Soft Fruit Breeding and Research at The James Hutton Institute

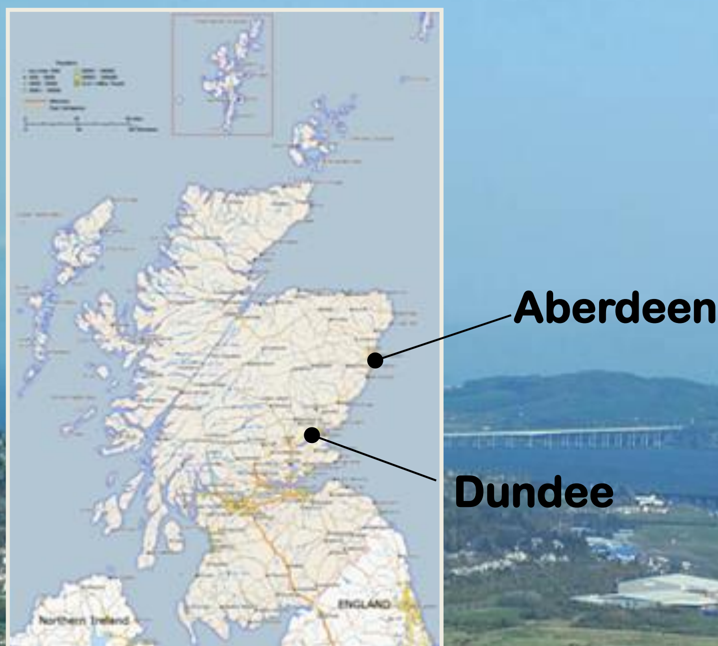
Rex Brennan

Fruit Breeding Group

The James Hutton Institute

Weinsburg, Jan 2013

James Hutton Institute, Scotland



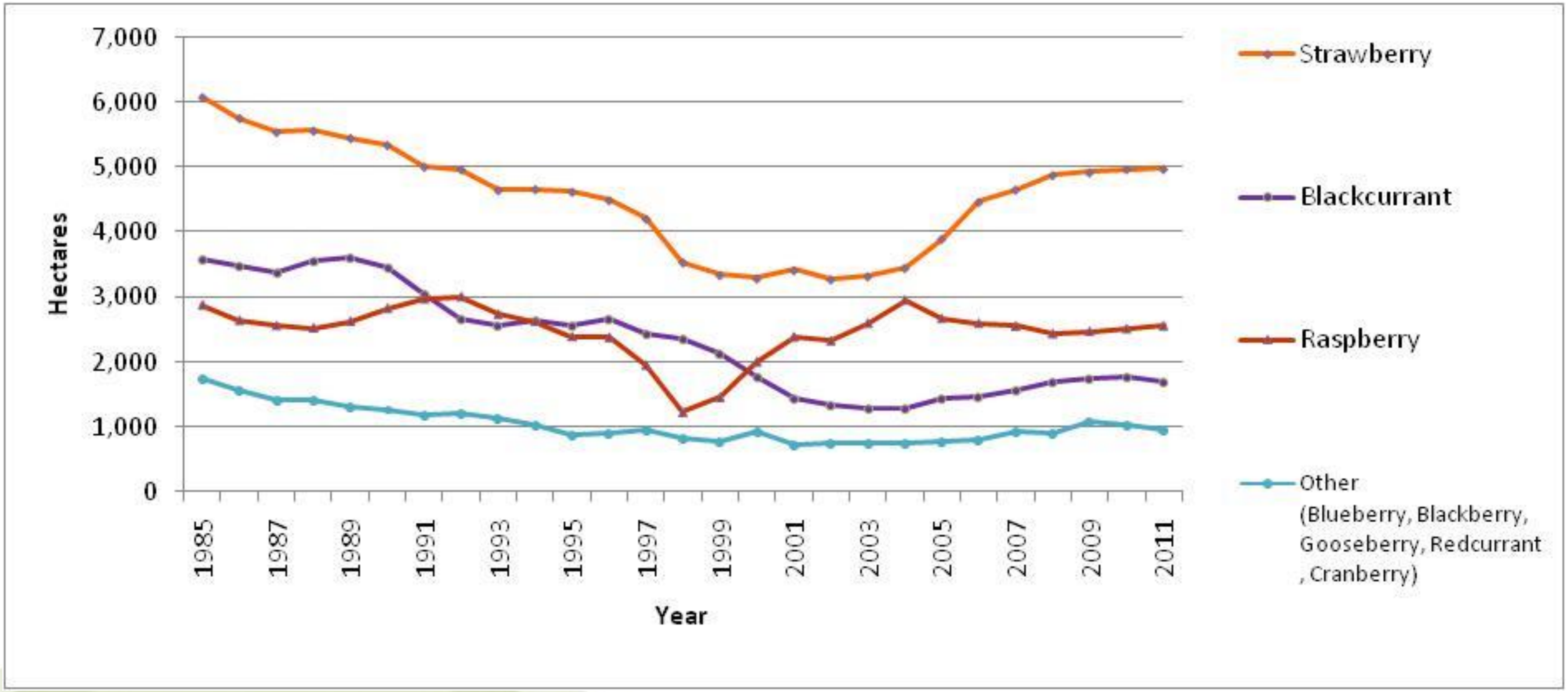
Formed in 2011 from the merger of two institutes in Scotland

- *Scottish Crop Research Institute*
- *Macaulay Land Use Institute*

Mylnefield Research Services Ltd

- *Commercial breeding programmes*
- *Propagation Licences*
- *Royalty collection*

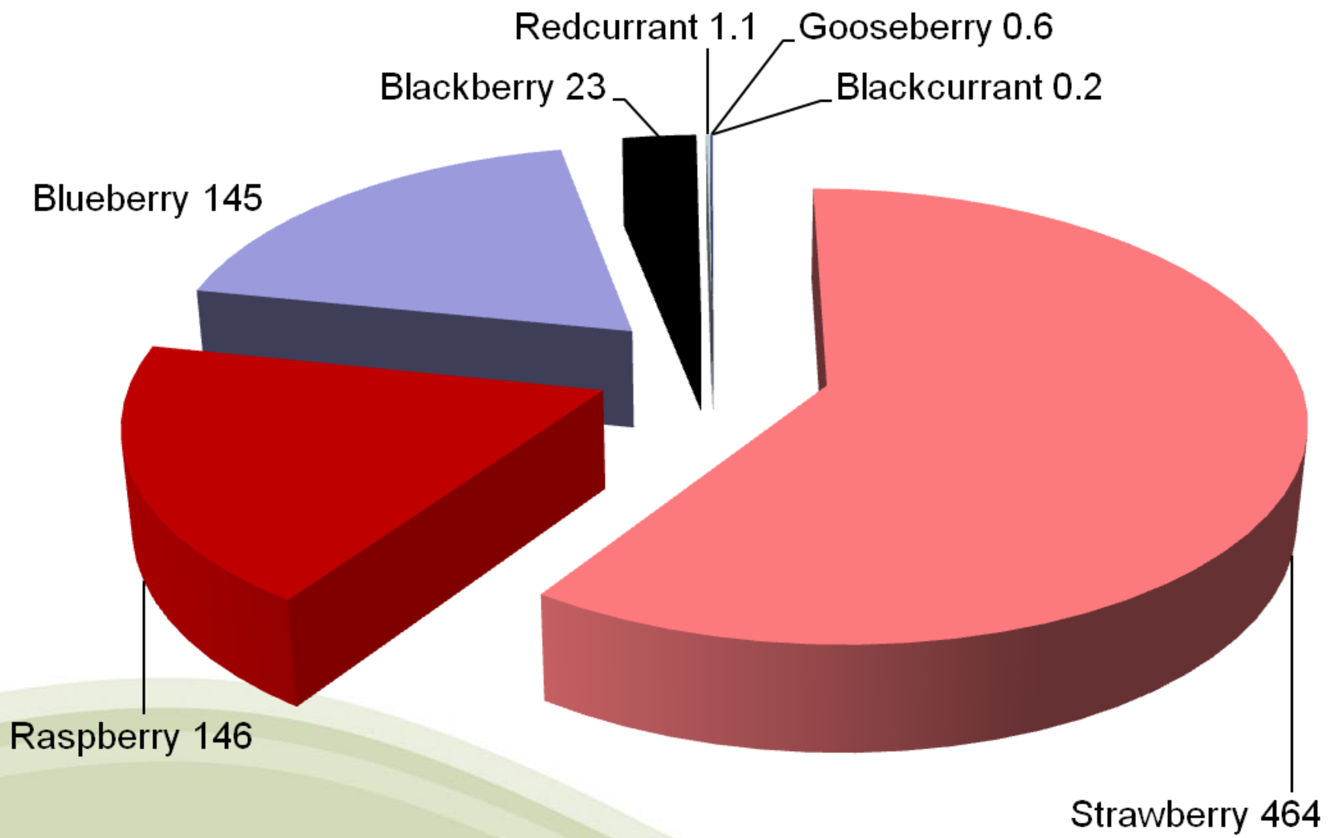
Soft fruit area in the UK (ha)



- 10,000Ha of soft fruit in the UK

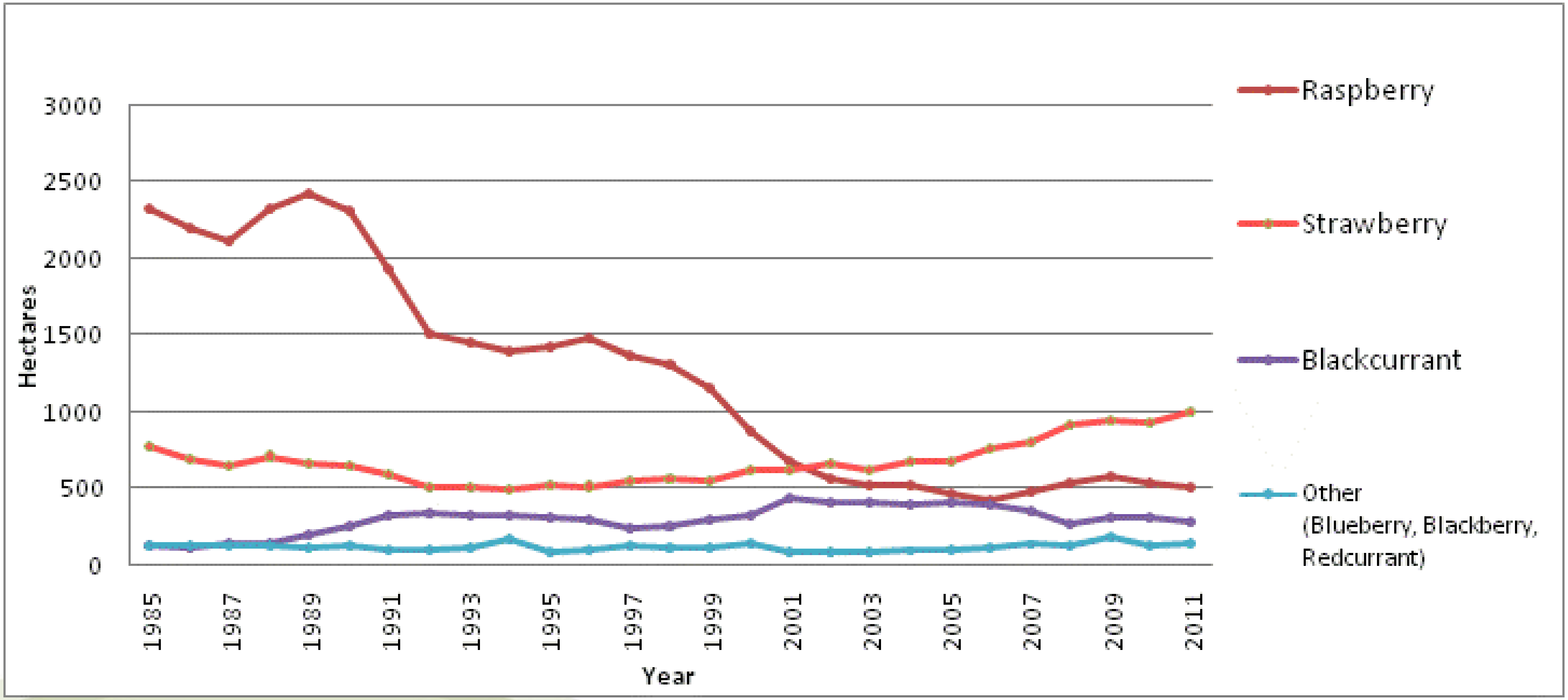
DEFRA Horticultural statistics 2012

Market size of soft fruit in UK - fresh market (£m)



Kantar Worldpanel 2012

Soft fruit area in Scotland 1985-2012 (ha)



Abstract of Scottish agricultural statistics, Scottish Government

Soft fruit in Northern Europe: challenges

- High costs of production and labour
- Low prices due to increased production
- Reduction in available pesticides
  - EU legislation (particularly herbicides)
  - Low input systems/ IPDM
- New cultural practices
  - Substrate / soil-less culture to avoid disease
- Protected cropping
  - Shift in pest and disease pressures
  - Planning permission, labour issues
- Climate issues
  - Chilling requirement
  - Water use
- Multiple retailers demand specific cultivars
- Private breeding programmes – exclusive cultivars

Table-top strawberries,
Angus Soft Fruits, Scotland

Long cane pot production,

Fruit breeding and research at the James Hutton Institute

Rubus breeding

- Raspberry
  - Funded by industry-based consortium
- Blackberry
  - Funded by JHI commercial arm (Mylnefield RS)

Ribes breeding

- Blackcurrant
  - Funded by GlaxoSmithKline for processing
  - Small industry-funded programme for fresh market
- Gooseberry

Breeding supported by underpinning science

- genomics, pathology, biochemistry

Blueberry

- Identify current varieties best adapted to UK climate

Breeding timescales

Pre-breeding

→ Selection of appropriate parents

Year 0

→ Hybridisations made in insect-proof greenhouse (120)

x

Year 1

→ Seed germination, seedlings raised (up to 20k)

Year 2

→ **Stage I** selections (vegetative characters only)

Year 3-5

→ **Stage II** selections (fruiting characters), single plants (300)

Years 6-8

→ **Stage III** selections (fruiting characters), 5-plant units (60-100)

Years 9-12

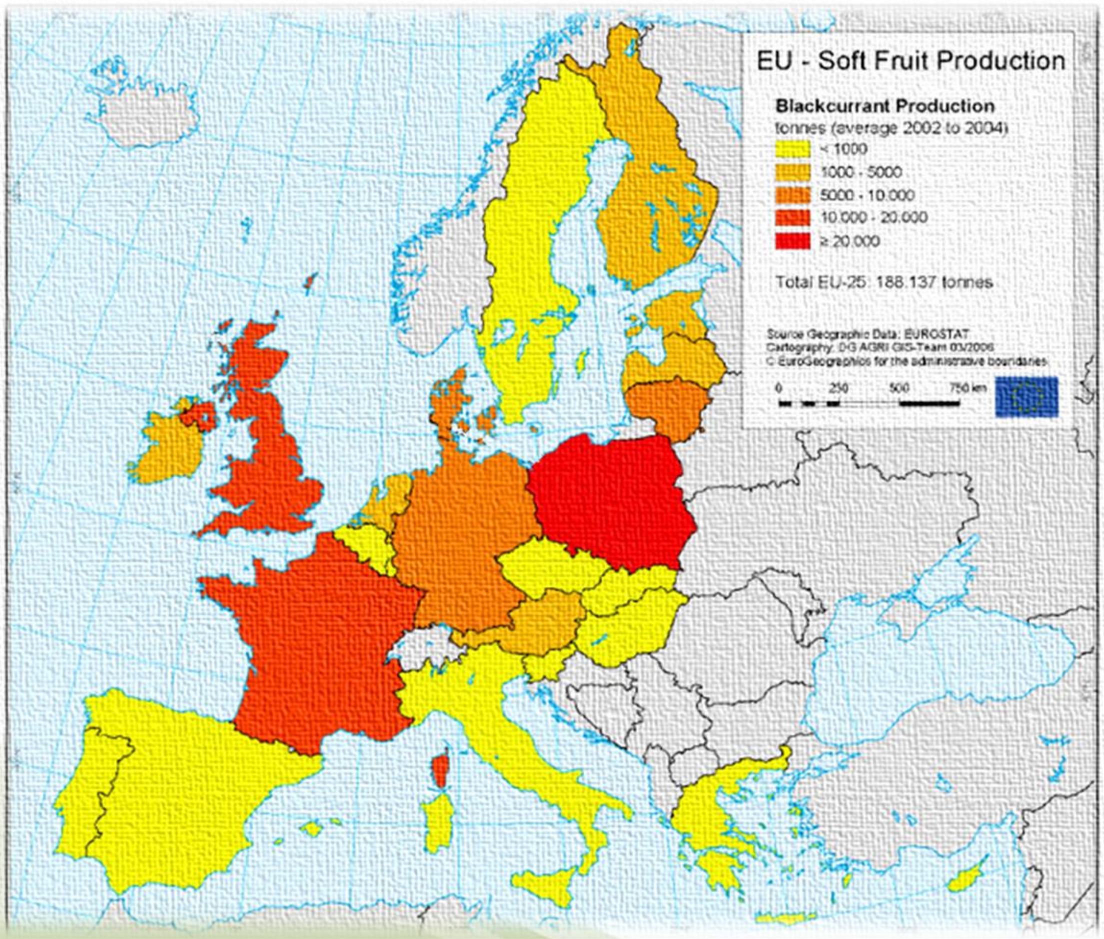
→ Commercial trials in England (6)

Years 13 onwards

→ Propagation of virus-tested plants for release to industry (?1)

Breeding techniques

- Expensive to run breeding programmes:
  - Lengthy timescales
    - Some traits take a long time to screen for, others are impossible to screen on a high-throughput basis
  - Field/glasshouse costs
- Timescales need to be reduced and efficiency needs to be increased
  - Time to cv. currently 12-15 years
- More extensive phenotyping in field, glasshouse and CE rooms
- Establish link between genotype and phenotype


EU - Soft Fruit Production
Blackcurrant Production
tonnes (average 2002 to 2004)
< 1000
1000 - 5000
5000 - 10.000
10.000 - 20.000
≥ 20.000
Total EU-25: 188.137 tonnes
Source Geographic Data: EUROSTAT
Cartography: DG AGRI GIS-Team 03/2006
© EuroGeographics for the administrative boundaries
0 250 500 750 km

ENESAD 2007

POLAND	80,000
UKRAINE	25,700
UNITED KINGDOM	10,750
DENMARK	8,400
FRANCE	7,500
LITHUANIA	6,000
GERMANY	4,500
FINLAND	2,500
NETHERLANDS	2,000
SWEDEN	1,000
HUNGARY	900
NORWAY	520
LATVIA	351
ESTONIA	200
EUROPE TOTAL	150,321 (t)

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iba2012 Dundee 16-18 May

Blackcurrant Cultivars

Big Ben

Ben Maia

Ben Hope

Ben Vane

Ben Avon[+]

Ben Dorain[+]

Ben Finlay*

Ben Gairn*

Ben Klibreck[+]

Ben Starav[+]

Ben Tirran

* First commercial UK cv. with resistance to BRV

* First commercial UK processing cv. with resistance to gall mite

[+] Exclusive to GSK growers

Breeding Objectives

Fruit quality

- High Brix/acid ratio
- Low total acidity
- Anthocyanins
  - Delphinidins
- Sensory traits
- Vitamin C (140 mg/100 ml)
- Berry size (1g minimum)

- Berry size 2g +
- Green strigs preferred
- Higher Brix/acid ratio

Processing

95% of fruit used for processing

Processing quality requirements

Agronomical suitability

Interest in nutritional aspects of the fruit

Fresh market

Agronomic

- Environmental resilience
- Winter chill levels
- Pest resistance
- Acceptable crop yield

(> 6t/ha)

- Juice yield also quantified

Often different cultural practices

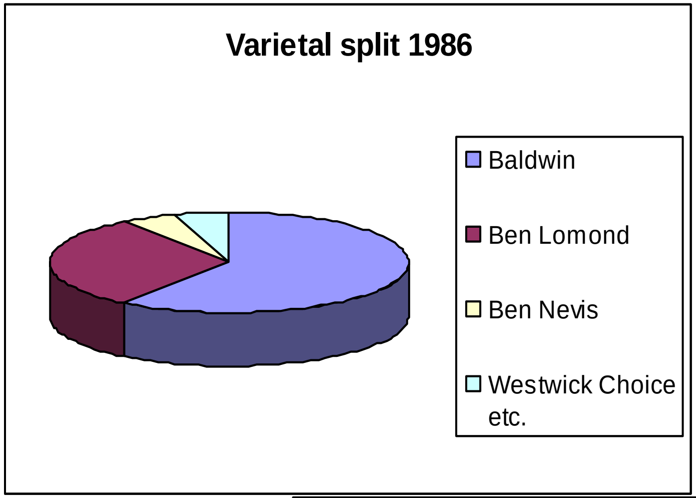
- Hand harvesting
- Grown on wires in some areas

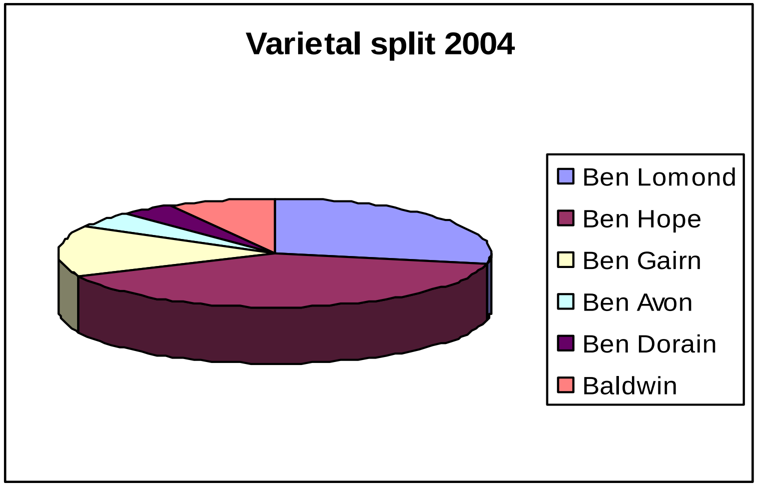
Fresh Market Blackcurrants

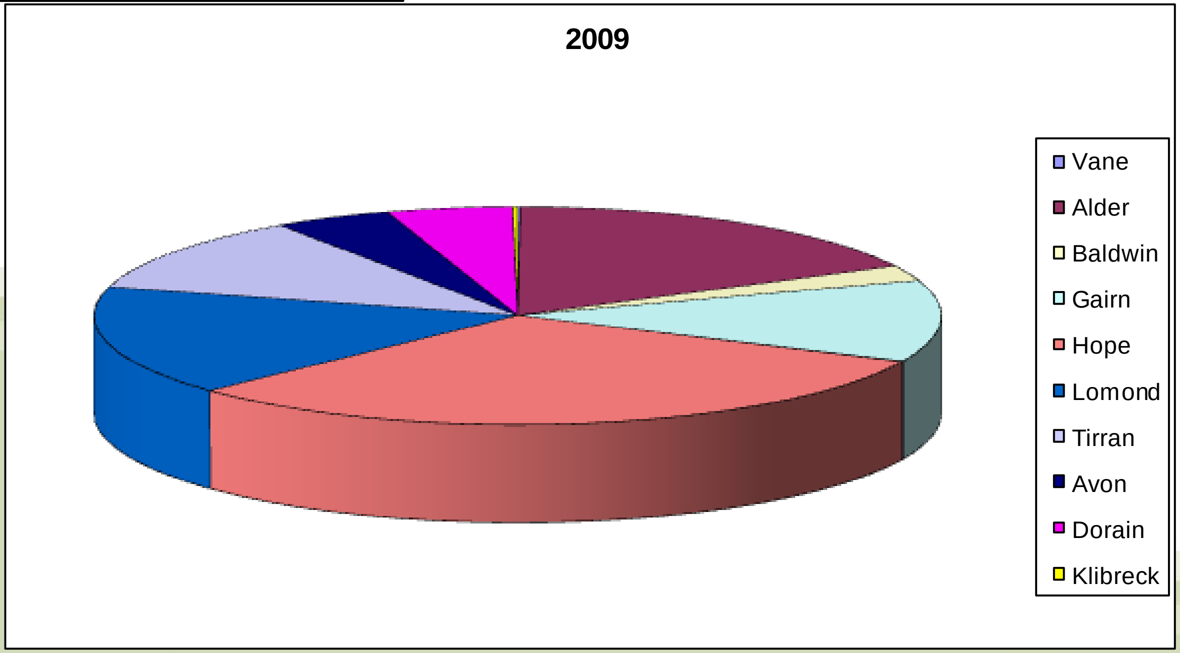
- Increasing interest
  - Predominantly related to health benefits

- Different requirements and breeding objectives
  - Often different cultural practices
    - Hand harvesting
    - Grown on wires in some areas
  - Large berries preferred
    - 2g +
  - Green strigs preferred
  - Aiming for berries suitable for eating fresh
    - Higher Brix/acid ratios

Big Ben


Varietal split 1986
Baldwin
Ben Lomond
Ben Nevis
Westwick Choice etc.


Varietal split 2004
Ben Lomond
Ben Hope
Ben Gairn
Ben Avon
Ben Dorain
Baldwin


2009
Vane
Alder
Baldwin
Gairn
Hope
Lomond
Tirran
Avon
Dorain
Klibreck

Recent releases

- **Ben Starav** (Ben Alder x ([E29/1 x (93/20 x S100/7)] x [ND21/12 x 155/9])
  - Consistently high yields (mean 10.07 t/ha in trials), medium berries, low-medium chilling reqt., high Brix and juice yield, very high anthocyanin content

- **Ben Klibreck** (Ben More x C2/13/15) x (Ben More x Ri-74020-16)
  - High yields (mean 10.2 t/ha in trials), medium berry size, good growth habit, moderate/high chilling reqt., high vitamin C and anthocyanin content

New release – Ben Finlay

- Gall mite-resistant
- Parentage: [(SCRI P10/9/13 x Ben Alder) x EM B1834-67]
- High yields, suitable for low-input growing
- Vigorous growth habit
- Early-midseason, medium sized berries
- Excellent flavour
- High Vitamin C
- Medium-low chilling requirement

Trial seedlings from JHI breeding programme

JHI 9253-1

Complex cross involving elite lines from Scotland, Sweden and England

Late mid season cv.

Tall vigorous growth

Good yields at Ben Hope/Alder levels

High AsA, v. good anthocyanins

JHI 92127-1

Complex cross incl. Ben Lomond, Ben Rua etc.

Early mid season

Yields good in trials in 2009 & 2010

Very stocky upright growth, with dense foliage
High anthocyanins, medium AsA

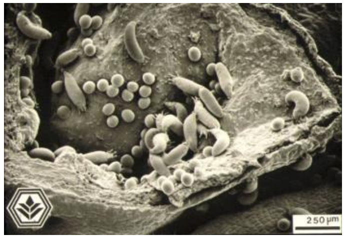
Good `hangability' (only 10% drop after 14 days)

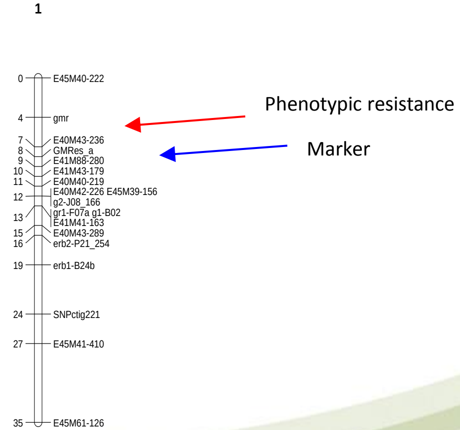
Molecular Breeding

- Rapid identification of genetically superior individuals in breeding populations
- Can be utilised in situations where:
  - Assessment in field takes a long time
    - Pest resistance (some)
  - Assessment can only be done on mature plants over time
    - Fruit quality
- Basic research costs relatively high, deployment costs low
- No environmental effects
- Must be associated with detailed evaluations of performance in field
- Marker-assisted selection possible by linking of genotype with phenotype
- Simple traits so far, more complex traits in development

Gall mite marker

- Gall mite still a v. serious problem
  - Pesticide withdrawals, plantation lifespan, etc.
- Resistance available from *Ce* gene from gooseberry (cf. EMR)
  - Material at JHI now at BC_9+
- Field infestation plot for screening new lines from breeding programme
  - 4 years
- Resistance mapped on genetic linkage map, associated marker identified
  - Accuracy > 95% across mapping population, cvs., trial lines etc.
- Converted to PCR-type (high throughput)
  - Can test 2-3k seedlings p.a.
- **Marker now routinely deployed in JHI breeding programmes as a selection tool**
  - Field infestation plot removed
  - Separate plots of exclusively resistant material initiated
  - Material tested for other programmes, eg. ISK, Poland





Mite-resistant lines in commercial trials

New cv. release:
Ben Finlay

JHI 9968R-1

91130-1 x JHI S36/1/100

JHI 92015-13

(JHI C7/4/24 x Ben Gairn) x EMR B1834-19

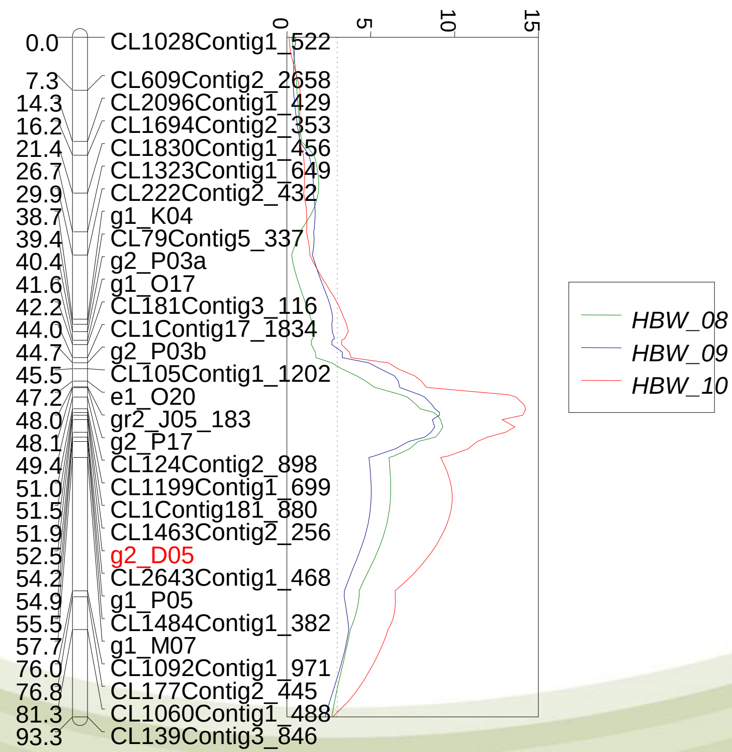
JHI 9154-4

Ben Dorain x EMR B1834-120

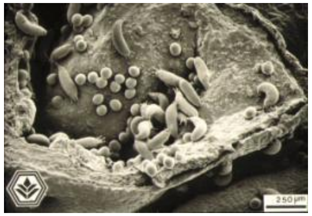
Ribes markers

- Phenotypic data collated for reference mapping population
    - Up to 10 years for some traits
- Quality and developmental traits mapped
- Identification of markers linked to key traits in progress
    - Markers linked to berry size and total anthocyanins
    - Berry size marker data undergoing validation at JHI and Poland (part of EUBerry project)
    - Preliminary associations for bud break, flowering, brix and other traits

SCRI9328 LG1



Reduction of seedling numbers using marker-assisted breeding



Marker for berry size
Est. 2013

Marker for gall mite resistance
2012

Markers for anthocyanins, sugars, vitamin C
Est. 2015

Reduced seedling numbers – but increased relevance to industry needs

Faster field selections and cv. releases

Relative costs

Gall mite resistance – conventional selection

- 4 years' field costs for replicated infestation plot = ca. £2k (€2.4k)
- Propagation of replicates for field screening
- Total time taken = 5 years

Gall mite resistance – marker-assisted selection

- Sample collection, DNA extraction, use of marker – total cost (consumables) = ca. £450 (€500) for 1000 genotypes
- Time taken = 3 months

- **Combination of markers will increase cost-effectiveness**
  - **Only worth doing for traits where screening takes several years, or where phenotyping is difficult/expensive**
- **Breeding efficiency is increased by having fewer genotypes in field but better aligned with target objectives**

Molecular Breeding

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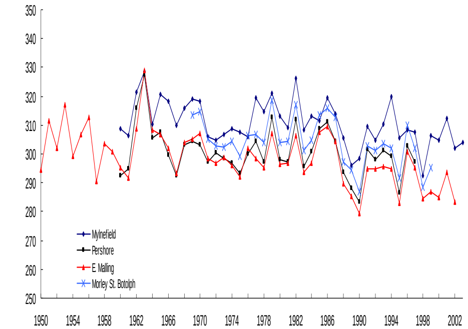
- Faster identification of genetically superior individuals in breeding populations
- Can be utilised in situations where:
  - Assessment in field takes a long time
    - Pest resistance (some)
  - Assessment can only be done on mature plants over time
    - Fruit quality
- Basic research development costs relatively high, deployment costs low
- No environmental effects
- **<u>Must be associated with detailed phenotyping</u>**

New challenges (& opportunities)

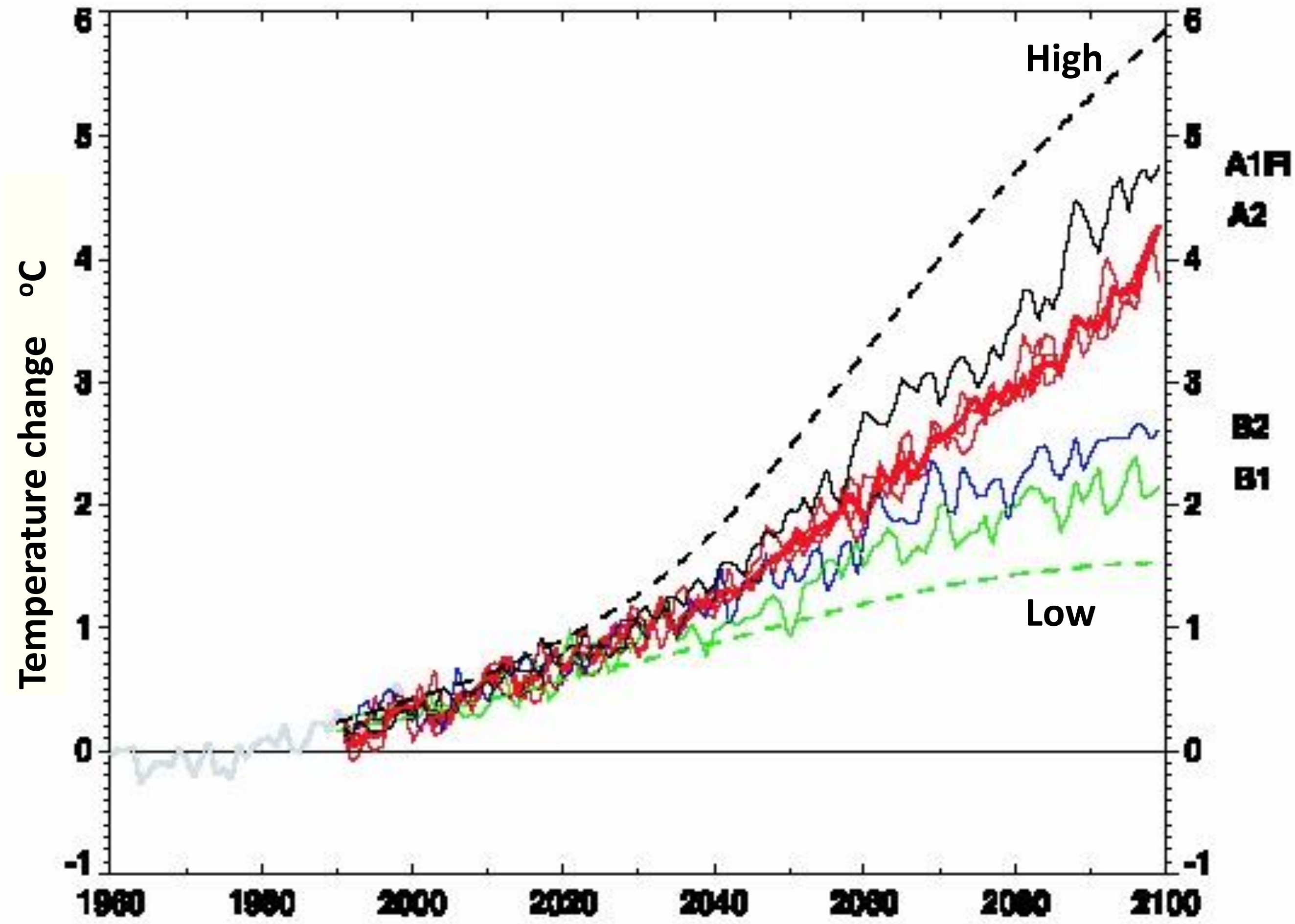
- Disease problems eg. *Phomopsis*
- Environmental effects on blackcurrants
  - Winter chilling reductions
  - Water use efficiency
  - Effects on fruit quality



Climate effects on berry fruits

- Long-term changes in climate
- Emerging problems due to changes
- Evaluation of environmental adaptability of germplasm
    - Phenotyping of germplasm
- Genetic characterisation for environmentally-important traits
    - Dormancy-related genes

Temperature - an uncertain future?



Data from IPCC 2007 report

Variation in chilling requirement (h < 7 °C) between fruit species

- Blackcurrant
  - 800-2500
- Raspberry
  - 800-1700
- Strawberry
  - 200-300
- Peach
  - 100-1250
- Grape
  - 100-1400
- Apple and pear
  - 200-1400

Case study: Ribes

TIMESONLINE

August 24, 2007

Problem of global warming is at heart of currant affairs

It is not only Bangladesh that is threatened by global warming. It is the British blackcurrant: warmer, wetter winters have led to a gradual deterioration in the quality of the blackcurrant crop. Without a heavy frost, blackcurrant buds do not break properly and the result is a decline both in the quantity and quality of the fruit. Climate change could make it impossible to grow two kinds of blackcurrant – Baldwin and Ben Lomond – in many parts of southern England within a decade.

Warm winters 'ruin' currant crop

Saturday, 11 November 2006

A Herefordshire farmer is warning of a shortage of blackcurrant squash and jam claiming global warming has affected his crop.

Edward Thompson, from Ledbury, said he first noticed a mild winter in 1998 meant only half as much fruit grew but he was baffled as to why.

Selection of new cultivars

- Selection from multi-site trials
- Phenotyping of elite germplasm
- On-going monitoring of future climate predictions

Ben Klibreck

GSK trials, Newent

Genetic resources relating to winter chill

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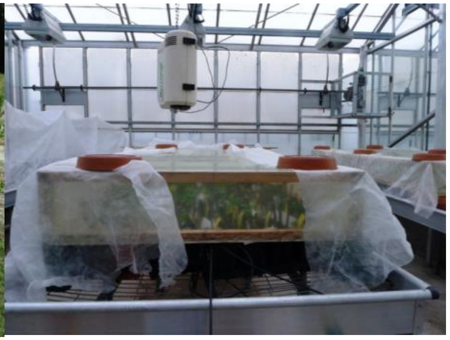
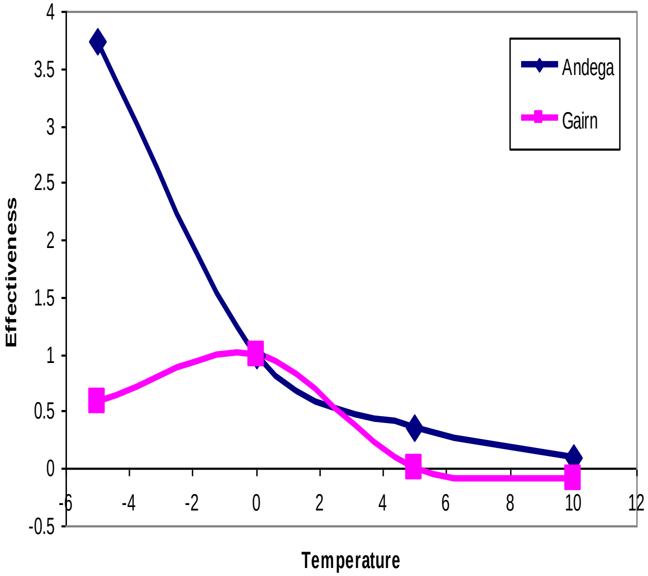
- Use of low-chill germplasm (ex. NZ) for environmental resilience
- Phenotyping of germplasm (selection for low chill)
- Mapping population grown in NZ and Scotland (from 2013)

Plant & Food RESEARCH



Population of `Ben Dorain' (high chill' ex. Scotland) x `Sefton' (low chill, ex. NZ)



Jones, Hillis, Gordon and Brennan (2013) *Plant Biology* **15**: 18-27

Frost damage

Mild early winter followed by severe temperatures prior to budbreak, with no snow cover

Mild winters followed by early budbreak

- Increasing problem with frost damage in northern latitudes, eg. Norway (cf. UK in 1960s/70s)
- Earlier varieties at most risk
- Need to diversify varieties grown

Pictures from Anita Sønsteby, Bioforsk, Norway

GOOSEBERRIES (*Ribes grossularia*)

- Dessert (red) and culinary (green)
- Virtually spinefree
- In trials at RHS

Scottish Raspberry Industry

- Traditional production for processing.
- Decline from early 1980’s
- Machine-harvesting to reduce labour costs
- Demand from supermarkets forced production to fresh market in 1990’s
- Unreliable weather conditions led to protected cropping
  - Covers >80% production

Raspberry machine harvester

Conventional breeding of raspberry

- Based on classical hybridisation (as in blackcurrant)
- 10,000 seedlings / year
- Spined and aphid-susceptible seedlings discarded in glasshouse
- 4000 evaluated in the field
- ~1% are selected after initial fruiting observations

Raspberry breeding at James Hutton Institute

- Breeding began in 1950s
- Renowned for the "Glen" series of raspberry cultivars
  - Glen Moy and Glen Prosen first spine-free cultivars
  - Glen Lyon is current industry standard in Spain
  - Glen Ample is the current industry standard in the UK
  - Floricane/summer-fruiting types
- Focused on needs of industry

Raspberry breeding objectives

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- UK Raspberry Breeding Consortium 2009-2014
  - Scottish Government, industry partners
- Select cultivars suitable for fresh and processing markets
  - Floricane and primocane types
- Create new hybrids with improved P&D resistance, especially to *Phytophthora* root rot
- Deployment of marker assisted selection

Breeding Programme: Selection Evaluation

- Detailed evaluations over 3 fruiting years
- Promising selections are trialled further on a diversity of geographical locations and cropping systems
- A decision is made to release a new cultivar

Current timescale min 15+ years

Protected 5-plant plots at James Hutton Institute

Current Industry Standards

Glen Ample

- Released from SCRI in 1996.
- Large fruit, large yield and sweet flavour.
- Spinefree.
- Very productive and easy to manage.
- Performs well in all cropping systems.
- Accounts for 80% raspberry area in Scotland.
- **Susceptible to aphids, virus, cane diseases and root rot**

Tulameen

- Released from British Columbia in 1989.
- Very sweet and aromatic.
- Large glossy fruit.
- Spiney.
- Less productive than Glen Ample.
- Poor plant habit.
- **Susceptible to aphids, cane diseases and root rot**

New cultivar in 2008

Glen Fyne

- More productive than Glen Ample
- Superb sweet raspberry flavour
- Large fruit with good shelf life
- Machine harvestable
- Spinefree and A_{10} resistance to aphids
- Suitable for fresh and processing markets

New cultivar in 2010

Glen Ericht

- High tolerance to *Phytophthora* root rot
- Good quality but high acidity
- Very upright cane habit
- Machine harvestable
- Spinefree and A_{10} resistance to aphids
- Processing market only

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Advanced stage raspberry selections

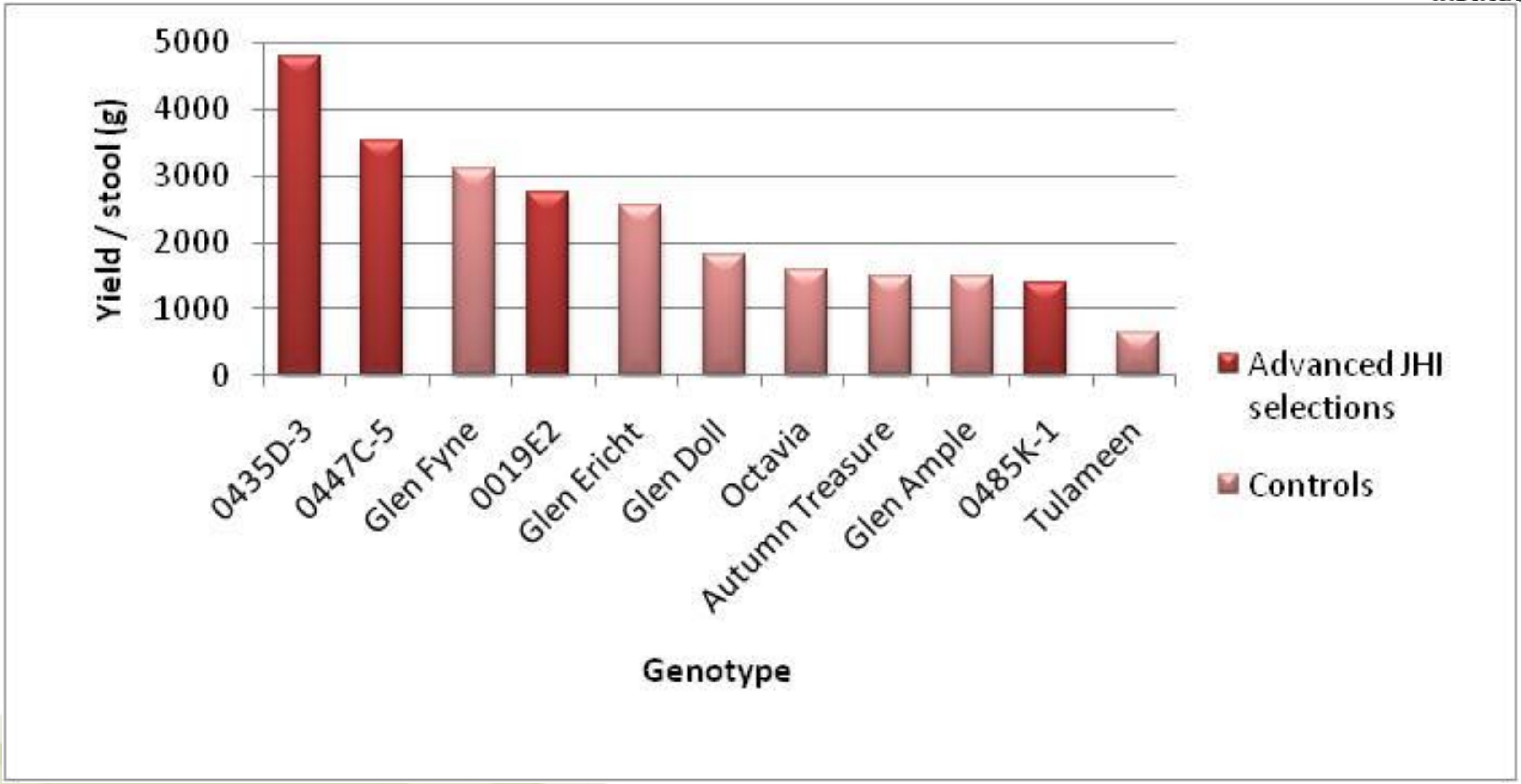
0435D-3
v early season, sweet

0019E2
large size

0485K-1
attractive, good flavour

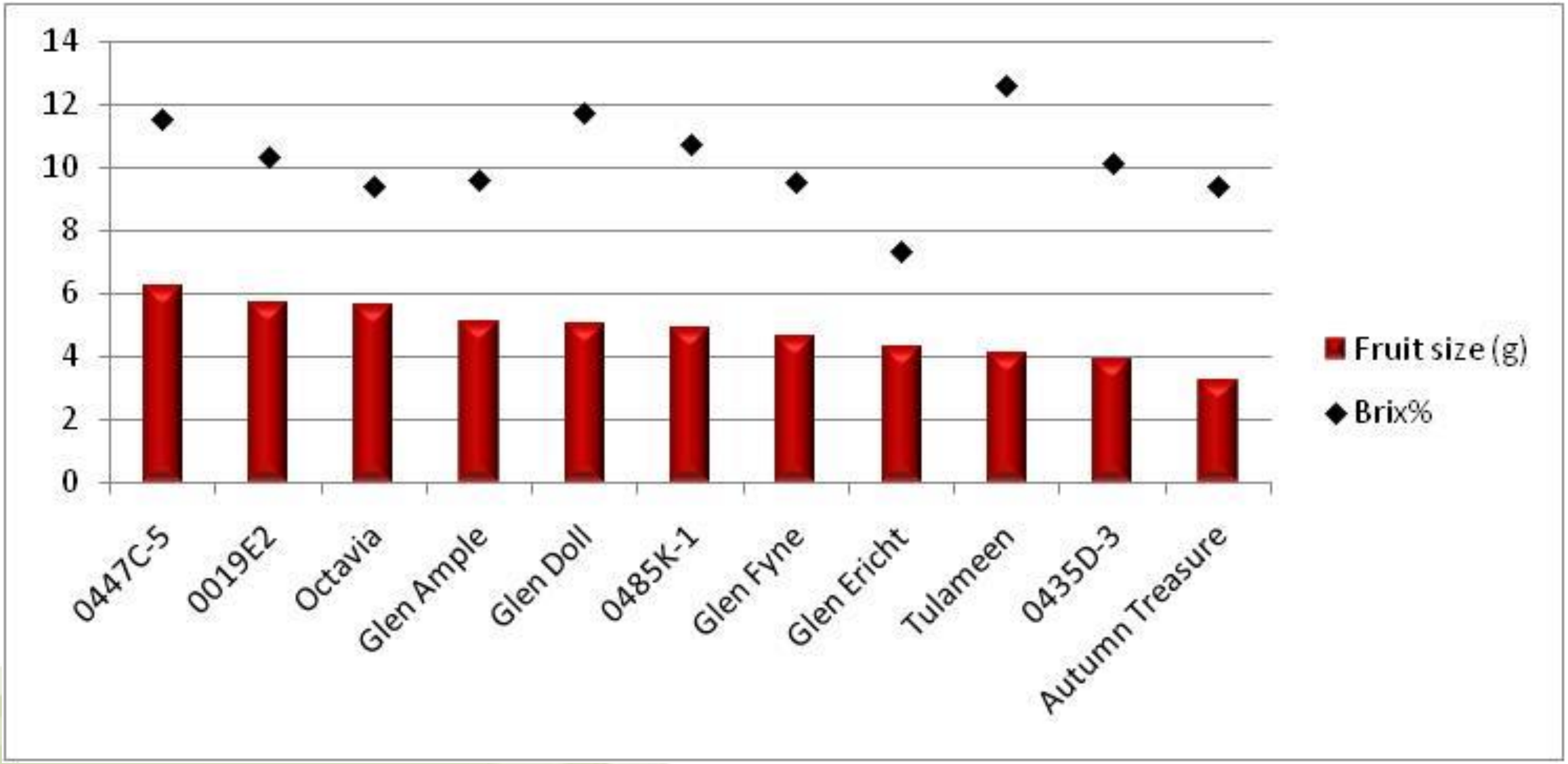
0447C-5
very late season

Fruit data from James Hutton Institute 2012: Yield



Stool equivalent to 8 canes/m

Fruit data from James Hutton Institute 2012: Fruit size and Brixº



Plant material available to trial from MRS

Primocane types at JHI

- Commercial cultivars in UK:
  - Maravilla (Driscolls, US)
  - Cardinal (Driscolls, US)
  - Erika (Santa Orsola, Italy)
- First crosses made at JHI in 2009
- Primocane x Floricane families
- Evaluated in10L pots, segregating for primocane habit
- Focus on primocane- fruiting types which are:
  - Early
  - High quality
  - Spinefree

Primocane selections from JHI

Raspberry root rot (*Phytophthora rubi*)

- Devastating to raspberries
  - Cool and wet conditions
  - Infection spread in soil water
  - Canes and laterals wilt and die
  - New growth will fail to emerge
- Spores can stay in the soil for 20+ years
- Extensive chemical control coupled with modified management practices
- Currently no true resistant cultivars with marketable quality

Conventional breeding for resistance to raspberry root rot (*Phytophthora rubi*)

- ~20% of the crossing programme
- Seedlings screened in a deliberately infested field
- Selections are identified when the controls are dead
- Additional 4-5 years to breeding timescale
- Glen Ericht currently identified with high tolerance

Deployment of markers for resistance to *Phytophthora* root rot

- Raspberry amenable for mapping
  - Diploid (2n = 2x = 14)
  - Very small genome (275Mbp)
  - Highly heterozygous
- First raspberry genetic linkage map developed 2004
- Development of PCR-based markers for *Phytophthora* resistance in 2008
- Parents with resistance marker identified for crossing in 2009 (25 families)
- >40 selections with the marker in field trials

Mapping key traits in raspberry breeding

Key traits mapped and deployed

- *Phytophthora* root rot
- *Gene H and* cane diseases

Other traits mapped

- Sensory characteristics
  - Fruit size
  - Colour, anthocyanins
  - Volatiles, Brix°
- Fruit development / ripening

Traits currently under investigation

- Fruit softening
- Crumbly fruit
- Plant physical mechanisms
  - Cane splitting
  - Leaf hairs / pest resistance

Blackberry / Hybridberry Breeding

- Thornfree cultivars “Loch Ness” and “Loch Tay”
- “Tayberry” and “Tummelberry” are Raspberry x Blackberry hybrids
- Increased demand from UK fresh market
- New germplasm imported from overseas breeding programmes to improve fruit size and quality

Blackberries

Loch Tay

- Released in 2003.
- Thornfree.
- Early season.
- Condensed ripening.
- Sweet and aromatic.

Loch Maree

- Released in 2006.
- Thornfree.
- Early-mid season.
- Beautiful pink double blossom
- Sweet and aromatic.

‘Fruit For the Future’
James Hutton Institute, Thursday 18th July 2013

The James Hutton Institute

Acknowledgements

James Hutton Institute

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Rob Saunders
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University of Dundee

Lyn Jones

University of Reading

Nick Battey
Paul Hadley

UK Growers

Overseas Collaborators

NZ

Geoff Langford, Cath Snelling, Alastair Currie

Poland

Stan Pluta
Edward Zurawicz

Other European breeders

The Scottish Government

Winterwood

gsk GlaxoSmithKline