Hop Breeding Principles

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Great Lakes Hops and Barley Conference

Kalamazoo, Michigan, USA
13th March 2018

WYE HOPS LTD

Early Programmes

- Wye, UK (1904) 1906
- USA, Oregon (1908) 1931
- Denmark, Carlsberg 1911
- Japan, Kirin 1912
- Germany, Huell 1926

- Czech Republic, Zatec 1924

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Plant breeding stages

- Objectives
- Germplasm
- Techniques
- Selection protocols
- Commercialisation

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Objectives

- Resin content
  - alpha-acid (and beta-acid) content
  - cohumulone content
  - storage stability

Fuggle	4%	(1875)
Brewers Gold	8%	(1934)
Northern Brewer	9%	(1944)
Wye Target	11%	(1972)
Admiral (CTZ, Herkules)	15%	(1996)
Polaris (Eureka)	>19%	(2012)

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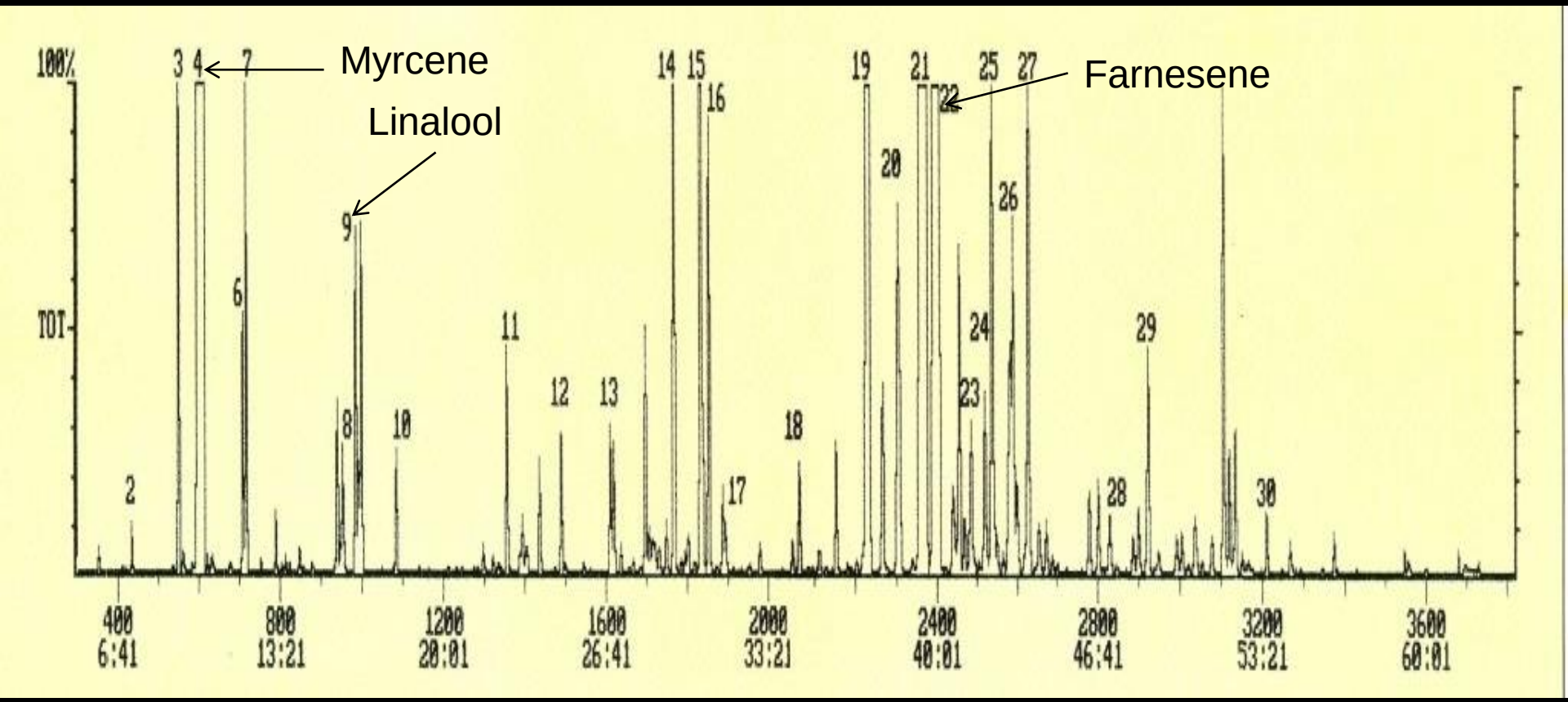
100%
TOT
Myrcene
Linalool
Farnesene
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18
17
28
30
2
400
6:41
800
13:21
1200
20:01
1600
26:41
2000
33:21
2400
40:01
2800
46:41
3200
53:21
3600
60:01

Objectives

- Resin content
- Aroma
  - Grower selections : Fuggle, Golding, Hallertau, Saaz, Cluster
  - Disease rest: Progress, Bramling Cross, Tradition, Perle
  - Adaptation: Willamette, Cascade, Mt Hood, Liberty
  - Impact: Nelson Sauvin, Citra, Galaxy, Lemondrop etc…

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Objectives

- Resin content
- Aroma
- Yield
    - cone size
    - cone weight / density
    - cone number
  - Triploids: Willamette, Blisk, Pacific Gem …
  - Diploids: Columbus, Herkules

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Objectives

- Resin content
- Aroma
- Yield
- Disease and pest resistance
  - Downy : Huell vars
  - Powdery : Wye Target, Endeavour
  - Wilt : Wye Target, Phoenix, Pilgrim
  - Black root rot : New Zealand vars
  - Aphids : Boadicea

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Objectives

- Resin content
- Aroma
- Yield
- Disease and pest resistance
- Dwarfness
  - Reduce inputs of labour, materials, pesticides
  - Sub-optimal production conditions

First Gold,

(Herald), Pioneer, Pilot, Boadicea, Sovereign, Endeavour

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Hop growing areas of the World

Objectives

- Resin content
- Aroma
- Yield
- Disease and pest resistance
- Dwarfness
- Adaptability
  - Daylength

South Africa : Outeniqua, Southern Star, African Queen, Southern Dawn, Southern Passion

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Germplasm

- Historic and commercial varieties
- Wild hops
- Derived genotypes from wild accessions
- Traits – single, combination
- Wide genetic base
- Useable, inherited variation

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Varietal differences in infestation by Hop Aphid (*P.humuli)*

Breeding line	No. aphids/ side-arm
Northdown	4364
33/75/9	1478
29/80/8	1258
27/76/8	630
19/65/29	524
11/68/15	256
Intro 101	60

Source: Darby & Campbell (1988)

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Varietal differences in reproductive capacity of Hop Aphid (*P.humuli)*

Breeding line	No. aphids from 10 individuals after 30 days
Northdown	8670
33/75/9	4481 *
29/80/8	3330 *
27/76/8	5159
19/65/29	5301
11/68/15	2330 *
Intro 101	2072 **

Source: Darby & Campbell (1988)

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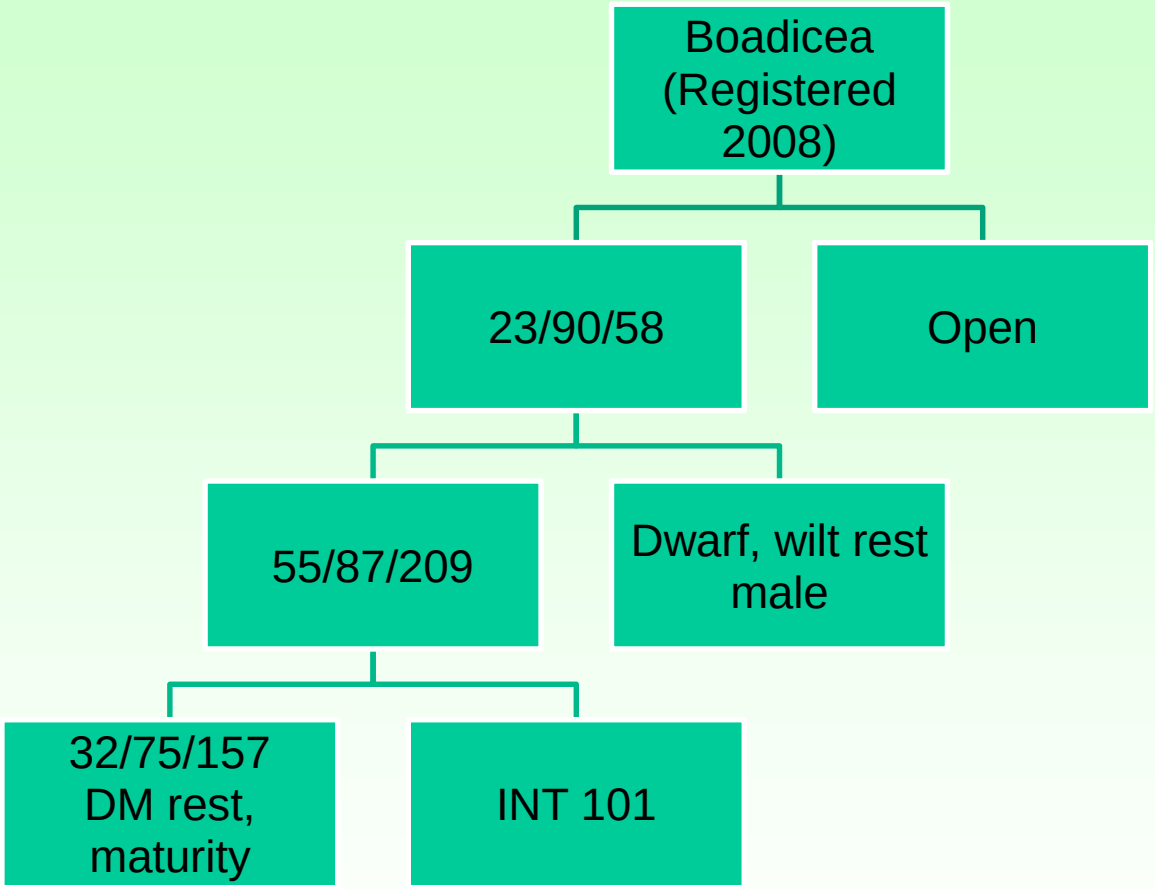
CHARLES FARAM & CO LTD
WWW.WELLHOPPED.CO.UK
BRi
BREW
3


Boadicea (Registered 2008)
23/90/58
Open
55/87/209
Dwarf, wilt rest male
32/75/157 DM rest, maturity
INT 101

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Techniques for hop breeding

- Separate ♀ and ♂
- ♀ - limited
- Uniquely variable
- Inbreeding depression
- Clonal
- Perennial
- Wind pollinated

Pedigree breeding
Progeny testing of ♂s
Individuals in F1
Limited backcrossing
Uniform and rejunenable
Mixing of generations
Barrier methods

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Selection protocols

- Probability of success – “the more the better”
  - selection criteria to reduce numbers
- Knowledge of heritability
  - genetic systems
  - genetic interactions, associations and linkage

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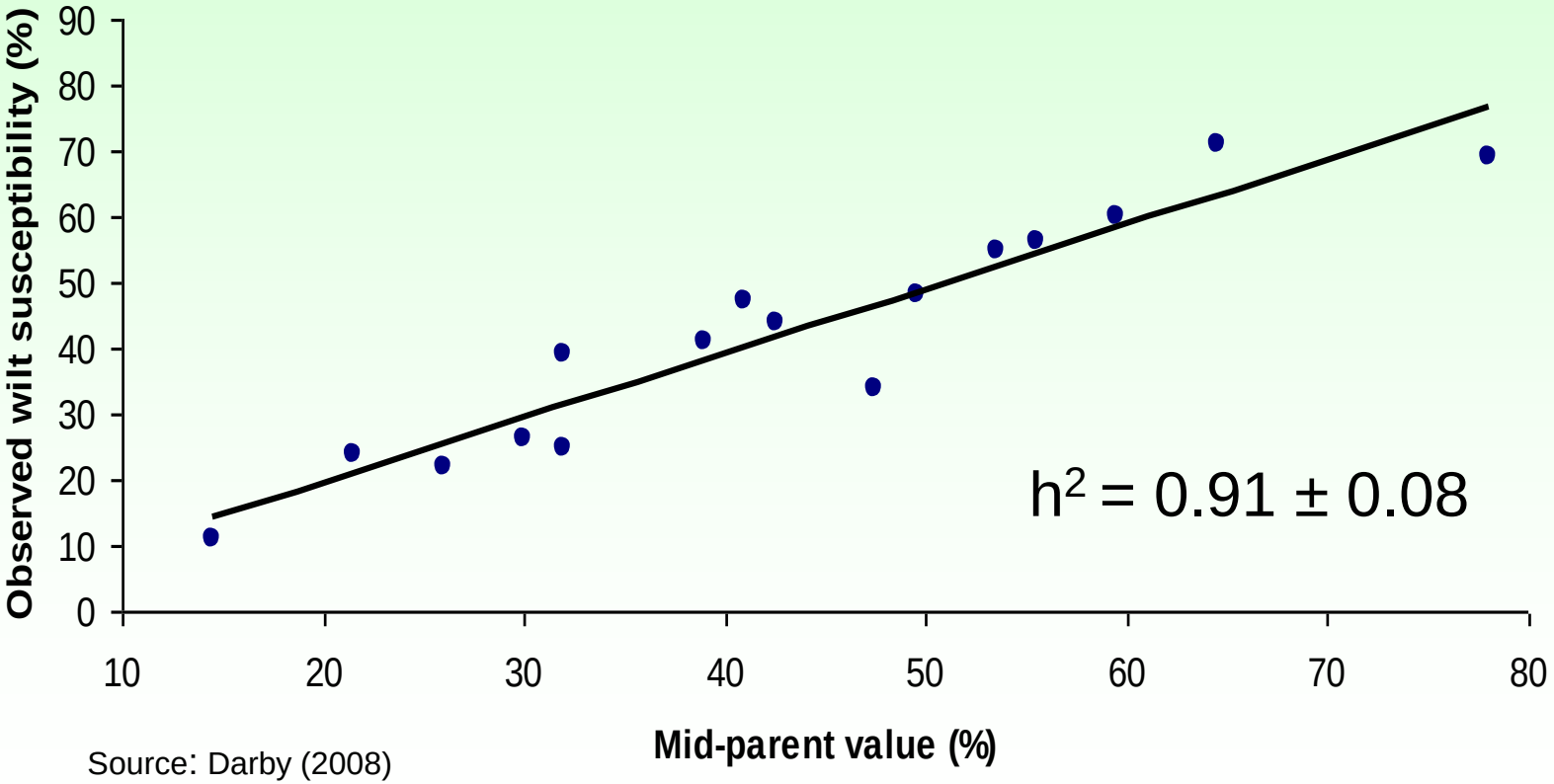
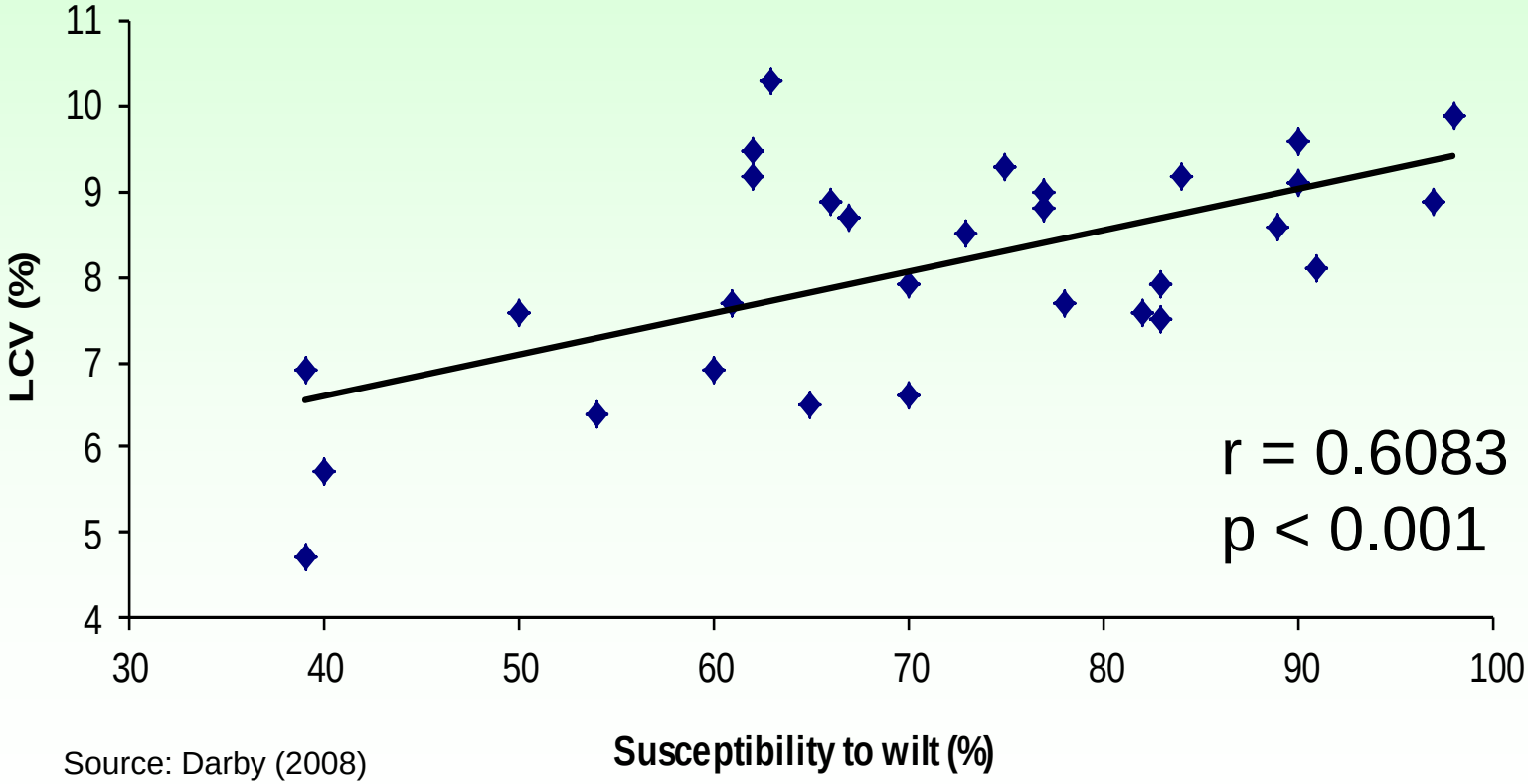
The inheritance of resistance to Verticillium Wilt
Wye 1935 - 1990

Heritability of resistance to wilt disease



Source: Darby (2008)

Interaction of resistance to wilt disease with alpha-acid content (and yield)



Source: Darby (2008)

Breeding for resistance to wilt

- Complex genetic systems
  - both single gene and multiple gene systems
  - different sources of resistance
  - combined in some parents
- Negative associations
  - yield
  - alpha-acid

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Wilt test values

Variety	%infection (1989-2006)
Fuggle	100
WGV	83
Progress	66
Target	28
Phoenix	19
Pilgrim	17
27/57/264	14

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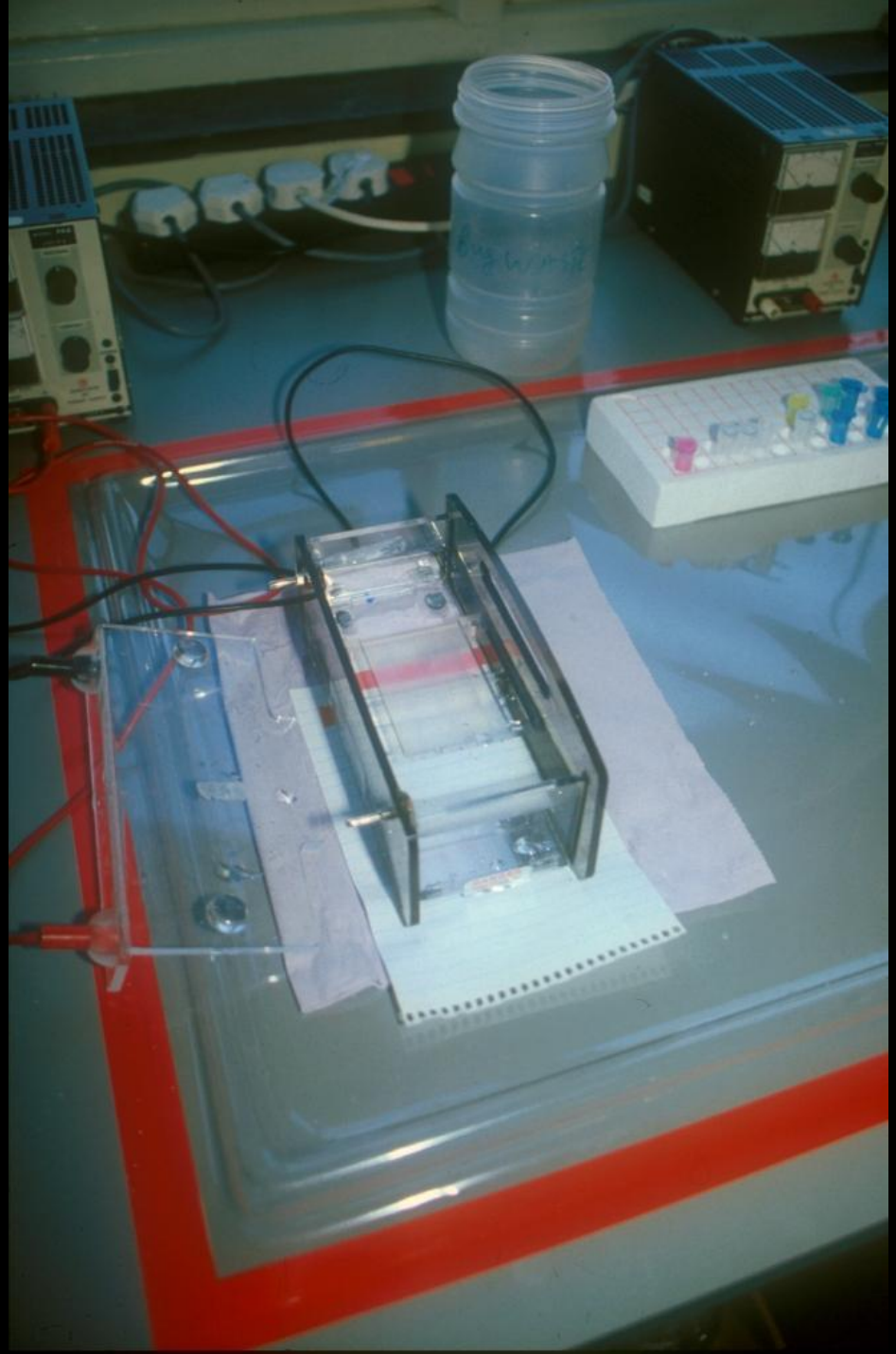
11/05/31

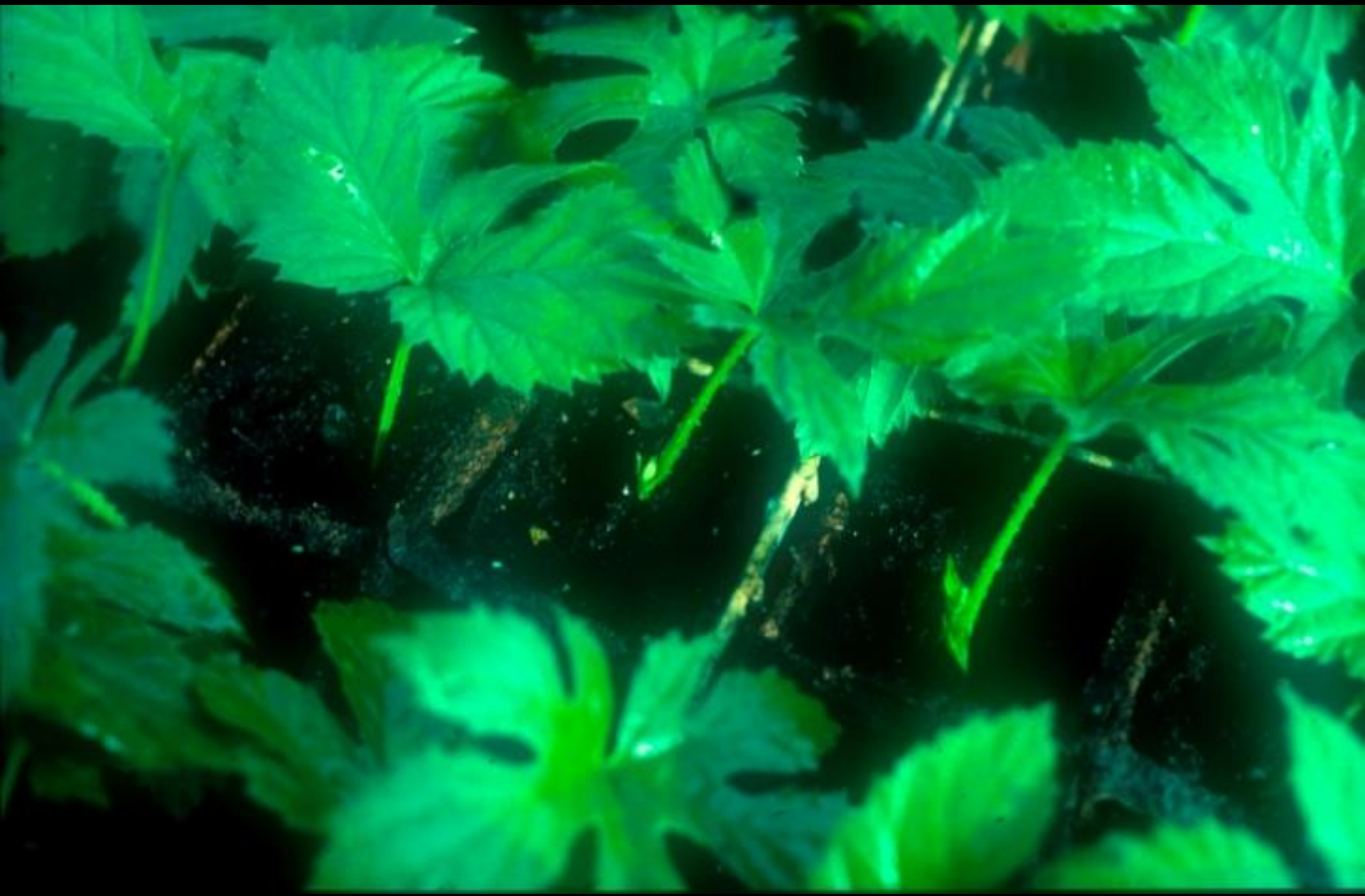
11/05/31


30/04/29

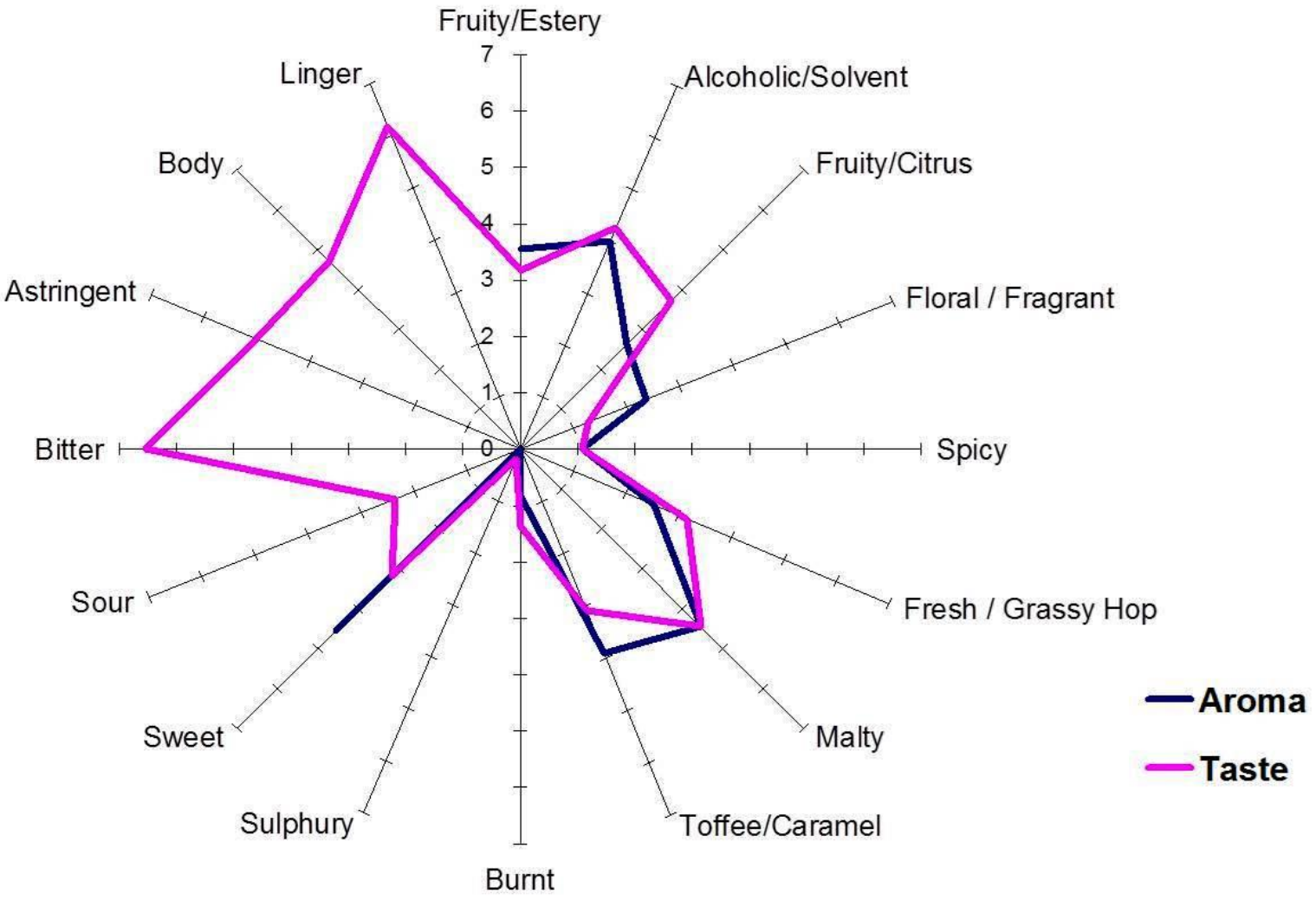
313/08 B




HIGHLY
FLAMMABLE
LIQUID




Caution


Fruity/Estery
Alcoholic/Solvent
Fruity/Citrus
Floral / Fragrant
Spicy
Fresh / Grassy Hop
Malty
Toffee/Caramel
Burnt
Sulphury
Sweet
Sour
Bitter
Astringent
Body
Linger
7
6
5
4
3
2
1
0
Aroma
Taste

Selection Process

Families (+20,000)	Year 1	Glasshouse disease screens
Individual seedlings (~1,400)	Years 2-3	Sex, Habit (cone), Pest & disease, Productivity
Selected seedlings (~100)	Year 4	Analysis, Propagation
Plots (~30)	Years 5-7	Commercial attributes (Yield), Wilt, Oils, Pest and disease, Pilot brews
Farm Trials (~2)	Years 8-11	Commercial acceptibility (Yield and Quality), Commercial brewing
Registration of a new variety		

Selection Process (shortened)

Families (+5,000)	Year 1	Field establishment
Individual seedlings (~1,400)	Year 2	Sex, Habit (cone), **Field** pest & disease, Productivity, **Aroma**
Selected seedlings (~50)	Year 3	**Micro-brews**, Analysis, Propagation
Plots (~15)	Years 4-5	Commercial attributes (Yield), Wilt, Oils, Pest and disease, **Pilot brews**
Farm Trials (~2)	Years 6-8	Commercial acceptibility (Yield and Quality), **Commercial brewing**
Registration of a new variety		

Commercialisation

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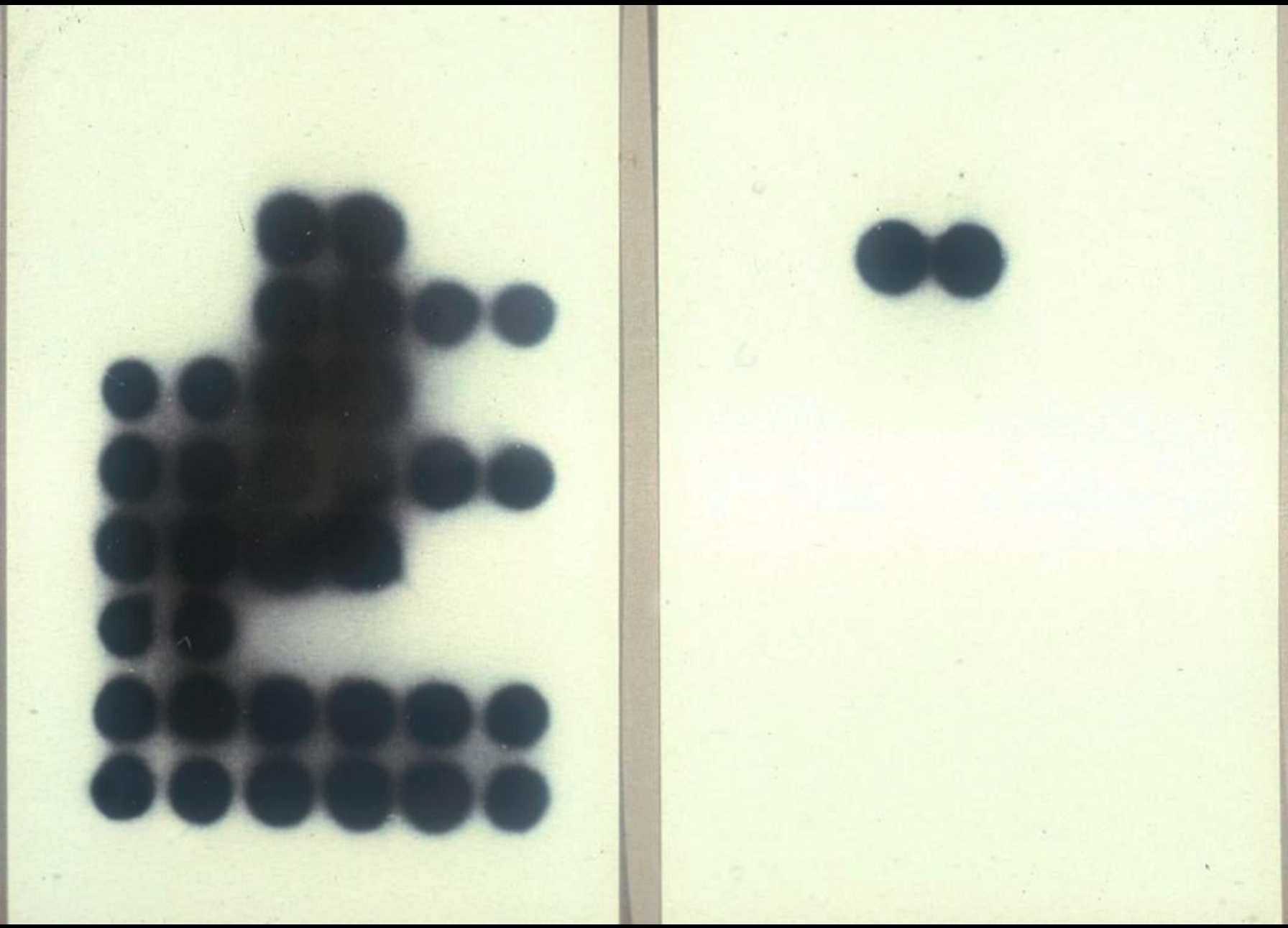

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THE COMMUNITY PLANT VARIETY OFFICE HEREBY ACKNOWLEDGES THE GRANT OF COMMUNITY PLANT VARIETY RIGHT BY ITS DECISION N° **EU 23382** OF **25 AUGUST 2008** TAKEN IN ACCORDANCE WITH COUNCIL REGULATION (EC) N° 2100/94 ON COMMUNITY PLANT VARIETY RIGHTS, WITH EFFECT FROM THE DATE OF THE DECISION REFERRED TO ABOVE, FOR

WYE HOPS LIMITED

BEING DOMICILED OR HAVING HIS SEAT OR ESTABLISHMENT IN

China Farm Office
Upper Harbledown
UK - CT2 9AR CANTERBURY - KENT

AS HOLDER OF THIS RIGHT, IN RESPECT OF THE VARIETY OF ***Humulus lupulus L.*** BEARING THE DESIGNATED DENOMINATION:

BOADICEA

FOR A PERIOD EXPIRING ON **31 DECEMBER 2038** AT THE LATEST.

THE COMMUNITY PLANT VARIETY RIGHT HAS UNIFORM EFFECT WITHIN THE TERRITORY OF THE EUROPEAN COMMUNITY AND MAY NOT BE TRANSFERRED IN RESPECT OF THIS TERRITORY OTHERWISE THAN ON SUCH UNIFORM BASIS. IT CAN BE EXERCISED AND ENJOYED BY THE HOLDER IN ACCORDANCE WITH COUNCIL REGULATION N° 2100/94 ON COMMUNITY PLANT VARIETY RIGHTS.

THIS ACKNOWLEDGEMENT DOES NOT AFFECT THE REQUIREMENT OF THE HOLDER TO PAY THE FEES DUE FOR EACH YEAR OF DURATION OF THE COMMUNITY PLANT VARIETY RIGHT.

OFFICE COMMUNAUTAIRE DES VARIETES VEGETALES - COMMUNITY PLANT VARIETY OFFICE

President of the Community Plant Variety Office

Bart KIEWIET


British Hop
Association


Hop Breeding Principles
Thank you for your attention
Any Questions?