Future technnologies to drive cereal productivity

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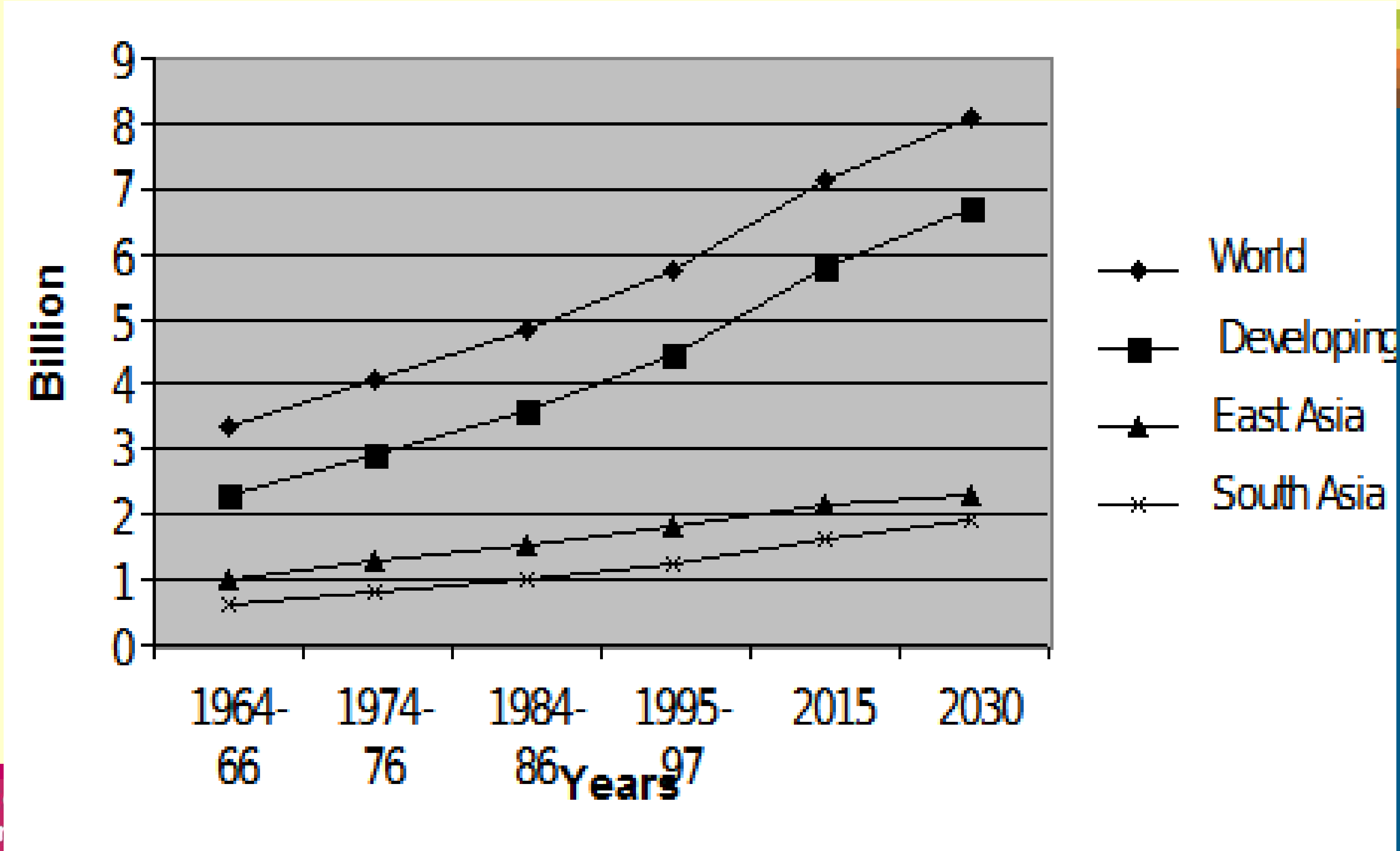
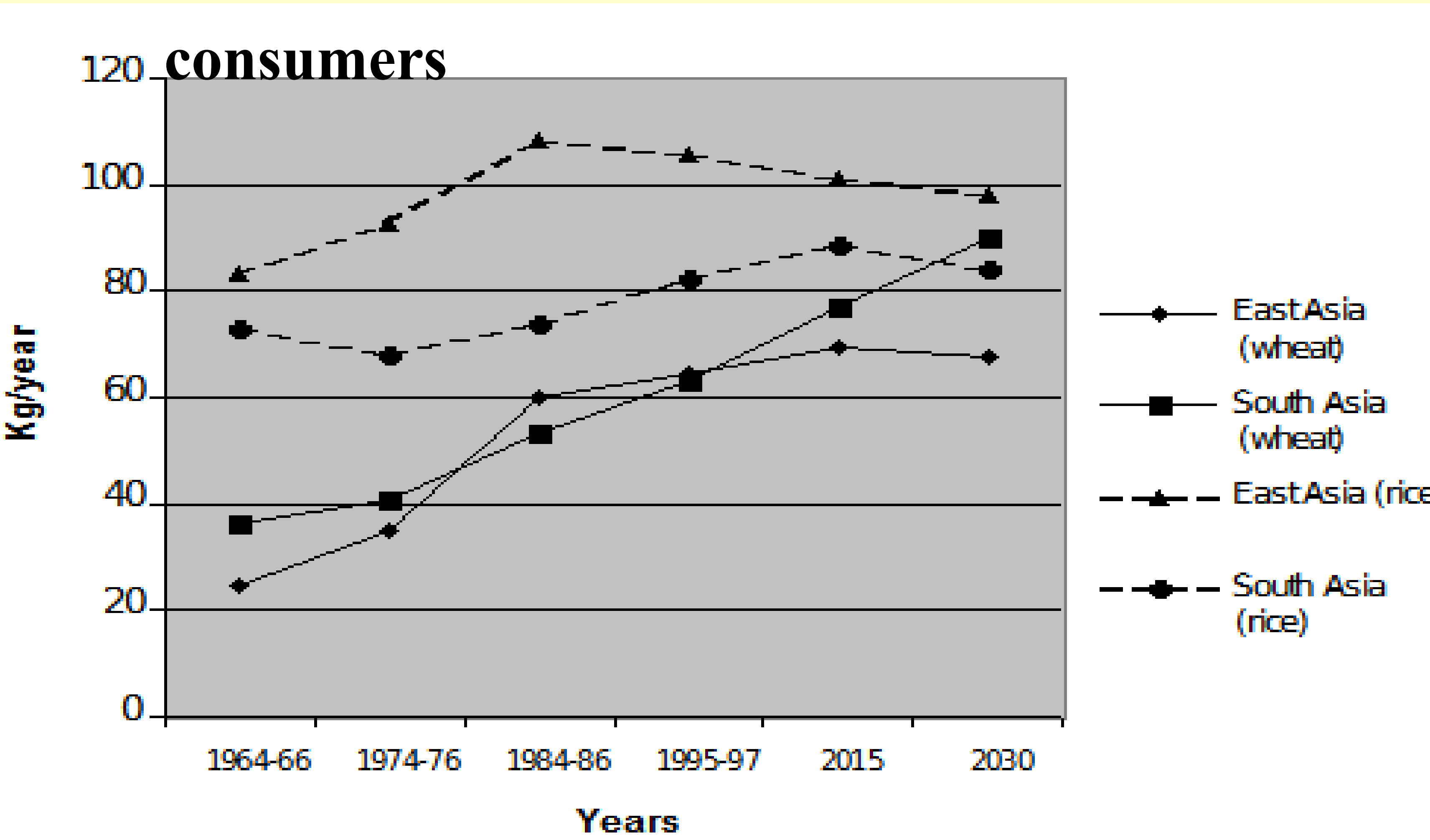
GLOBAL WHEAT DEMAND

- **Population increase**

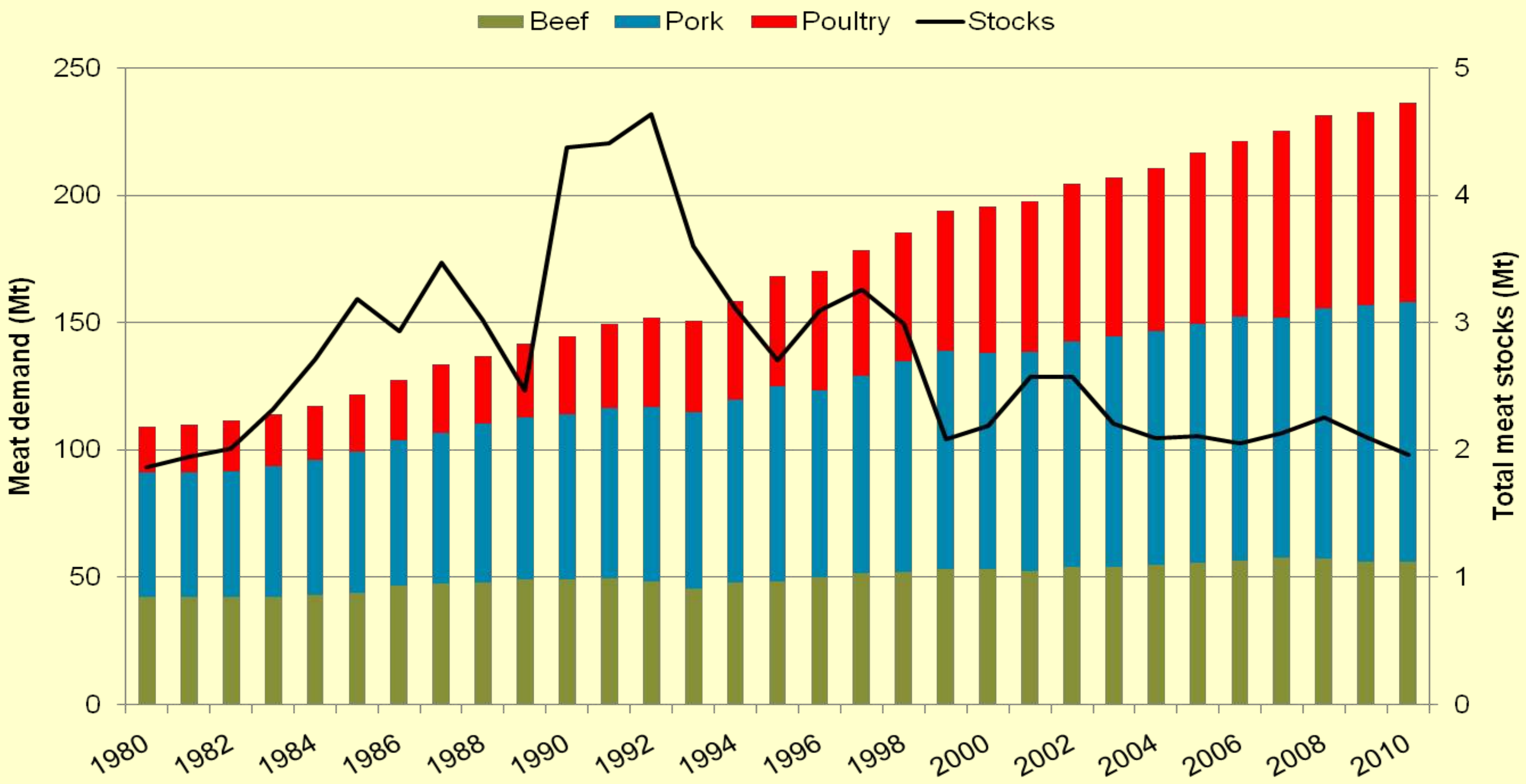


EVOLUTION OF WHEAT AND RICE CONSUMPTION

- **More “sophisticated” consumers**



Global meat - *record demand for grain-fed meat but stocks at almost 30 year low*

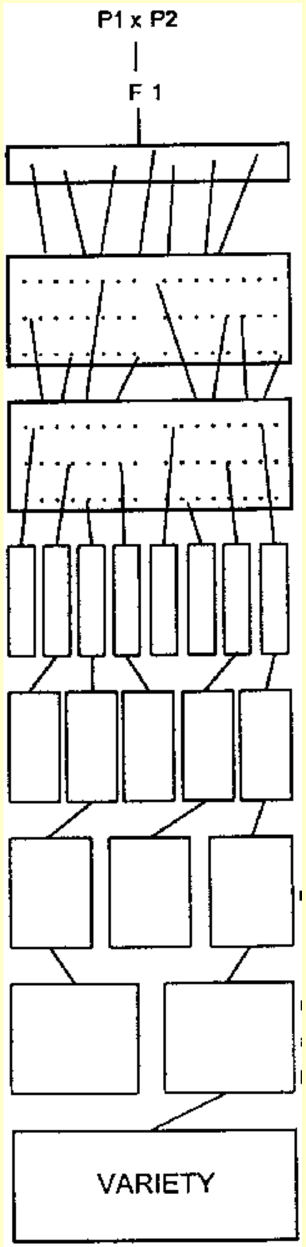


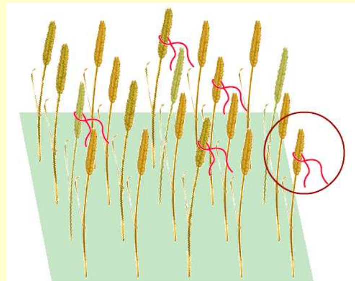
Pedigree breeding (wheat)

Low yield
High quality

High yield
Low quality

F2
F3
F4
F5
F6
F7
F8





Plant / row selection

Trials/yield/quality

High yield?
High quality?
Stability? (…)

End of fixing (inbreeding)

High market share

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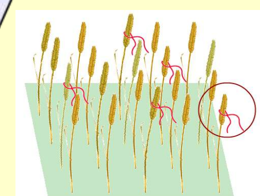
A typical wheat breeding program

Breeding program/country

Time : 10 years

F1	1,000 hybridisations
F2	1,000,000 plants
F3	
F4	100,000 nursery lines
F5	3,500 lines
F6	700 lines
F7	70 lines
OT1	7
OT2	3
Variety release…	1



Information

Observations (diseases, morphology)

Scoring & quality tests

Scoring, quality tests & yield

Scoring, quality tests, yield & yield stability

Total : 200,000 field plots + 25,000 yield plots

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Investment in Wheat Breeding

- Traditional 'technologies'
- Single Seed Descent
- Double Haploids
- Markers
- Genetic modification (GM)

Field evaluation

- Now often called 'phenotyping' !
- Significant advances in the last five years – On board weighing/ GPS etc

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How it used to be.....

Courtesy Jim Burke

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FIELD EQUIPMENT INVESTMENT

- Automatic cassette drills
- Precision spraying
- Accurate on combine weighing systems

Field trials

Single Seed Descent

- A growth room system to allow more than one cycle to be carried out per year
- Speeds up the breeding process

Single Seed Descent

Single Seed Descent

Double haploids

- A laboratory technique to reduce time to develop new varieties
- Cross wheat with maize – embryo rescue and develop via tissue culture

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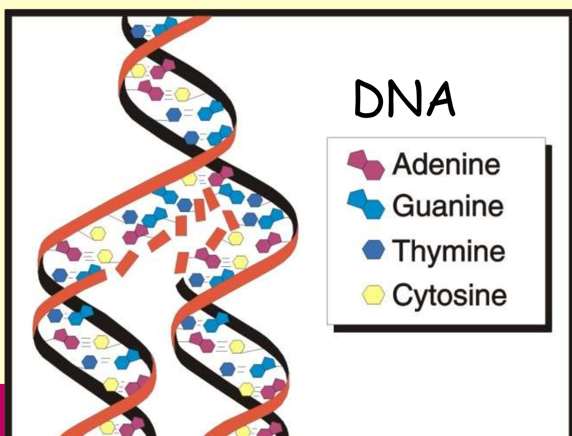
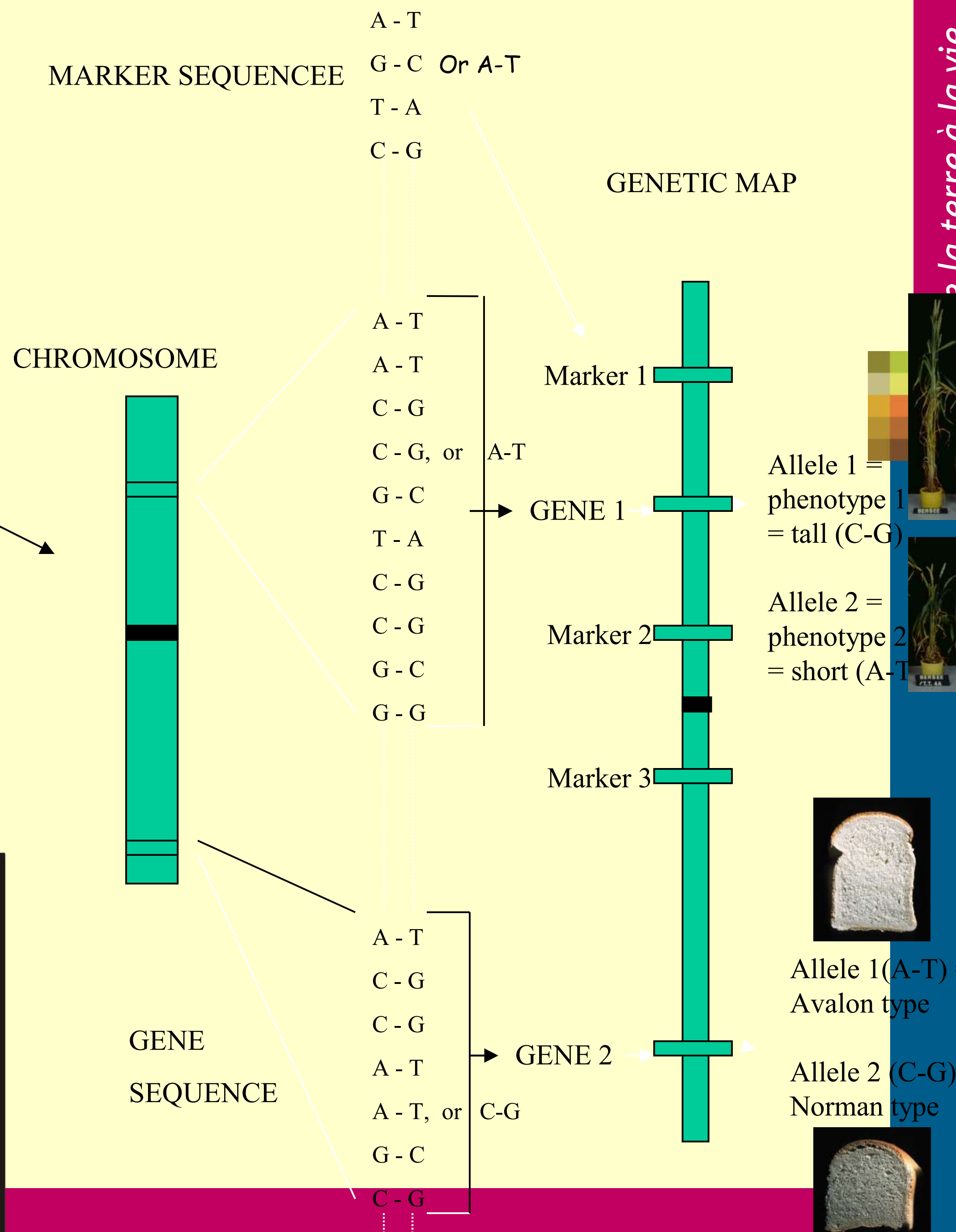
Marker assisted selection (MAS)

- Used to identify and track newly found and known 'genes'
- increases efficiency in variety selection
- Aids 'pyramiding' known genes in 'robust' combinations
- Increases selection efficiencies for complex traits eg yield

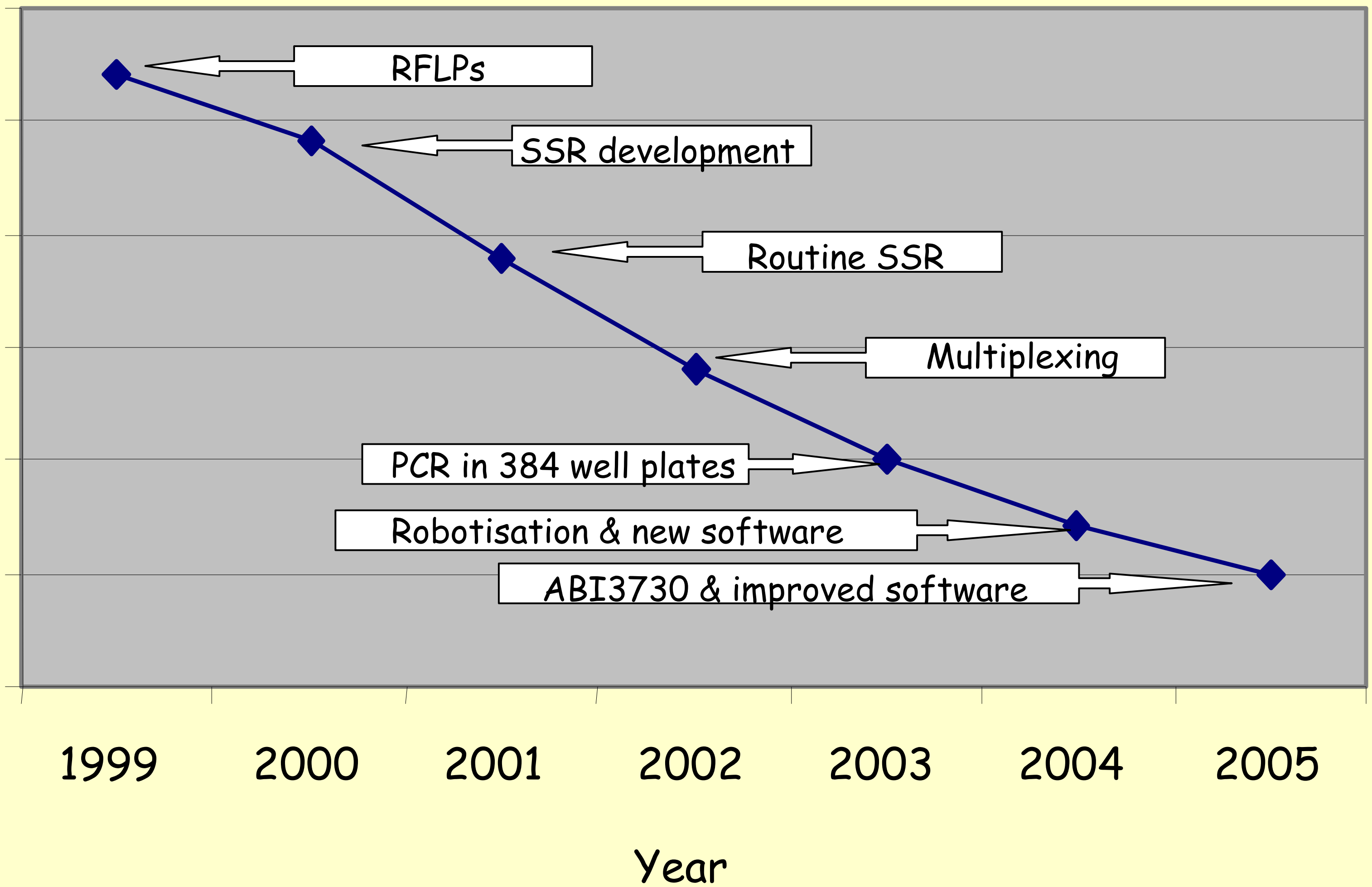
Genetic maps of the wheat genome

Wheat chromosomes stained in a root tips cell, total of 42 chromosomes, 21 pairs





Reduction in cost per data-point



Which markers are available for the UK?

- Dominant marker for *Sec1* (STS)
- High m.w. glutenins (protein)
- *Pch1* (isozyme & SSR)
- Codominant marker for *Lr37* (STS)
- *Rht1* and *Rht2* (ASA.SNPs)
- Puroindolines (ASA,CAPS,SNPs)
- *Ppd-D1* (INDEL,SNPs)
- *Sbm1* (SCAR)
- *Yr32* (SSRs)
- FHB QTL (SSRs)
- *Bdv2* (SSRs)
- Various *Stb* genes (SSRs)

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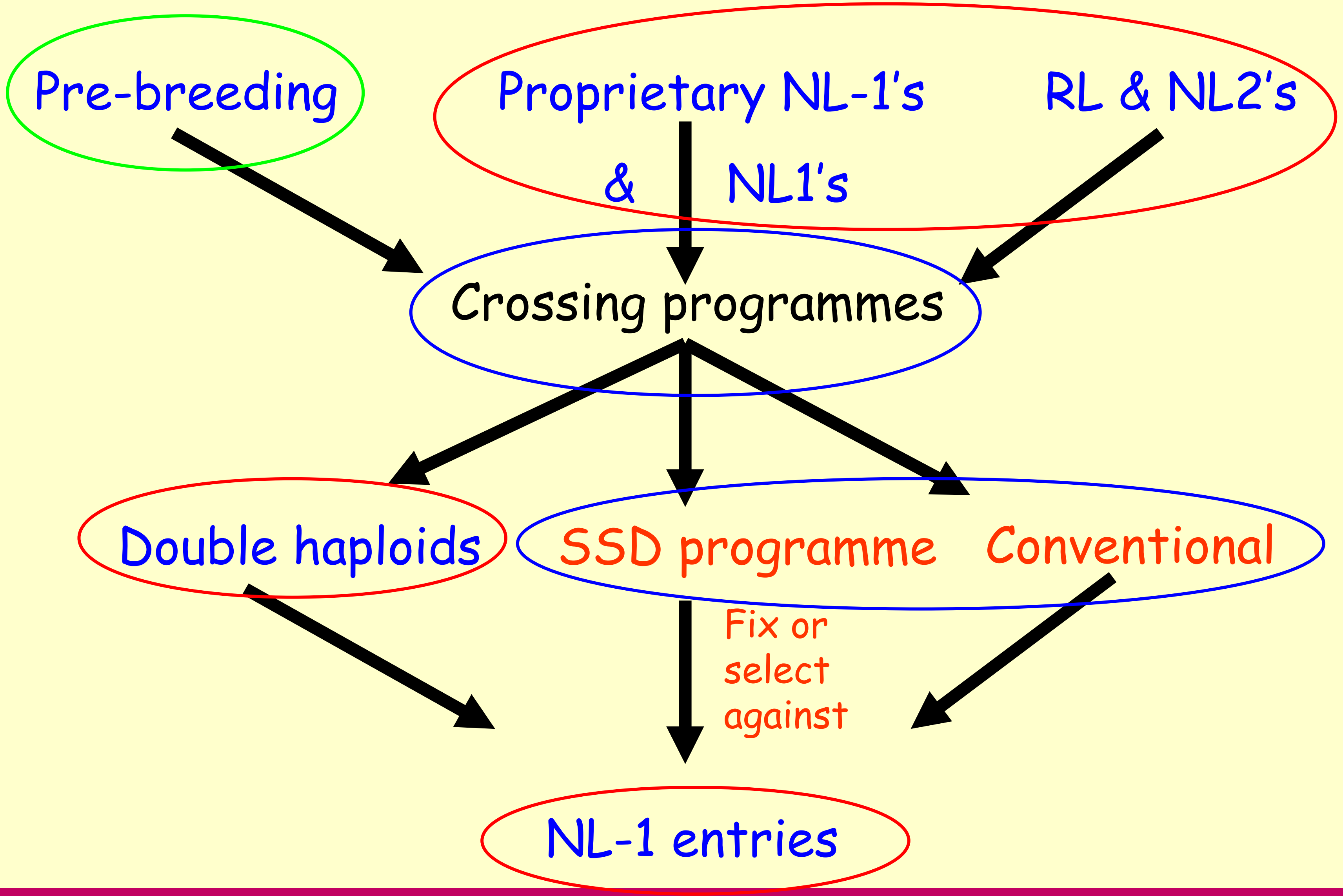
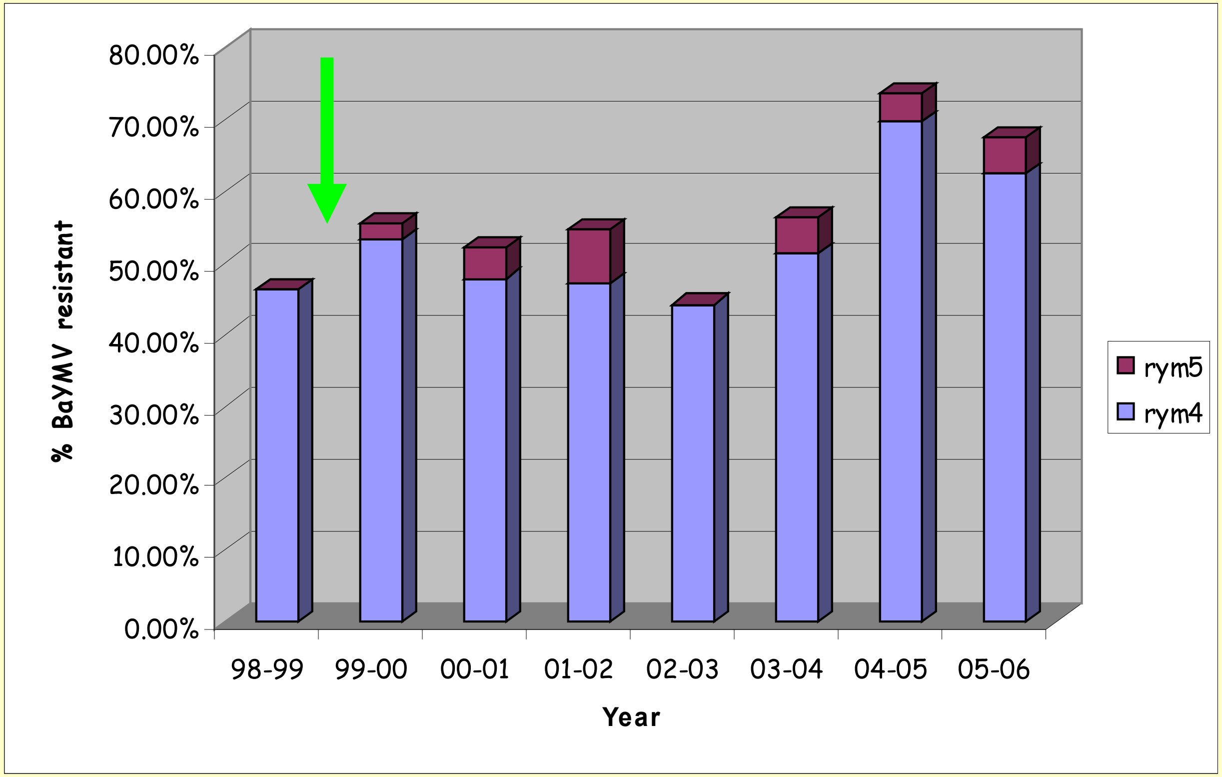
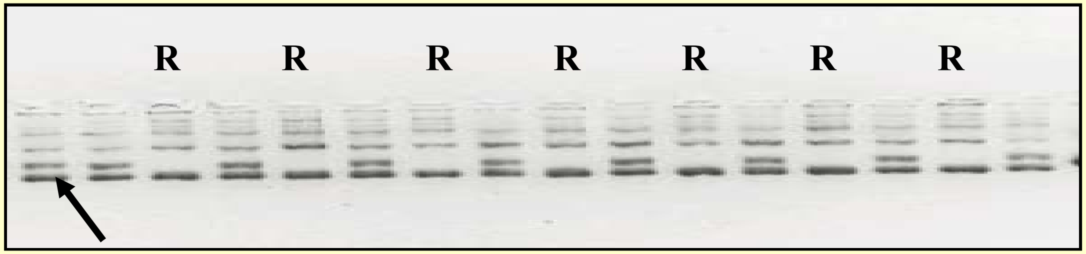
When to use markers

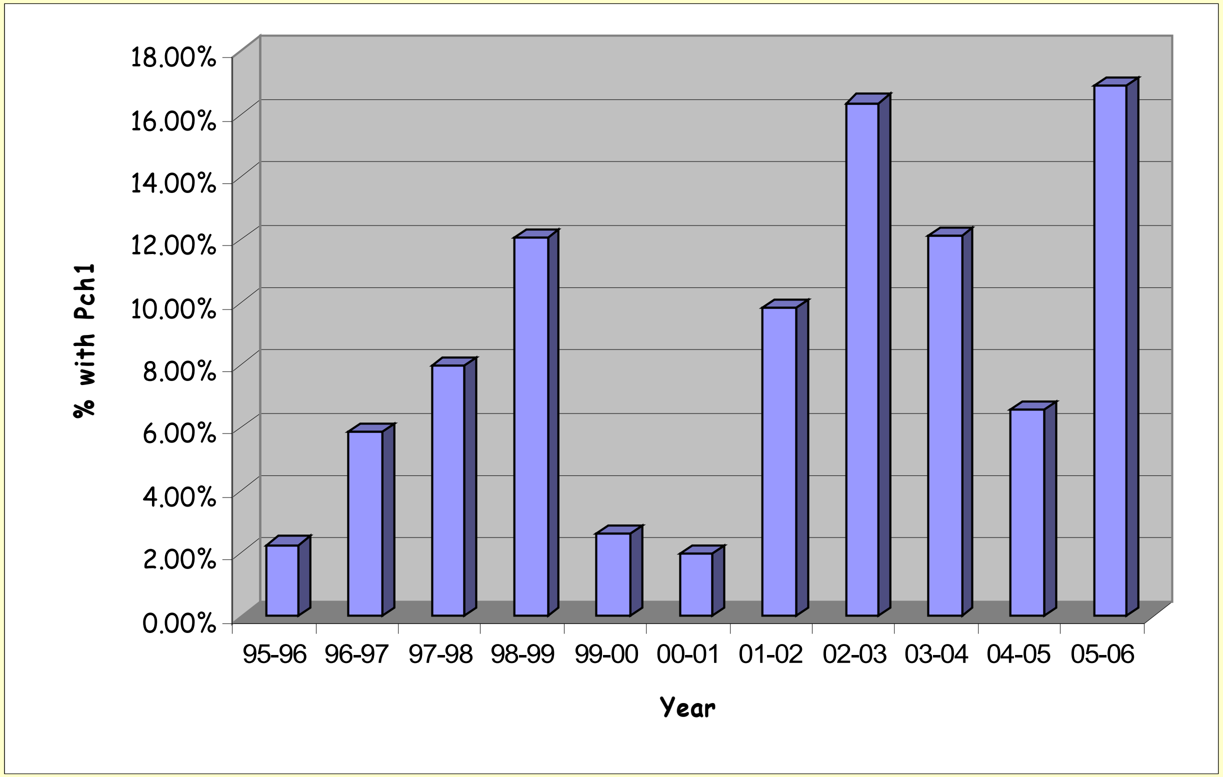


BaYMV resistance in winter barley



Eyespot resistance in winter wheat

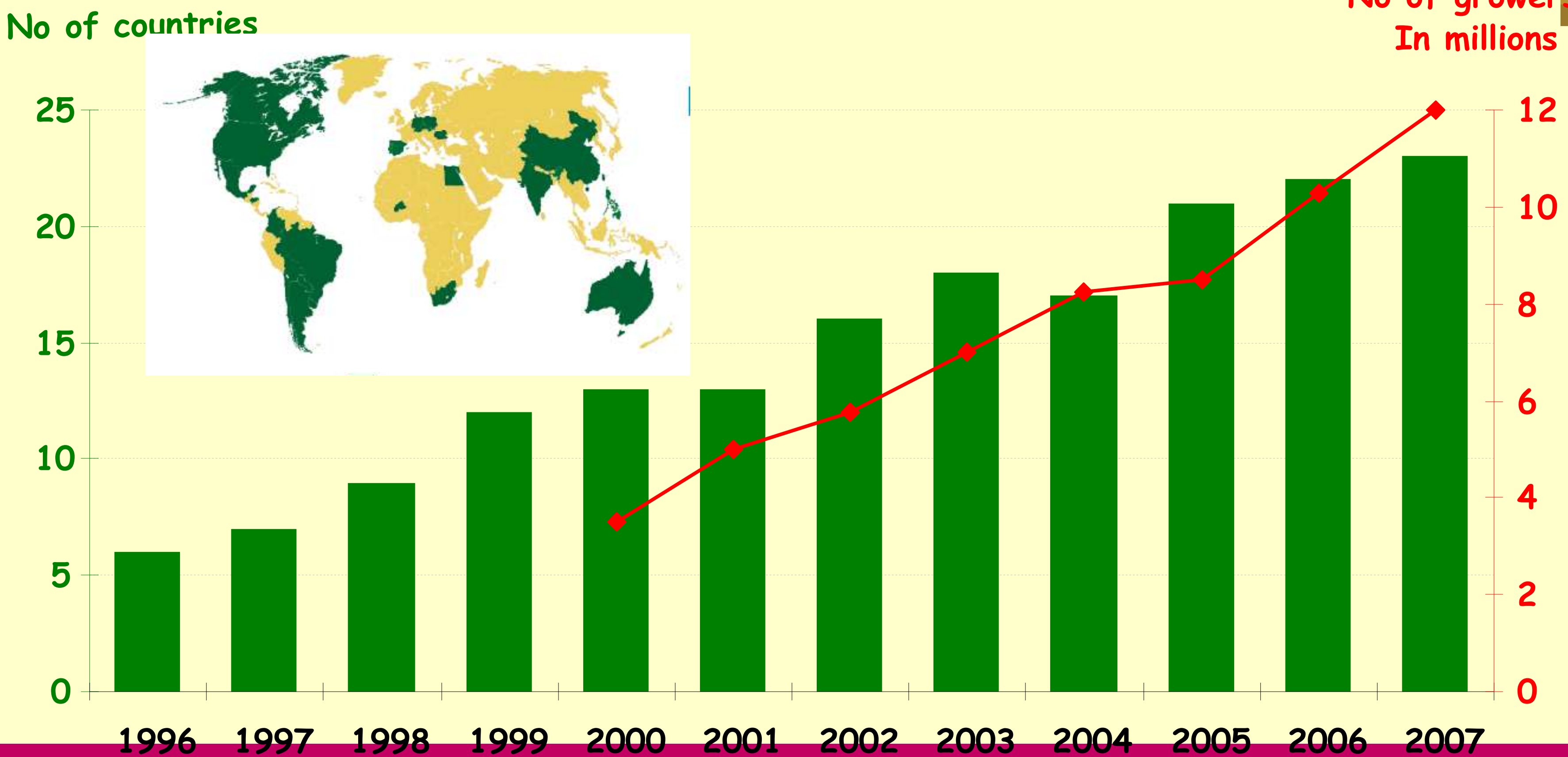




Genetic Modification (GM)

GMO – Evolution of number of countries and growers

- Total surface 2008 : 125 M Ha (+ 9.4 %)
- 12 million growers in 23 countries



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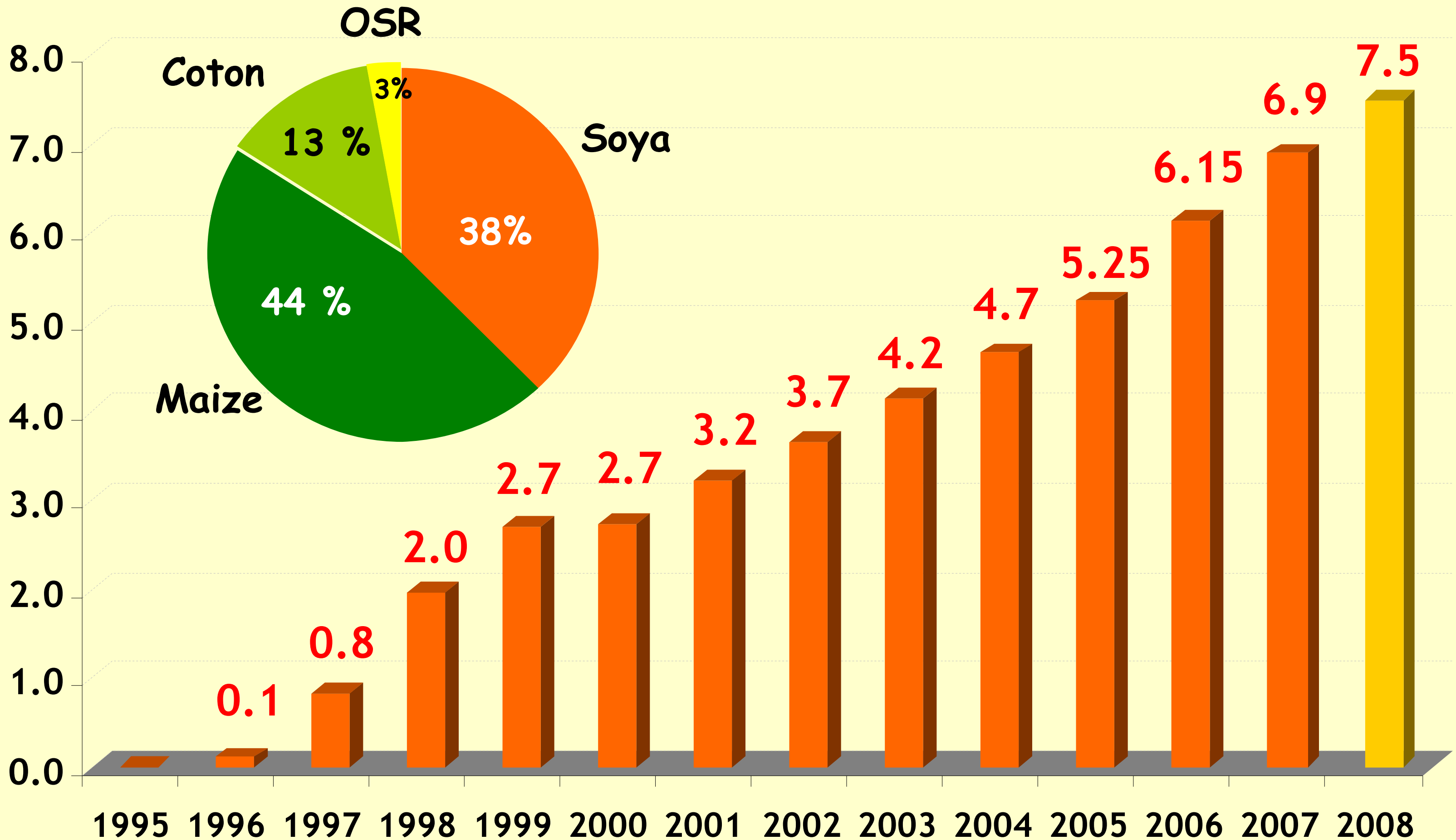
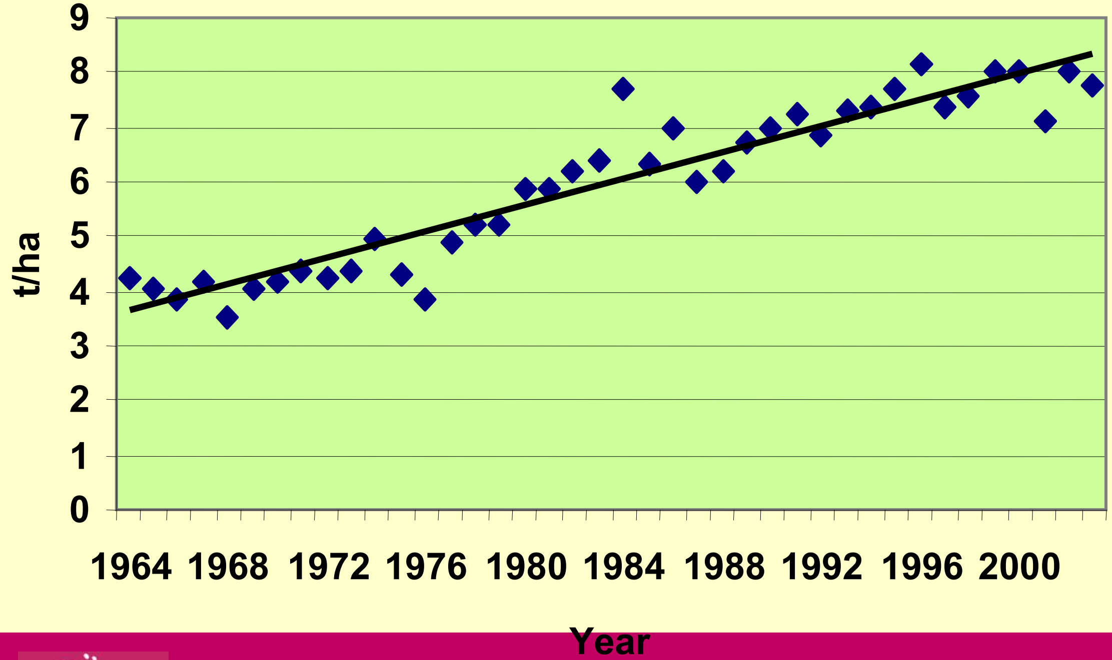
GMO: Evolution of the Market

- market (Seeds + Technology Fees): $ 6.9 billion
- (1/3 of the total seed market value of $ 21.7 billion)



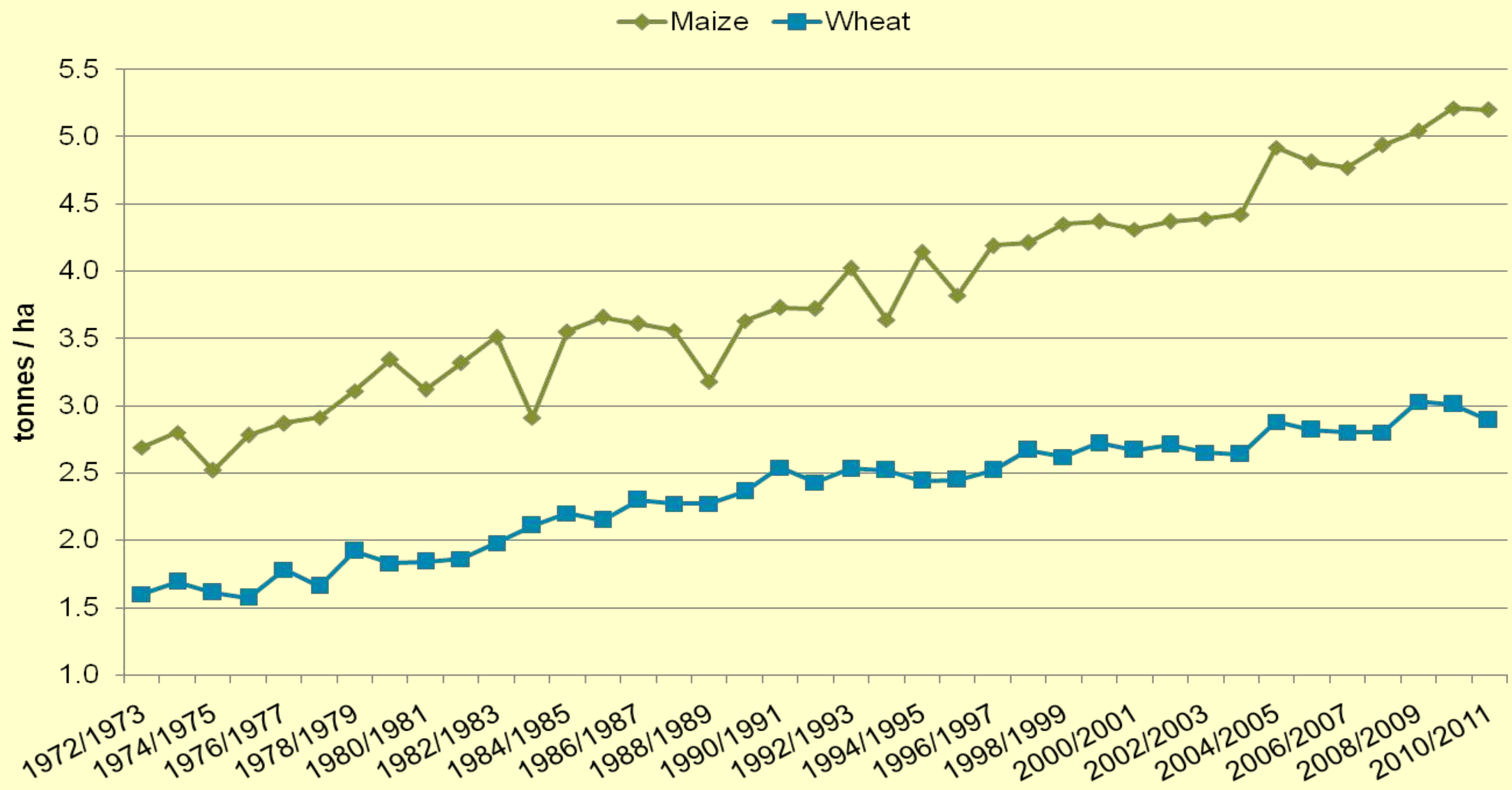
ACHIEVEMENTS OF UK WHEAT BREEDING – CROP YIELD

UK Wheat Yields 1964-2003 (National Average - Source: FAO)



UK wheat yields have increased at an average rate of 1.8% every year for the past 30 years

World wheat and maize yields
- the widening spread: GM?



Source: USDA

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Why no GM wheat (anywhere) ?

- Difficult crop to transform
- Lack of incentives
  wheat self pollinating – saved by farmers
  poor financial returns for breeders
- Public/ political objections

Lack of incentives

- Cereals such as wheat are self pollinating and can be self saved by growers
- Maize and Soya are hybrids and new seed must be purchased annually
- Research investment in wheat is just 25% of that in Maize and primarily in the public sector

Difficult Crop to transform

- This was true but now transformation is routine and success rates much improved

Public/ Political objections

- Needs to be re-visited with a ***balanced*** debate
- The World demands more food – a political dilema – The Perfect Storm (Beddington 2009)
- How can we feed 50% more people in the World by 2050?
- What are the political/ military consequences of failure?

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Potential targets for GM

- Agronomy traits – eg herbicide resistance, insect/ disease resistance
- Output traits – eg modified starches – animal feed/ biofuels/ 'nutrifoods'
- Yield and consistency of performance

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So where now?

- The challenge for the World to produce more food is enormous
- The political consequences of mass starvation should not be underestimated
- There needs to be a coordinated and international response to these challenges

So where now?

- Increased production will come about by the integration of a range of technologies
- There is no 'silver bullet'
- Investment is the key

An example…..

- GM trait – resistance to 'take all'
- Allows continuous wheat growing
- Modified starch profiles to meet different food requirements eg potato starch
- Modified photosynthetic pathways to enhance biomass production
- Herbicide resistance – one pass weed control
- Higher levels of resistance to key diseases – particularly Septoria
- More biomass but earlier harvests to avoid wet weather

An example…..

- Breeders could use GM technology to introduce
- Track 'event' using marker assistsed selection
- Purify material using double haploid technology
- Integrated management tools with extension services

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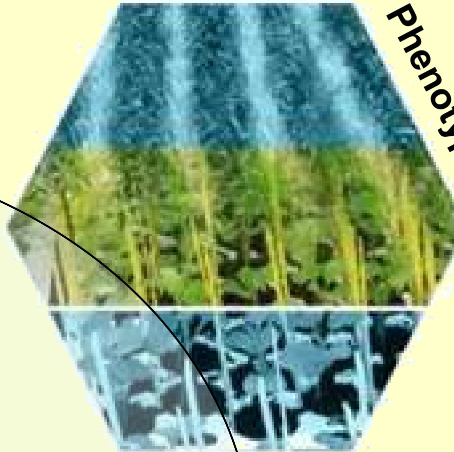
The variety creation process

Genetic Resources

Phenotyping



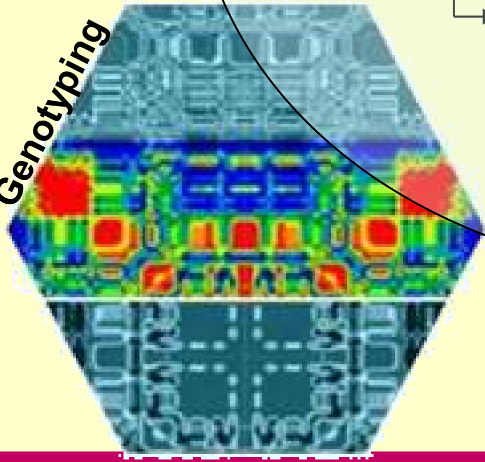
Information management system

Market Analysis

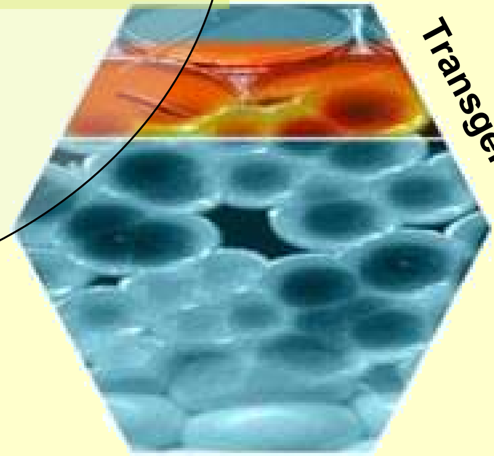
Market segmentation → Choice of strategy → Conventional breeding / Breeding via GMOs → Official registration → Launch

Marketing

Genotyping

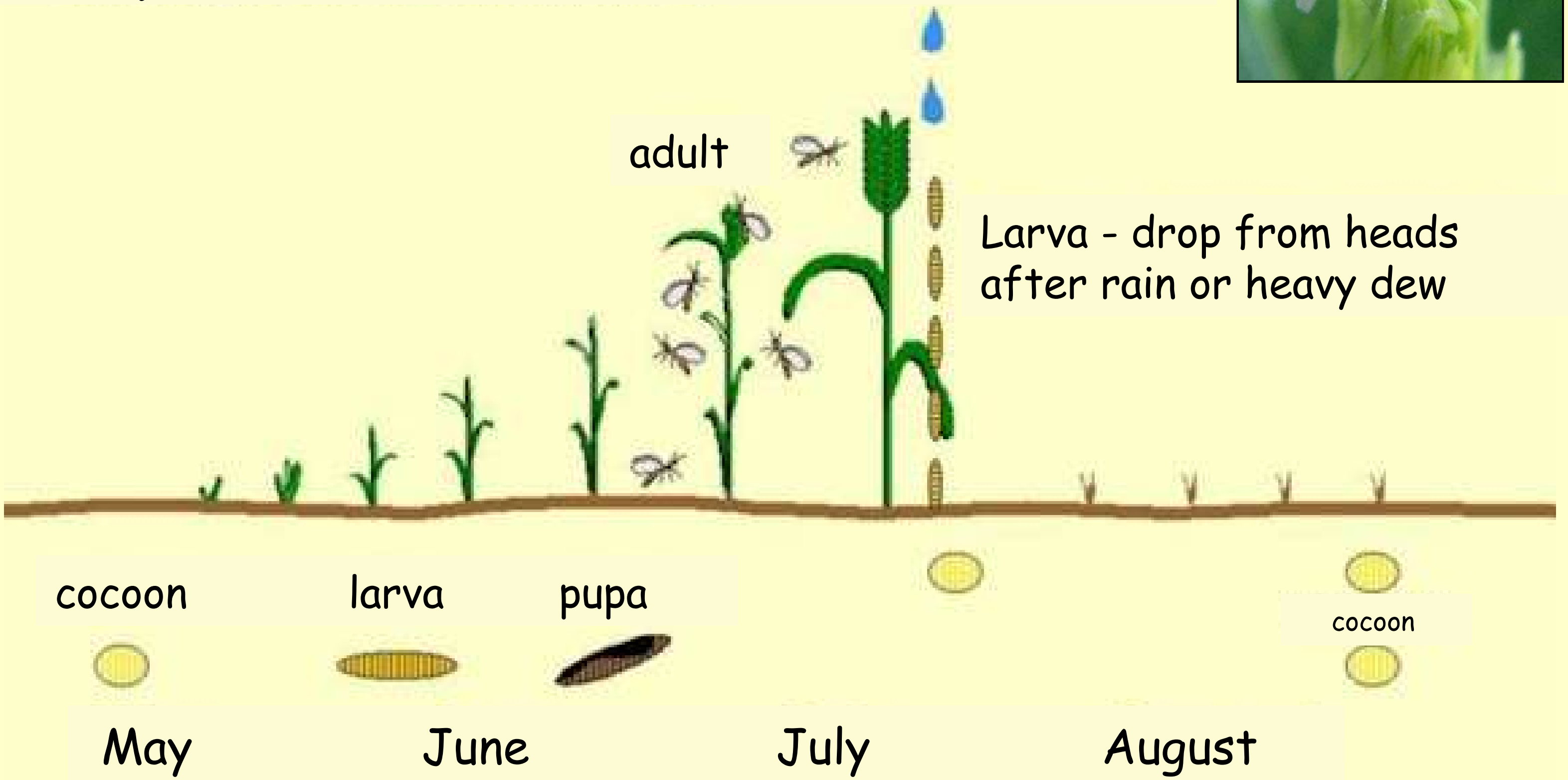


Transgenesis



The Life Cycle of Orange Wheat Blossom Midge

Sitodiplosis mosellana



Orange Wheat Blossom Midge

- Sporadic insect pest, but widespread
- Controlled with organo-phosphates
- Can cause major yield losses & reduction in quality
- Very time consuming to phenotype
- Several resistant sources now being grown commercially – eg Robigus, Viscount, Oakley, Glasgow

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Markers for OWBM resistance

- Identified markers for all known sources of OWBM resistance in the UK
- Marker-assisted selection of resistant lines before harvest
- Environmentally friendly alternative to organo-phosphate insecticides
- Pyramiding of OWBM resistance with other traits now possible
- Immediate target to produce a quality bread variety with midge resistance

	21 DAYS AFTER INOCULATION							
Variety	Rep1	Rep2	Rep3	Rep4	Rep5	Min	Max	Mean
CM 82036	0	0	0	0	0	0	0	0
APACHE	15	12	4	9	10	4	15	10
SOKRATES	3	13	22	18	21	3	22	15
GATSBY	17	25	15	20	12	12	25	18
Xi19 BC3F2 3B+5A	23	20	9	30	15	9	30	19
Xi19 BC3F2 3B+5A	32	20	17	24	12	12	32	21
Xi19 BC3F2 3B+5A	21	35	19	25	22	19	35	24
Xi19 BC3F2 3B+5A	25	25	30	35	20	20	35	27
Xi19 BC3F2 3B only	37	39	27	41	12	12	41	31
Xi19 BC3F2 5A only	35	40	35	35	45	35	45	38
Xi19 BC3F2 5A only	33	55	50	30	55	30	55	45
Xi19 BC3F2 3B only	24	86	48	40	32	24	86	46
Xi19 BC3F2 5A only	70	50	35	35	75	35	75	53
Xi19 BC3F2 3B only	75	54	55	50	34	34	75	54
CHARGER	70	45	55	55	50	45	70	55
Xi19	100	40	30	40	80	30	100	58

Summary

- Northern Europe will need to produce more output – but with more environmental constraints
- New biotechnological adavnces such as marker assisted selection are now commonplace within breeding programmes
- GM technology should be 're-visited' to explore its potential
- More investment in plant breeding is required – but not at the expense of farmer control