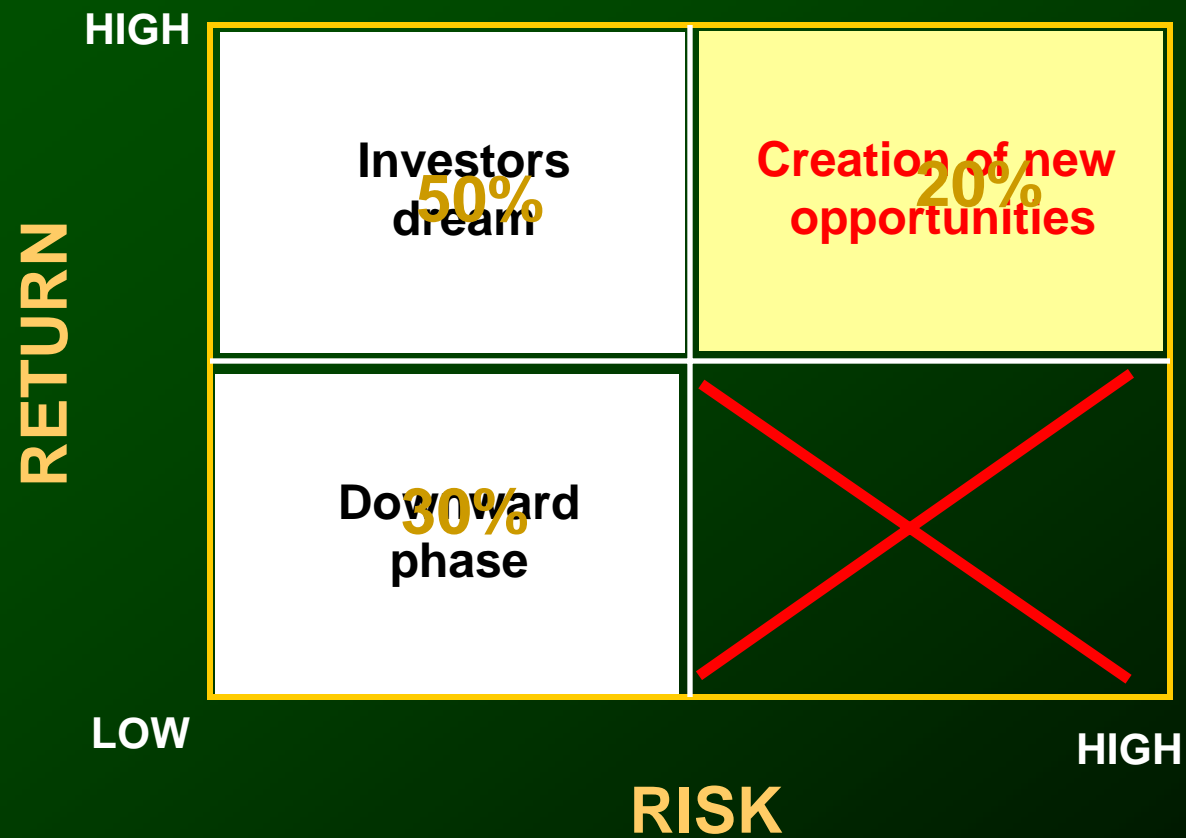
Industry Life Cycle



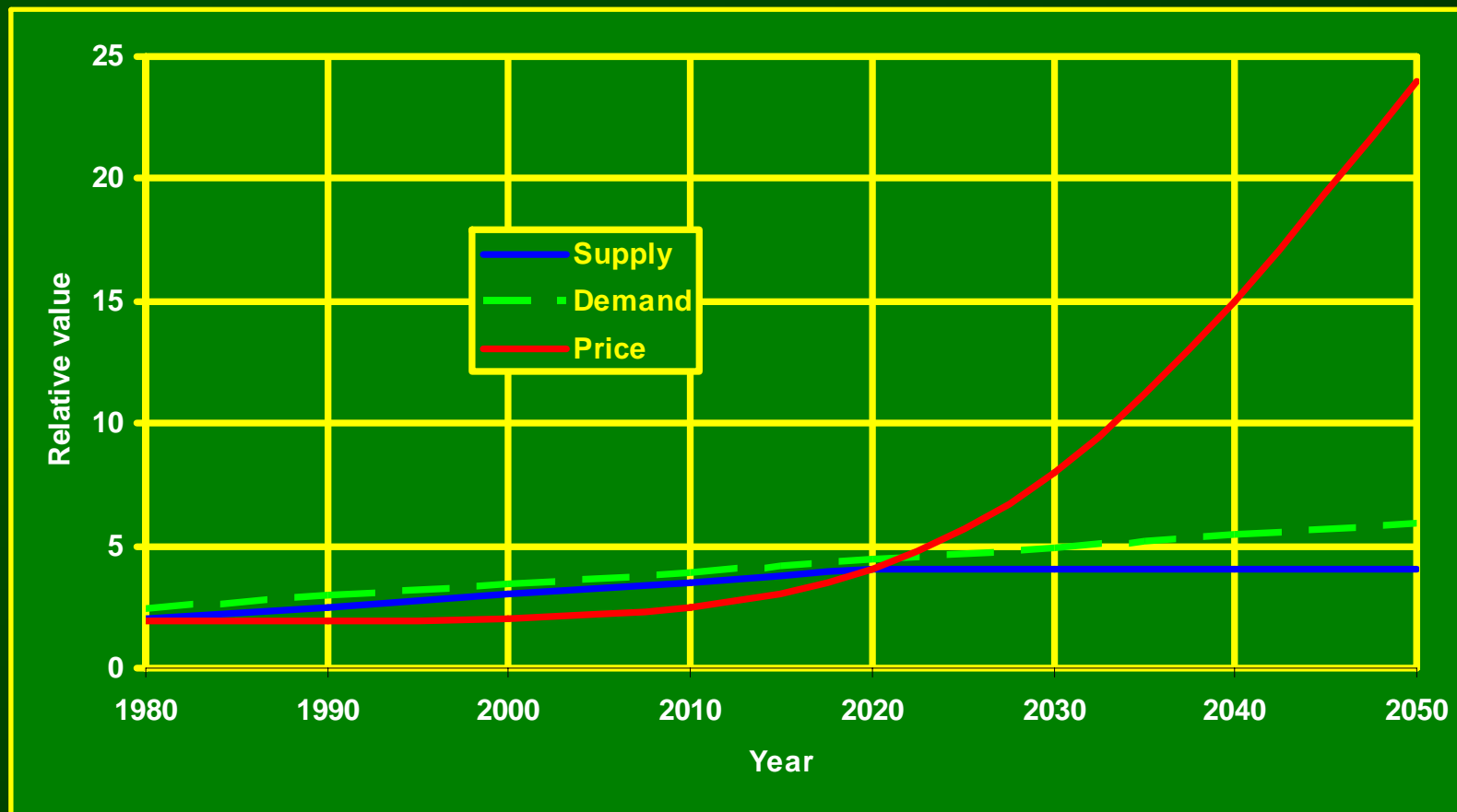
Changing the Fate of Industry Life Cycle



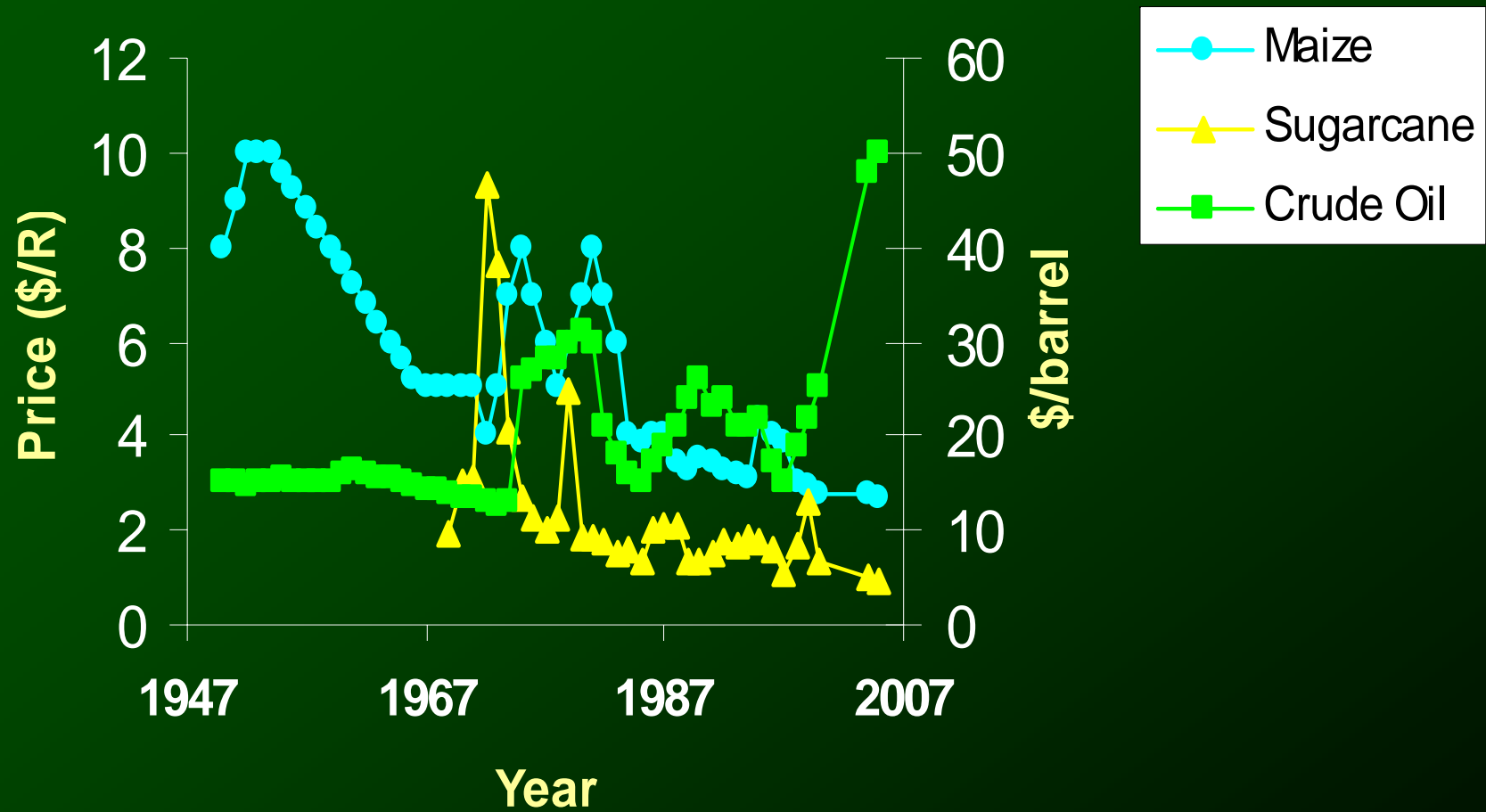
R&D Investment Profile



Demand and supply of fossil fuel



Crude product price – adjusted to 1996 dollar value



Plant-based versus petrochemical based raw material

Product	Production Million tons	Conventional \$/lb	Plant derived \$/lb	Plant derived %
Furfural	0.3	0.75	0.78	97
Adhesives	5.0	1.65	1.41	40
Fatty acids	2.5	0.46	0.33	40
Surfactants	3.5	0.45	0.45	35
Acetic acid	2.3	0.33	0.35	18
Plasticizers	0.8	1.5	2.5	15
Carbon black	1.5	0.5	0.45	12
Detergents	12.6	1.1	1.75	11
Pigments	15.5	2.1	5.81	6
Dyes	4.5	12.0	21.1	6
Wall paints	7.8	0.5	1.22	4
Inks	3.5	2.0	2.53	4
Special paints	2.4	0.81	1.75	2
Plastics	30.0	0.51	2.1	2

Transgenic technology is significant and moving rapidly



A new door has been opened on the opportunity for plant-based materials to provide useful sources of both molecular building blocks and more complex molecules for manufacturing industries

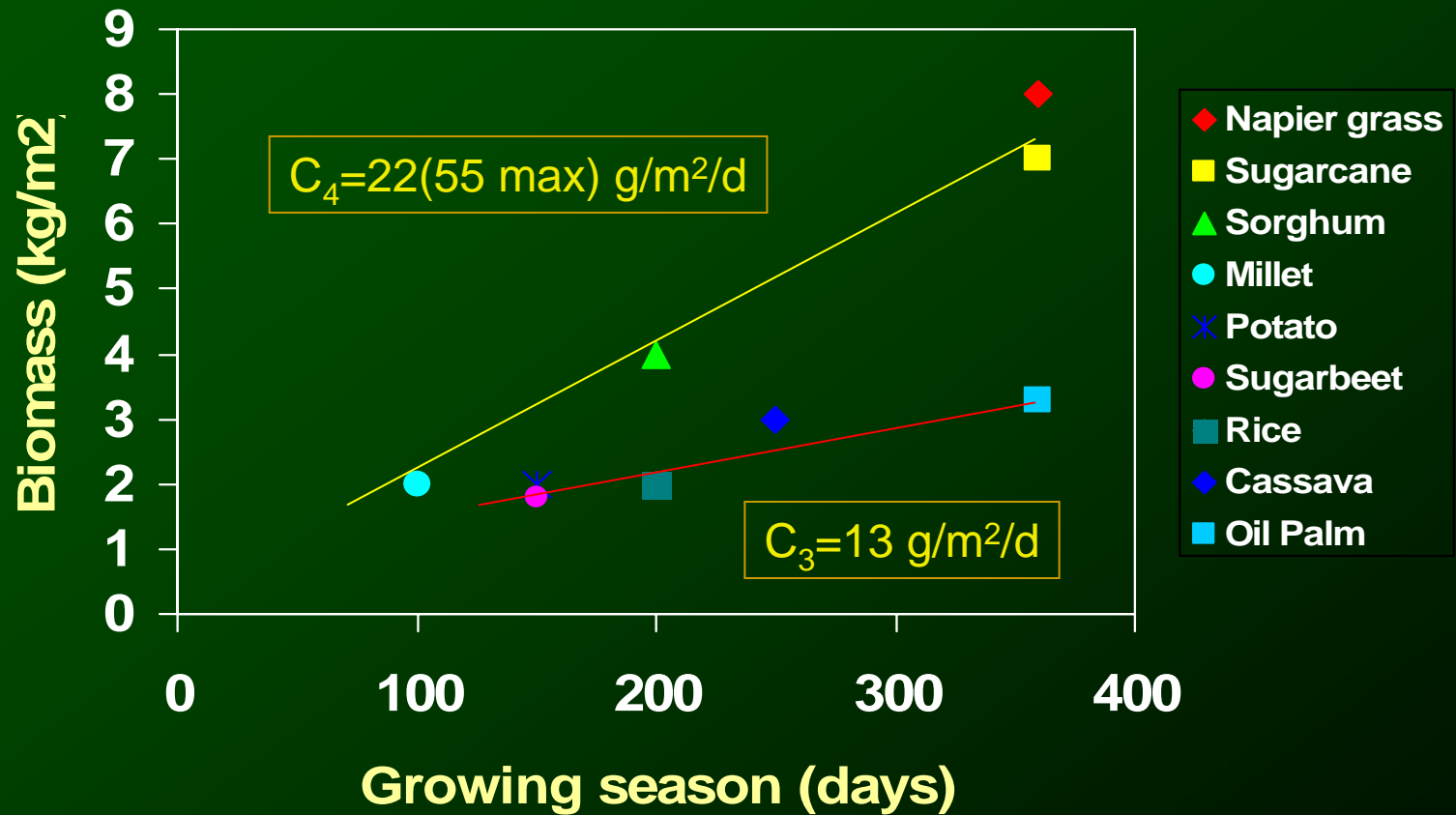
Why Sugarcane?

- The sugarcane is genetically complex hybrids bearing enormous potential for increased biomass and multiple-product yields
- They have been bred and optimised for one purpose only namely sucrose production
- Sucrose accumulation is probably a major obstacle for full realisation of biomass production potential
- Unfortunately huge lack of fundamental knowledge

Water use efficiency

Species	Water use efficiency Kg Water/Kg dry matter
Alfafa	850
Soybeans	650
Potatoes, Oats	580
Wheat	550
Sugar bet	380
Maize	350
Sorghum	300
Sugarcane	250

Biomass Production



Sugarcane Yields

Sugarcane yields are among the highest of any crop

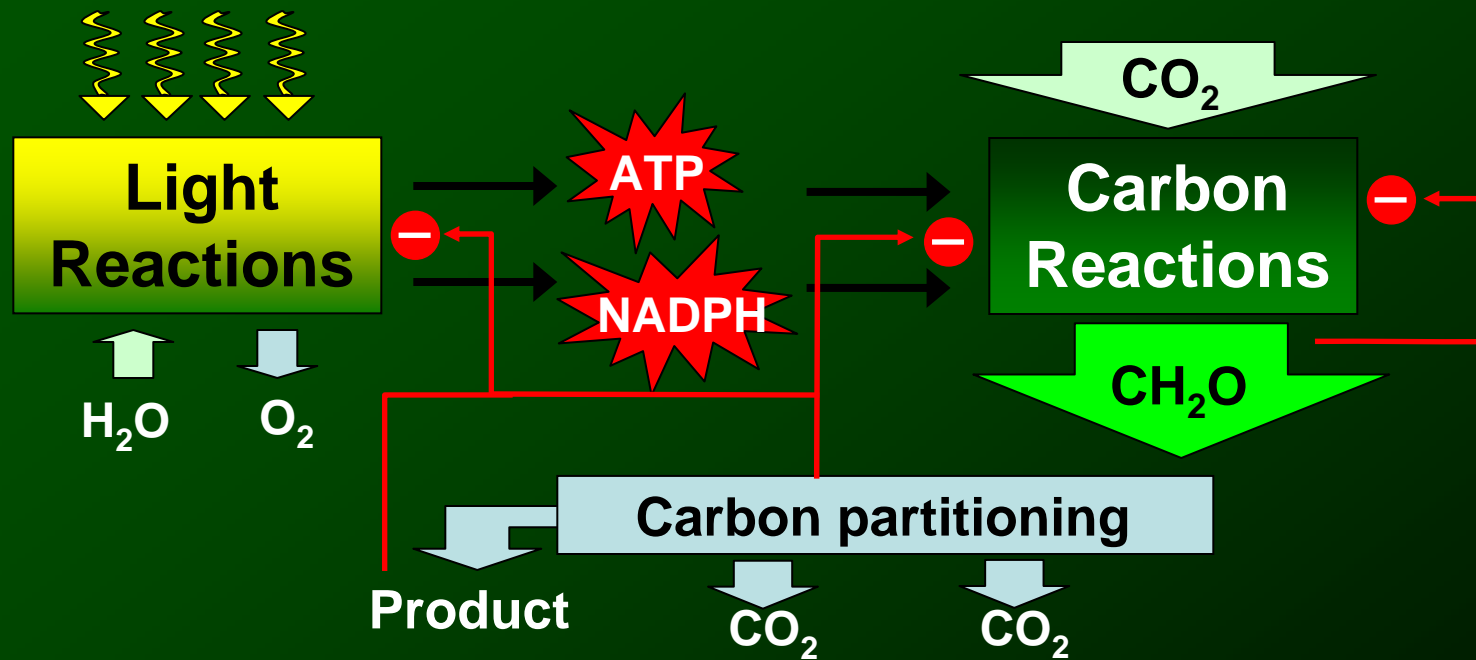
- 20-35 tons sucrose hectare⁻¹ year⁻¹
- 86 tons dry weight hectare⁻¹ year⁻¹ (Hawaii)
- 80 tons dry weight hectare⁻¹ year⁻¹ (Australia)

Management Practice and Yield

Management Emphasis	Green Yield (tons/hectare/Year)
Sugar	54.6
Sugar	80.3
Biomass	205.1

Varieties = NCo310, PR980 and PR64-1791

Biomass Production



$$\text{Biomass Prod} = \text{PAR} \bullet \text{RUE} \bullet \text{Stress} \bullet (1 - \exp(-\text{LAI}))$$

An 'Energy- cane' business

Long term

The plant breeders role to support an “energy-cane’ business will require improvements for:

- Higher tonneages of biomass i.e. more lignocellulose and fermentable solids
- High tonnages that are supportive of industrial conversion

Short to medium term

Major changes in production management

- Whole cane plant is the biomass resource
- The 70% non-sucrose becomes the main focus

Farming for Lignocellulose

Component	Biomass (tons/hect/yr)		Energy (mmBTU/hect/yr)	
	Sugarcane	E. cane	Sugarcane	E. cane
Total Sugars	7	21	101	301
Lignocellulose	11	50	168	778
Total	18	72	268	1079

Species	Cross& Bevan Cellulose	Alpha Cellulose	Lignin	Pentosans
	%			
Sugarcane	49-62	32-44	19-24	27-32
Softwood	53-62	40-45	26-34	7-14
Hardwood	54-61	38-49	23-30	19-26

A Plant packed with chemicals

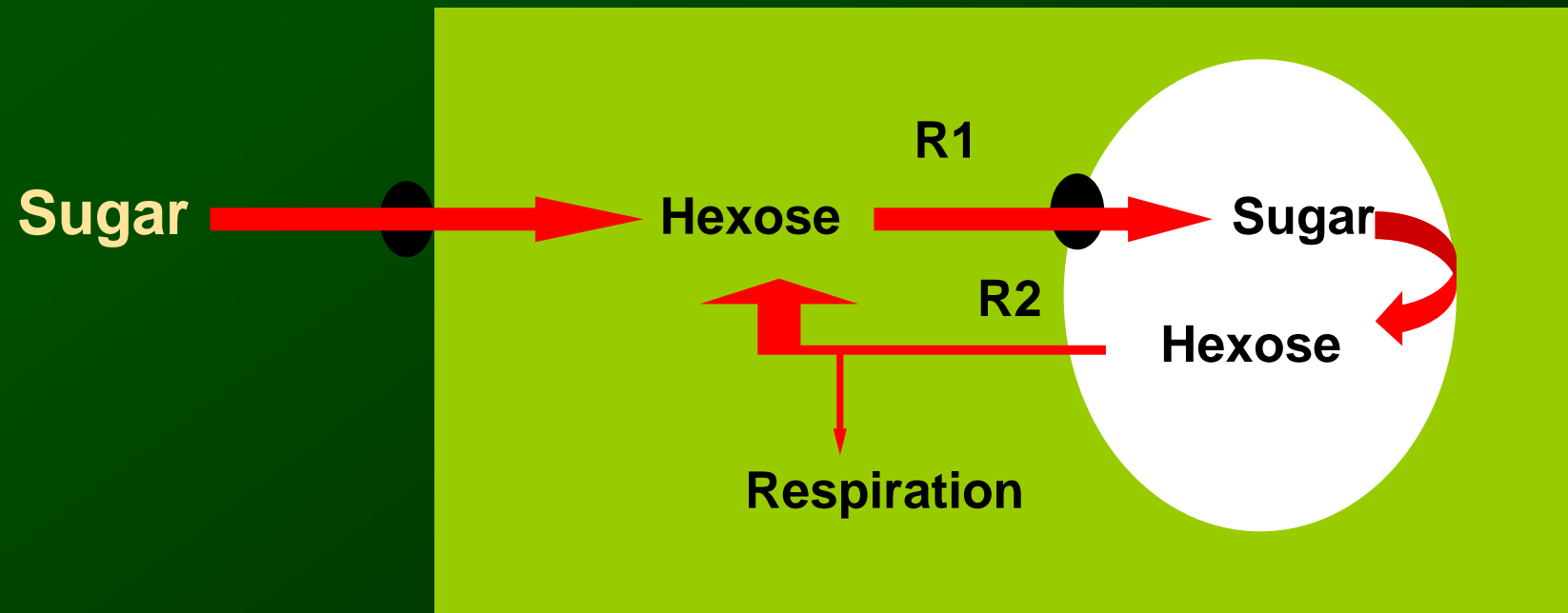
The sugarcane does not consist of only fiber and sucrose but can be a source of multiple products

It is a folk remedy for:

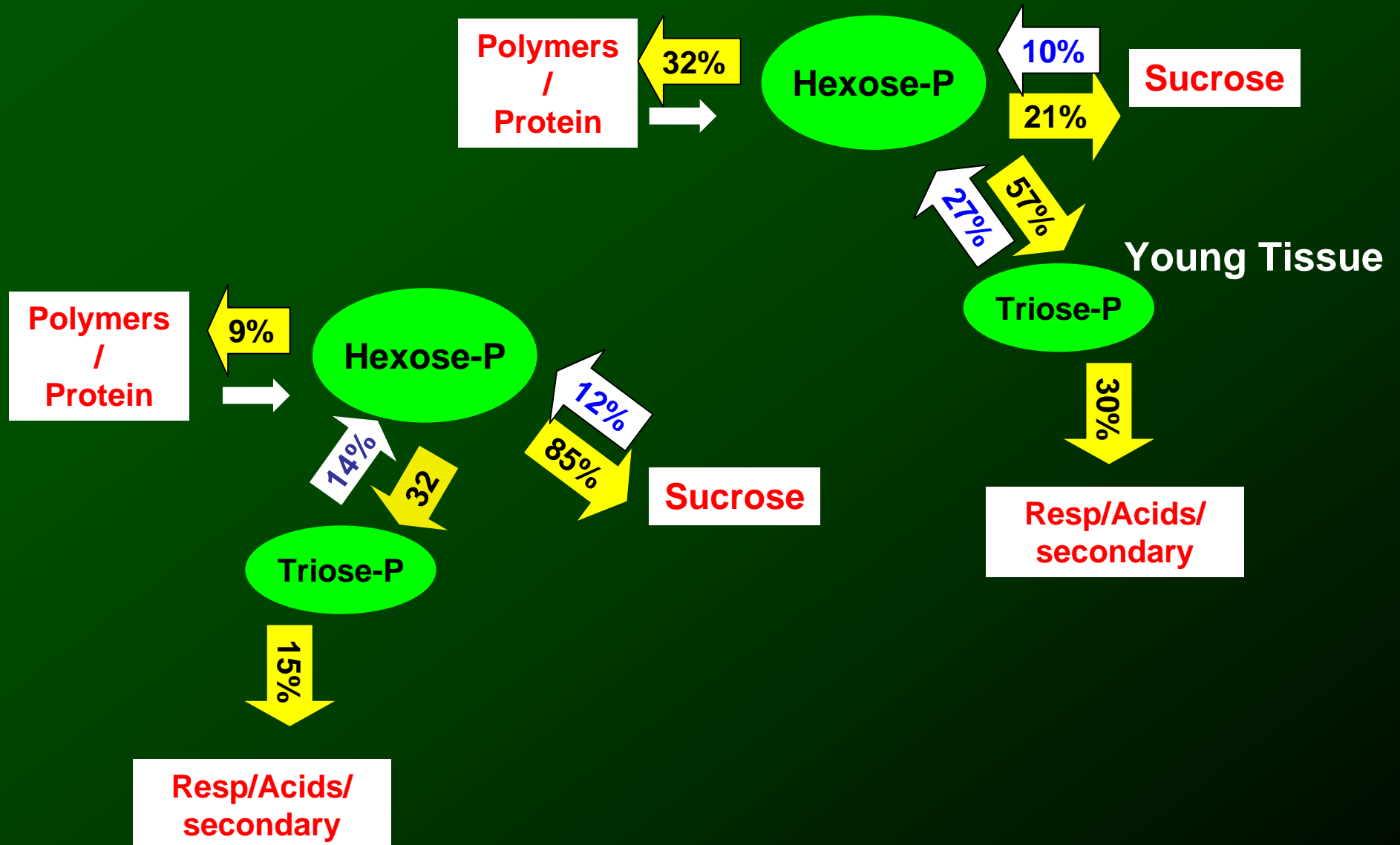
- Arthritis
- Bedsores
- Boils
- Cancer
- Colds
- Cough
- Diarrhoea
- Dysentery
- Eyes
- Fever
- Hiccups
- Inflammation

- Laryngitis
- Opacity
- Skin
- Sores
- Sore throat
- Spleen
- Tumours
- Wounds
- Gonorrhoea
- Vaginal discharges
- Abdominal tumours

Sucrose accumulation a simple process?

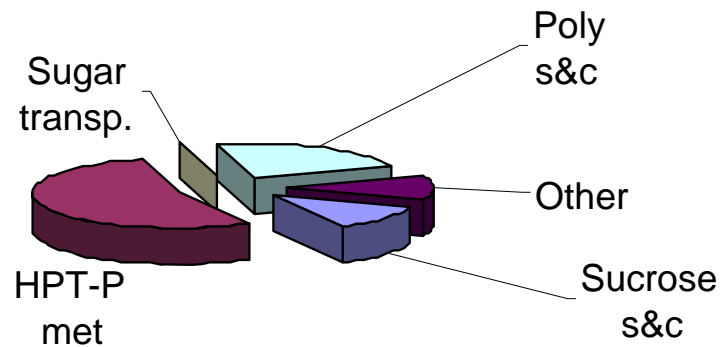


Carbon partitioning in sugarcane

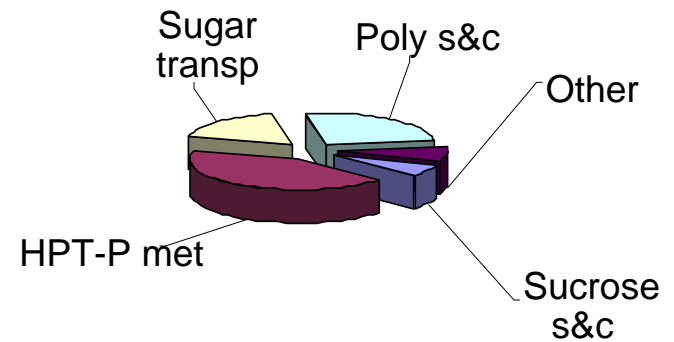


Complex gene expression in the culm

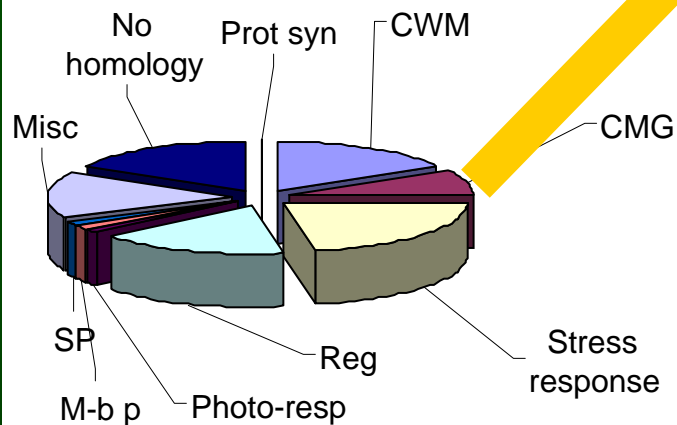
immature CMGs



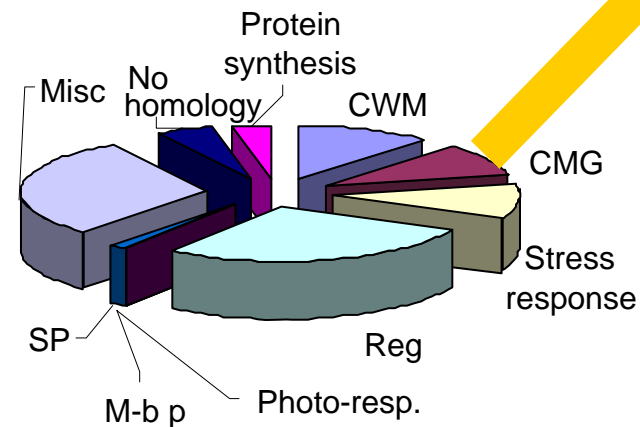
Mature CMGs



Immature int.

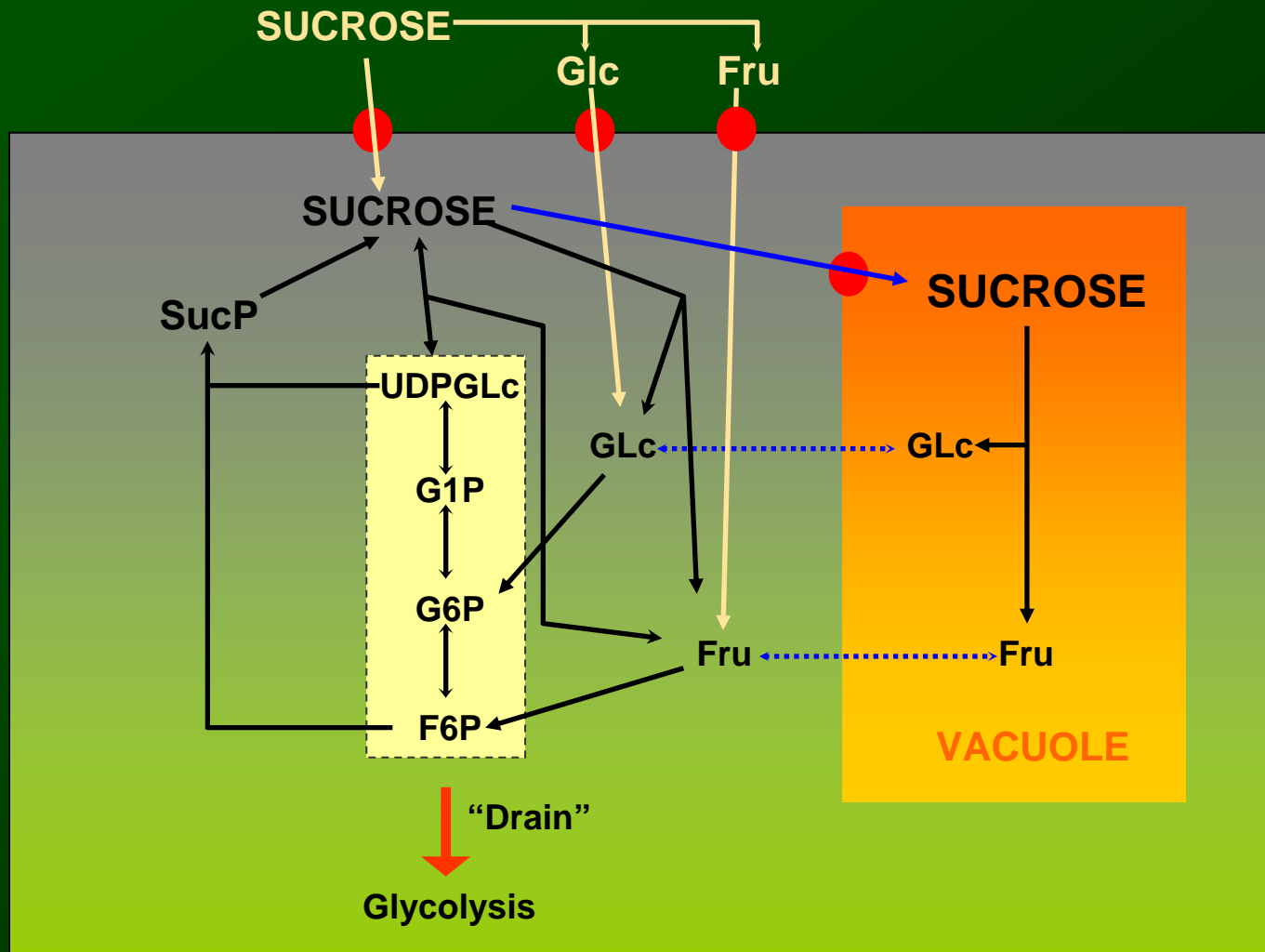


Mature int.



(Redrawn from data from Carson et al., 1997, and Casu et al., 2003)

Sucrose metabolism - kinetic model



Reconstitution of pathways

(WO 2004/006657 Transgenic Plants as a Biofactory)

Indigo: Two critical steps (EC 4.1.99.1) and β -D-glucosidase (EC 1.14.16?) are missing.

Sorbitol: Already present in sugarcane seeds, stems leaves, callus and stem bark of sugarcane. Sorbitol is present in internodal tissue (>6.5 to 1540nmol.mg⁻¹ protein)and increases with maturation.

Vanillin: The last two enzymes to synthesize vanillin are lacking. Similarly the last two enzymes for resveratrol synthesis are also lacking.

Adipic acid: Can synthesise the required precursor but lacks the two essential enzymes.

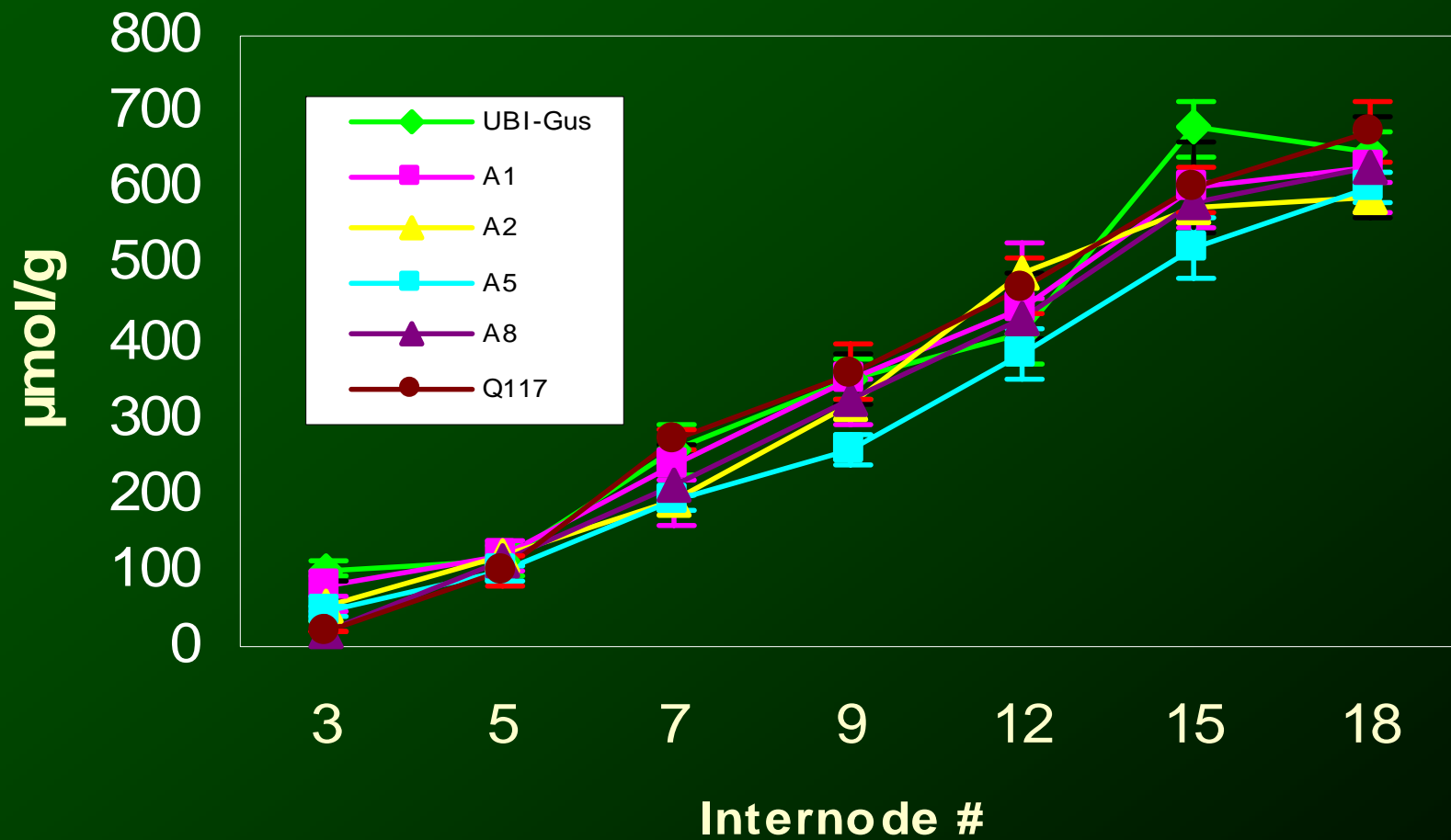
1,3-propanediol: Several steps appear to be lacking

2-phenylethanol: Very likely with enhanced alcohol dehydrogenase (EC 1.1.1.90) activity

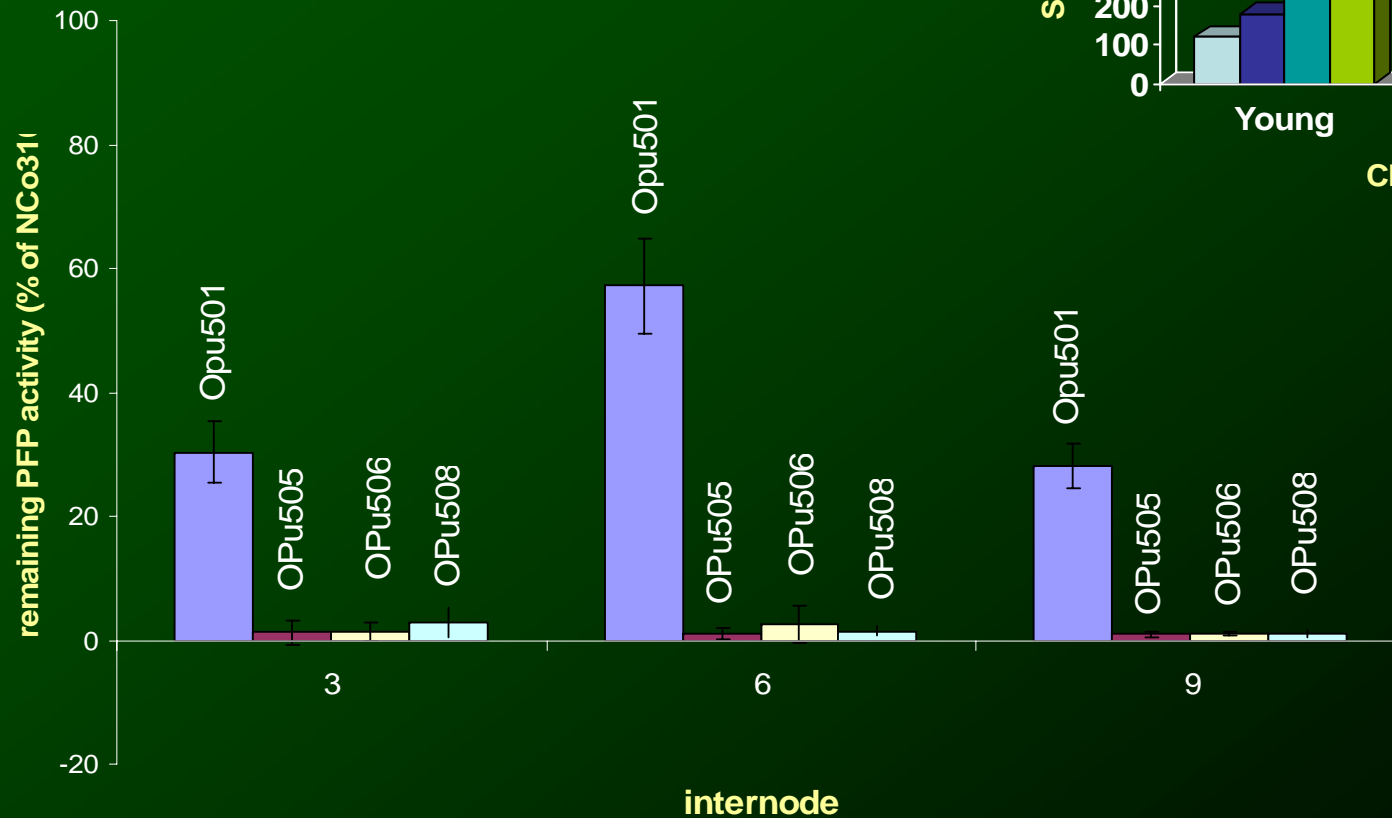
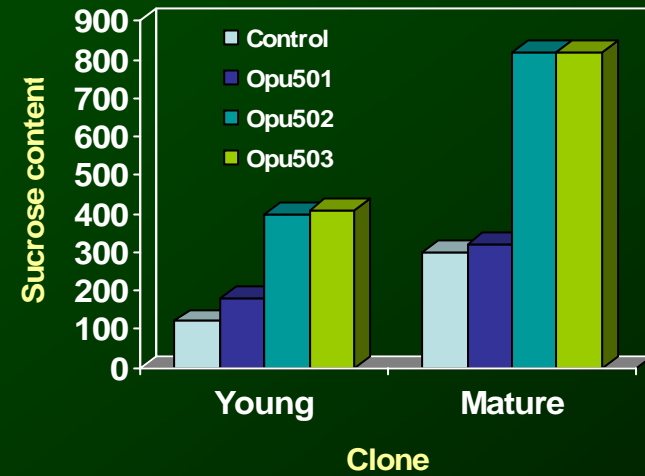
Sugarcane GM Technology

- Several industries and research organisations have GM technologies in place
- GM field trials in progress or have been completed
- Many GM lines in laboratory evaluation
- Traits under investigation:
 - ★ **Herbicide resistance**
 - ★ **Insect resistance**
 - ★ **Disease resistance**
 - ★ **Sucrose levels**
 - ★ **Polymers**

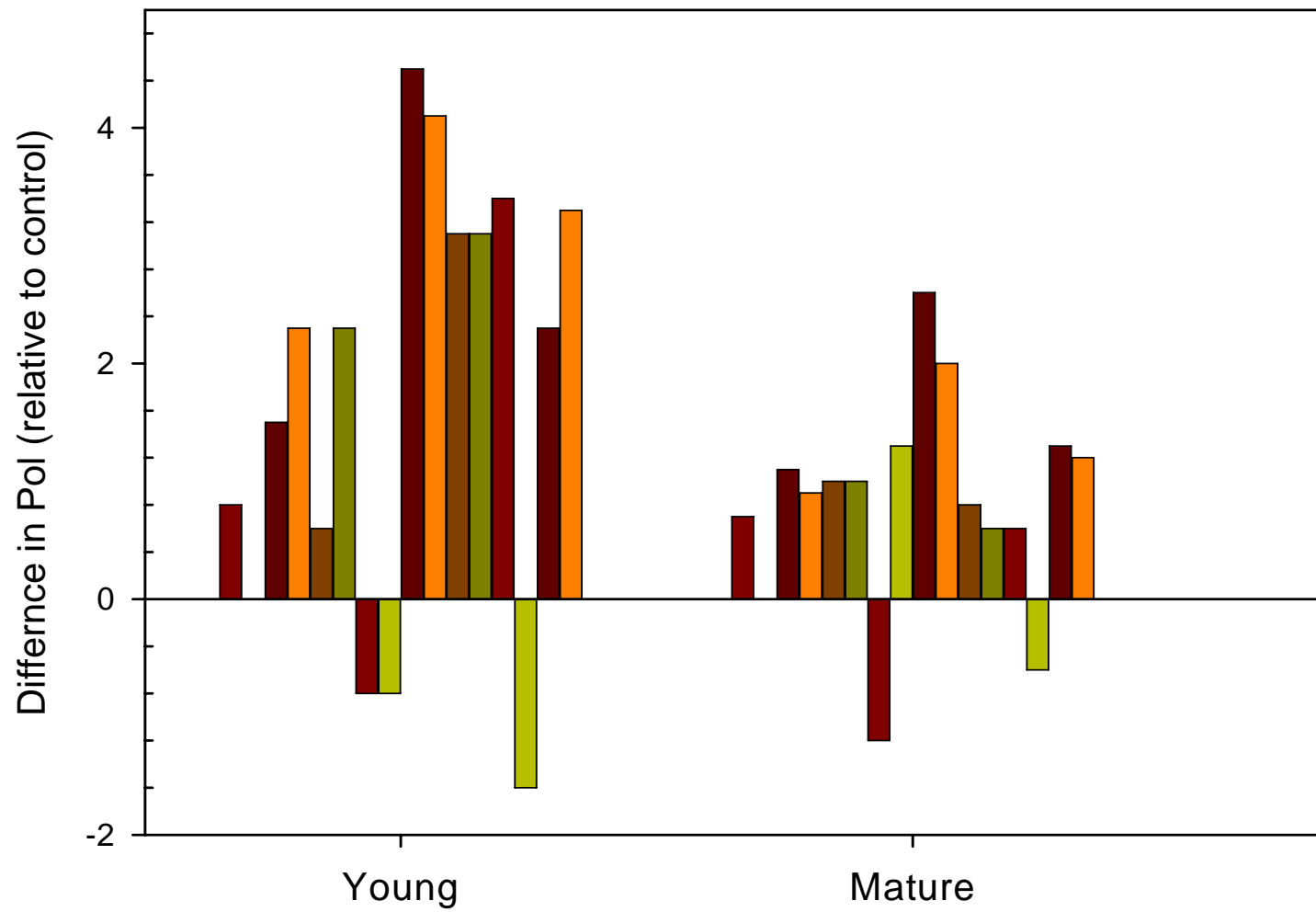
Sucrose in Al- Transgenic Sugarcane



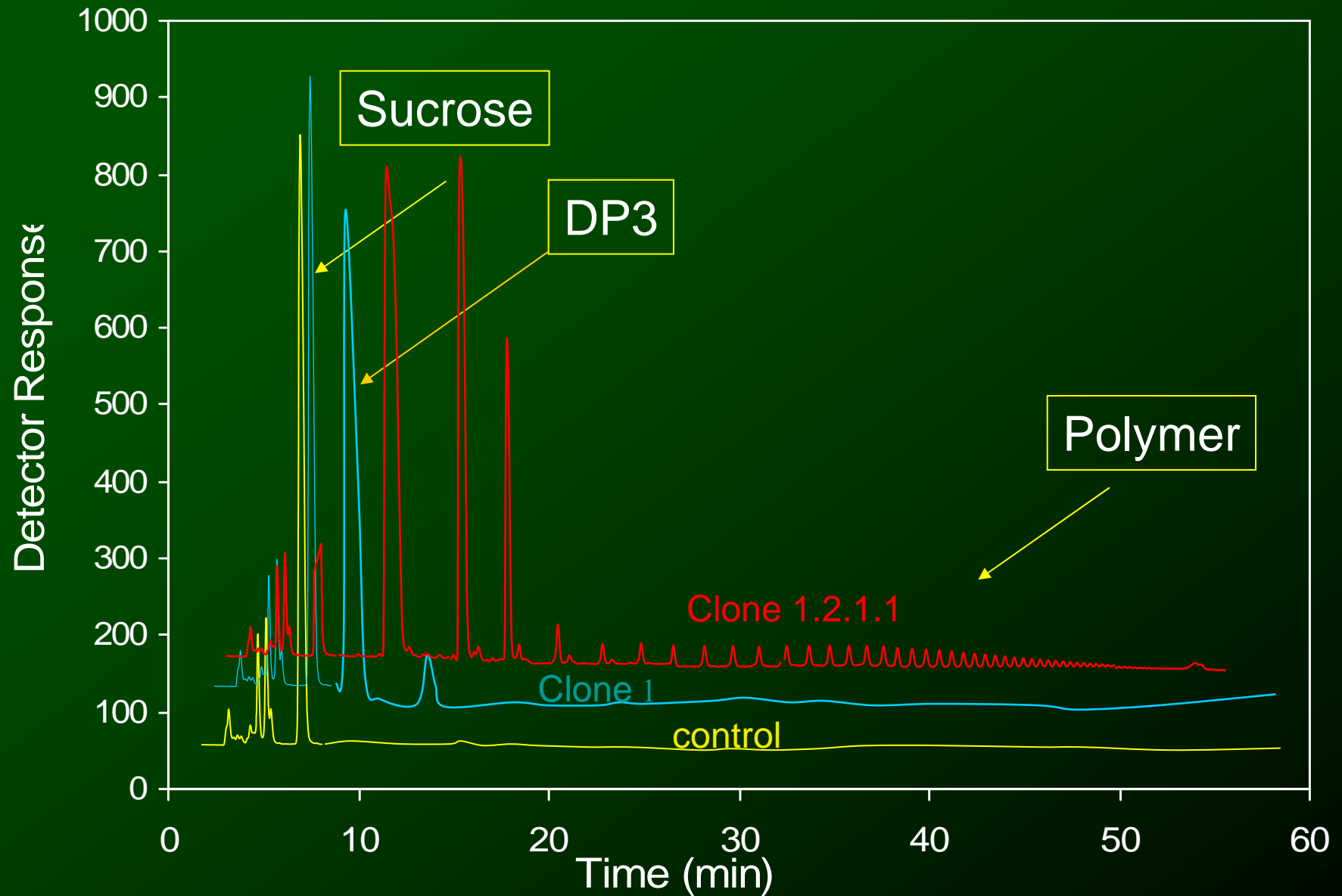
Sugarcane with altered PFP activity



GM Sugarcane



Alternative Sugars



Conclusions

- It is sometimes hard to think of sugarcane as a plant that does well other things than accumulating sugar.
- It is even more difficult to realise that sugar accumulation is not even the thing that it does best.
- Above all else, sugarcane is a producer of biomass unequalled by any other plant when managed as a growth commodity
- Modern technologies are rapidly developing to enable a broadening of economic opportunities

Conclusions (cont)

For industries using sugarcane, **there is still time for constructive and meaningful change.** There is time to prepare its place as a future sugar crop, a domestic energy crop, and a multiple-products commodity in service to all future generations.

Alex G. Alexander, 1985

The Future

Within the next generation the world will change in many irrevocable ways. Do we envision the need and have the scientific intellect to keep pace with these changes and benefit from the opportunities that will arise?

Plant/crop-based renewable resources are a strategic option to meet the growing need for industrial building blocks , and to maintain a leadership position in the future. There will be economic, environmental and social advantages for the development of this resource base. The opportunity is clear. However, it requires forward-thinking vision, integration of stakeholders, investment in new approaches, and coordination of research to generate a secure future.

PRESENTATION COMPLETE