Blackcurrant breeding at JHI – where we are now and what's coming next

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The James Hutton Institute

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Plan

- Progress to date
  - Existing varieties and the commercial landscape in the UK
- New challenges
  - Breeding objectives and how they have changed
- Trial lines
  - The next raft of varieties for the processing and fresh markets
- Molecular breeding strategies
  - Genome sequencing
  - Marker-assisted selection

JHI/MRS *Ribes* breeding

- Breeding at SCRI from 1960s
- GSK funding since 1990
  - Contracted until 2015
- First release – Ben Lomond (1974)
- Subsequent releases (all Bens) increasingly successful commercially
    - Ben varieties now account for 99% UK production, ca. 50% global
- Emphasis on quality for processing, reflecting the funding source for the breeding programme
- Very wide genetic base – variety and species collection maintained as part of Scottish Government Underpinning capacities programme
- New varieties **must** combine quality with agronomic performance

Blackcurrant supply chain

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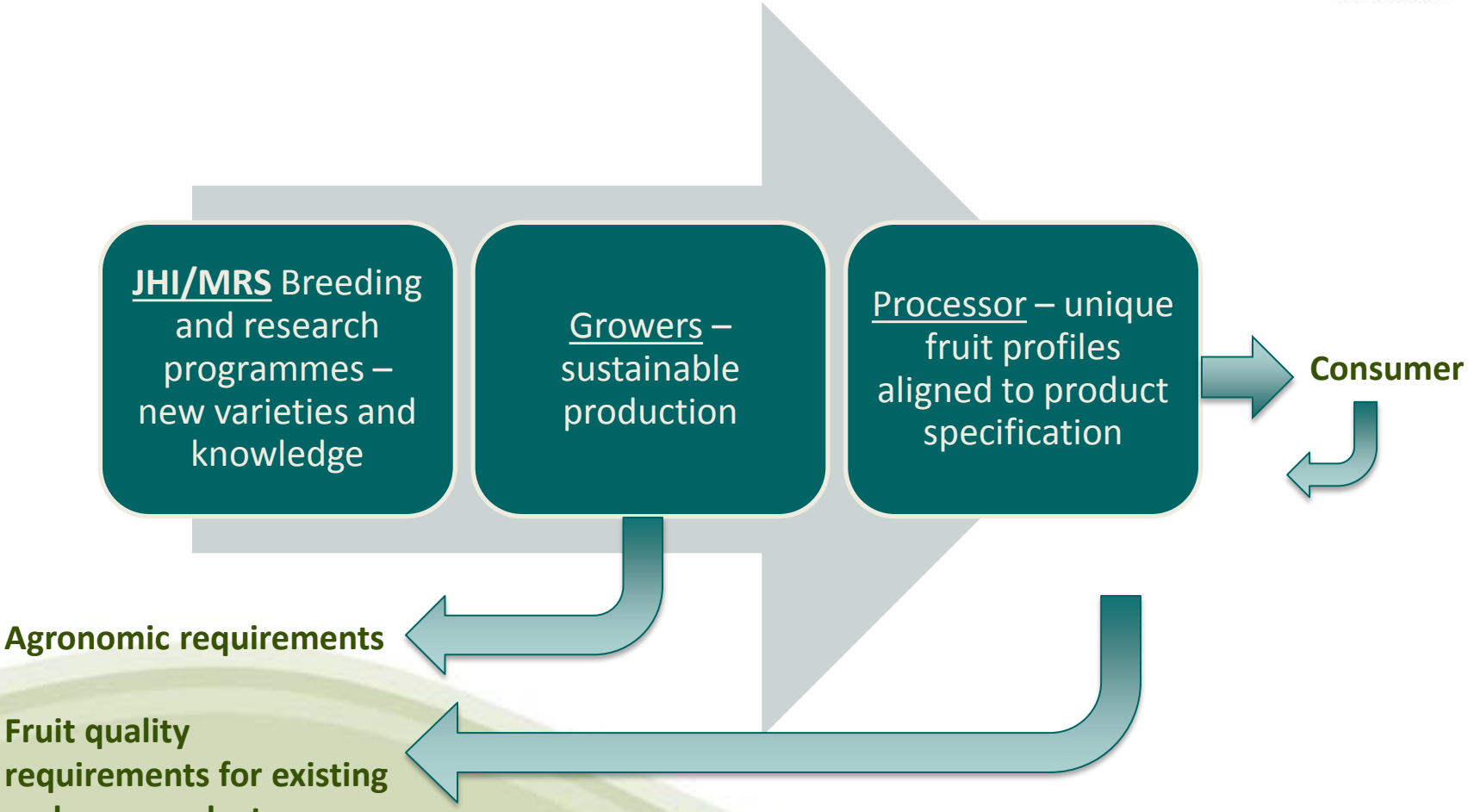

More varieties produced

- 1986
  - Ca. 4 main varieties, Baldwin is widest-grown
- 2000
  - Ca. 5 main varieties, Ben Lomond is most popular
- 2004
  - Ca. 6 main varieties, Ben Alder is most popular
- 2009
  - Ca. 10 main varieties, Ben Hope is most popular
- 2014
  - Ca. 10 main varieties, Ben Hope is most popular (just)

Varieties – past and present

`Baldwin' - > 100 years old, mainstay of UK blackcurrant industry up to l980s

`Ben Lomond' – released from SCRI 1974, most popular variety in 1980s – early 90s

`Ben Starav' – released 2008

The new standards……

- **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

Blackcurrant Breeding Objectives

Fruit quality

- High Brix/acid ratio
- Low total acidity
- Anthocyanins
  - Delphinidins preferentially selected
- Vitamin C (AsA)
  - > 140 mg/100 ml
- Sensory traits
- Berry size

Agronomic

- Environmental resilience
  - Winter chill levels
    - < 2000 h/7.2°C
- Pest resistance for low-input growing
- Acceptable crop yield
  - > 6 t/ha
  - Juice yield also quantified

Attributes Ranking 2012

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- Top 5 attributes for new variety selection are quality-related
  - From GSK Breeder's Guidelines
- Flavour is top criterion
  - Potential cultivars all screened at processor
    - Some rejected as poor, or different to other 'Ribena' varieties
  - Better screening for flavour needed at early stages
- Yield/regularity of cropping is top agronomic trait
- Pest and disease resistance has lower priority

Breeding Programme Design

- Identification of best parents
  - Combination of best quality traits and superior agronomic performance
  - Database development

- Identification of areas requiring improvement
  - Sources of characters to be improved identified within database
  - Knowledge of heritability of traits essential
    - » Eg. anthocyanins – strong maternal influences

- Development of crossing schedule
  - *Ca*. 100 crosses every 2 years
  - Spread of cropping seasons

- Crosses made March/April in insect-proof glasshouse

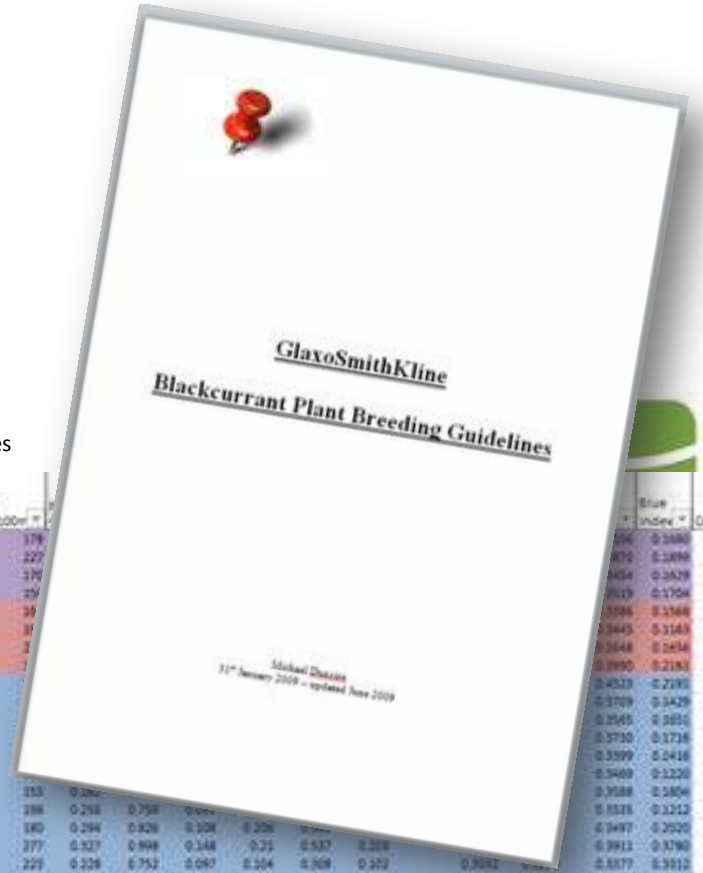
Plant resources within blackcurrant breeding programme

- Blackcurrant seedlings (unselected, Stage 1)
  - > 10k
- Blackcurrant single plant selections (Stage 2)
  - > 2000 including dedicated mite-resistant plot of > 500 selections
- Blackcurrant 5-plant selections (Stage 3)
  - > 400
- Trial lines
  - > 40 including 9 mite-resistant
- *Ribes* germplasm collection
  - Species, old varieties etc.
  - New genotyping techniques developed in *Ribes* have potential application in identifying useful traits within germplasm collection

- ~ 100 crosses made bi-annually
- ~ 500 selections evaluated annually
- 10 new lines selected for trials

Ranking

6	not complying with AsA	
5	Yellow	High AsA (>145)
4	Green	High AsA + High Brix (>13.5)
3	Blue	High AsA + High Brix + Brown index (< 0.38)
2	Red	High AsA + High Brix + Brown index (< 0.38)+ Blue index (>0.15)
1	Purple	High AsA + High Brix + Brown index (<0.38)+ Blue index (>0.15) + field scores



Consistency of quality

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•	Ranking within the year	Expt no.	Selection/cultivar	Parents		Field score	E/M/L	100 b/wt (g)	Juice yield	pH	Brix	Spec grav	AsA mg/100ml	Brown index	Blue index	Vigour	Overall
2009	1	C8	00-25-16					116.3	85	3	16.4		144	0.370	0.171		
2010	5	E13	00-25-16	8955-2	8999-9			127.7	87	2.72	15	1.066	152	0.334	0.141		
2011	1	C8	00-25-16			7+	L	80.4	94	2.75	15	1.0624	209.9	0.365	0.157	7	7+

	Ranking within the year	Expt no.	Selection/cultivar	Parents		Field score	E/M/L	100 b/wt (g)	Juice yield	pH	Brix	Spec grav	AsA mg/100ml	Brown index	Blue index	Vigour	Overall
2009	1	C8	9838-4	836-3-73	8.7E+57			188.9	87	2.76	16.3		186	0.330	0.150		
2011	1	C8	9838-4			7	M	96.3	89	2.65	16.3	1.0828	245.4	0.360	0.162	7	7

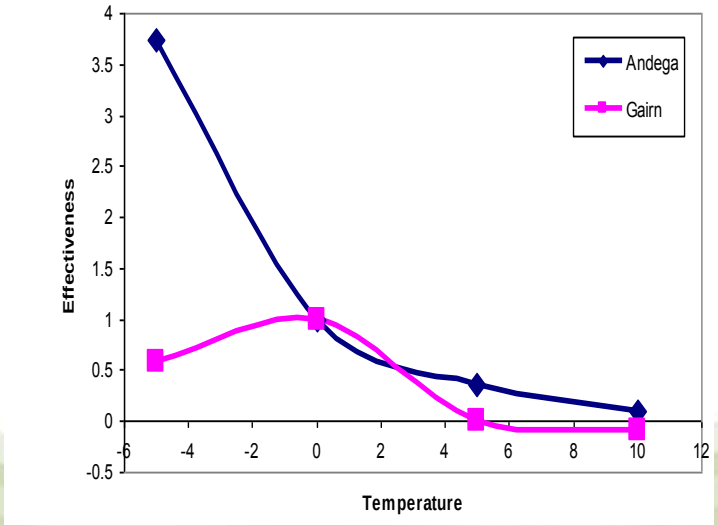
	Ranking within the year	Expt no.	Selection/cultivar	Parents		Field score	E/M/L	100 b/wt (g)	Juice yield	pH	Brix	Spec grav	AsA mg/100ml	Brown index	Blue index	Crop	Habit	Berry	Branch	Pests	Mildew	Strigs	Height	Vigour	Overall	Com
2009	1	C8	998-4	917-4	8828-18			91.5	82	2.85	19.5		234	0.366	0.163											
2010	5 (low brix)	C8	998-4				M/L	128.5	89	3.06	13	1.0571	149	0.407	0.159	8	7	7	7	UM5	0	7	5	6	7	
2011	1	C8	998-4			7	M/L	97.5	82	2.64	16.3	1.0763	201.9	0.345	0.156	7	7	5	7	UM5	0	6	6	6	7	Infe

	Ranking within the year	Expt no.	Selection/cultivar	Parents		Field score	E/M/L	100 b/wt (g)	Juice yield	pH	Brix	Spec grav	AA mg/100ml	Brown index	Blue index	Crop	Habit	Berry	Branch	Pests	Mildew	Strigs	Height	Vigour	Overall
2009	1	E10	999-1					116.7	90	3.08	16.4		167	0.366	0.168										
2009	1		999-1					124.9	82	2.85	14.5		168	0.371	0.154										
2010	1	E10	999-1	917-4	917-4	7+	M	123.6	89	2.77	19	1.0599	170	0.368	0.156	9	7	6	7	UM3	0	4	7	7	8+
2010	6 (low AsA)	C8	999-1			8+		112.3	92	2.95	13.3	1.0619	138	0.324	0.130										
2011	3 (=blue index)	C8	999-1			7	L	95.4	91	2.74	15.7	1.0759	170.8	0.350	0.139	7	7	6	7	0	0	5	7	6	7

	Ranking within the year	Expt no.	Selection/cultivar	Parents		Field score	E/M/L	100 b/wt (g)	Juice yield	pH	Brix	Spec grav	AA mg/100ml	Brown index	Blue index	Crop	Habit	Berry	Branch	Pests	Mildew	Strigs	Height	Vigour	Overall
2009	1	E10	9998-1					95.3	88	2.88	16.7		209	0.377	0.192										
2010	1	E18	9998-1	917-4	8828-18	7+	M	143.6	89	2.77	14	1.0465	151	0.366	0.165			8	0	UM4	0	7	0	0	7+
2010	3 (=blue index)	E13	9998-1				M	111	93	2.44	13.9	1.0588	149	0.331	0.138										
2011	6 (low AsA)	E18	9998-1			7+	M	41.7	4				92.3	0.351	0.162	8	6	7	7	UM2	0	7 GREEN	6	7	7+

Winter chilling and climate change

- Potentially major limiting factor for blackcurrant production in some areas
- Differences in chill requirement identified, models developed (but need to be refined)
- Collaboration with Plant and Food NZ
  - Mapping population in 2 locations, correlation of post-chill responses
- Identification of genes/genetic regions that control differences in climate response



Ongoing work on climate effects

- 2012-3 and 2013-4 we have been harvesting shoots from field at weekly/bi-weekly intervals to see if we can fit models to actual data
  - 4 cvs. (2 high chill, 2 low chill)
- Accompanied by bud samples for microarray/gene expression analysis
  - Alignment of gene expression with bud dormancy and development
- 2012/13 Continuously cold – so little discriminatory power
- 2013/14 Lowest levels of chill in over 20 years

New release – 9521-2 (prov. Ben Lawers)

- Early-mid (Lomond) season
  - after Ben Vane but before Ben Starav, at a time of potentially low fruit supply
- Typical yields 7 - 8 tonnes per hectare
- Not fully resistant to gall mite, but slow to become infected in a high pressure field situation
- Very low susceptibility to Botrytis
- Averaged Brix levels of 16.6 (though has been as high as 18.9)
- High levels of AsA
- Good flavour
  - `Fresh fruity blackcurrant'
- Low chilling requirement
- Exclusive to contract growers

New trial lines 1

JHI 9918-3 (GSK 2008-6)

- Ben Hope x JHI 91130-1
- Mite resistant
- Mid-season
- Upright growth habit
- AsA > 200 mg/100 ml

JHI 9998-2 (GSK 2010-14)

- JHI 917-4 x 8828-18
- Early ripening, similar to Ben Vane
- Brix 15.8
- High yields of large berries (> 1g)

New trial lines 1

JHI 00-37-29 (GSK 2010-17)

- Ben Klibreck x JHI 8992-11
- Late season, possible Ben Tirran replacement
- AsA > 230 mg/100ml, Acy > 1, Brix > 16
- Berries > 1g

JHI 9918-1 (GSK 2008-6)

- JHI 91130-1 x Ben Hope
- Good yields
- Mid-late season, potential Ben Klibreck replacement
- AsA > 230 mg/100 ml
- Gall mite-resistant

New trial lines 2

JHI 00-54-21

- Ben Hope x JHI 8837-11
- Late season
- Large berries
- ASA > 180 mg/100 ml

JHI 00-54-30

- Sister of 00-54-30
- Late season
- Avge berry size 1.23 g
- AsA > 190 mg/100 ml, better colour

New trial lines 2

JHI 92105-13

- JHI S36/2/21 x B1834
- Early-mid season
- Gall mite-resistant
- Sl. spreading habit
- AsA > 220 mg/100 ml, high colour

JHI 92127-1

- JHI S36/3/51 x B1834
- Early-mid season
- Upright with strong branches
- Consistent cropping
- V high colour, AsA > 160 mg/100 ml

Ben Finlay

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- (JHI P10/9/13 x Ben Alder) x EMR B1834
- Gall mite-resistant
- Early-mid season
- AsA > 240 mg/100 ml
- High anthocyanins
- Registered for EU Rights

Fresh Market Types

JHI P8-5-24

- Berry size 1.29g
- Brix 13.9
- Green strig colour, storage at 4C quite good

Ben Maia

- Berry size < 1g, strong green strigs
- Brix > 14

Fresh Market Types

JHI 01-33-1

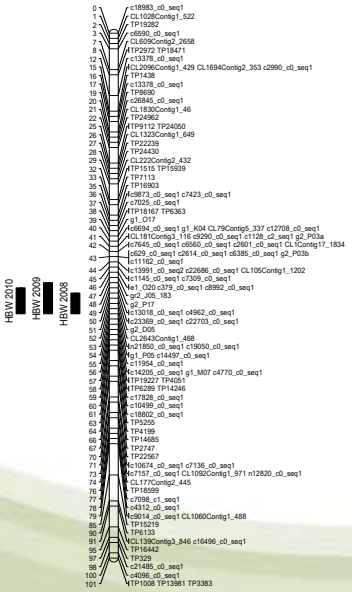
- V large berries (avge. 1.42g)
- Good storage potential at 4C
- Brix avge. 16.48, has been up to 18

JHI 00-50-1

- Large berries (avge. 1.28g)
- Green strigs, outstanding storage potential
- Brix avge. 14.54

Selecting for berry size

- Key trait for fresh and processing markets
- SNP markers associated with large berries identified
- Validation of markers on diverse breeding populations is in progress as part of EUBerry project
  - Joint work with InHort Poland
  - Phenotype data from 2014 harvest will be used to confirm effectiveness of markers
    - Other putative markers available



Future prospects

- Range of new mite-resistant varieties with enhanced juice quality
- Better understanding of environmental effects on fruit quality and cropping
- More markers in the breeding programme
  - Berry size by end of 2014
  - Anthocyanins by end 2015
- Variety selection more closely linked to specific products

Ribes genomic resources

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- Genotyping by sequencing (GBS)
  - 1.58k new SNP markers identified
  - Map length increased by 33% to 780.7 cM
  - Model for mapping and identifying SNPs in crop species lacking reference genome
  - Further GBS in progress on NZ Dorain x Sefton population
- Shotgun sequencing of *Ribes* genome in progress
  - 50x MiSeq coverage

Russell, J., Hackett, C., Hedley, P., Liu, H., Milne, L., Bayer, M., Marshall, D., Jorgensen, L., Gordon, S. and **Brennan, R.** (2013). The use of Genotyping by Sequencing in blackcurrant (*Ribes nigrum*) - developing high-resolution linkage maps in species without reference genome sequences. *Molecular Breeding* DOI 10.1007/s11032-013-9996-8

Future challenges and opportunities

- Move towards sustainable cropping
  - Climate change effects
    - Poor budbreak
    - Frost damage
  - Reduced pesticide inputs (IPDM systems)
    - Emerging pest and disease problems, eg. *Phomopsis,* winter moth

- Molecular breeding offers increased efficiency and resilience within the programme for many of the traits of interest
- The JHI/MRS breeding programme is able to combine underpinning science and wide genetic resources with commercially-facing varietal production

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BBC `Harvest', August 2013