Impact of the use of fungicides on resistance development in *Botrytis*

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1. **Biology of *Botrytis***
2. Fungicide resistance in space and time
3. Results from Norway
4. Recommendations

Botrytis on strawberries

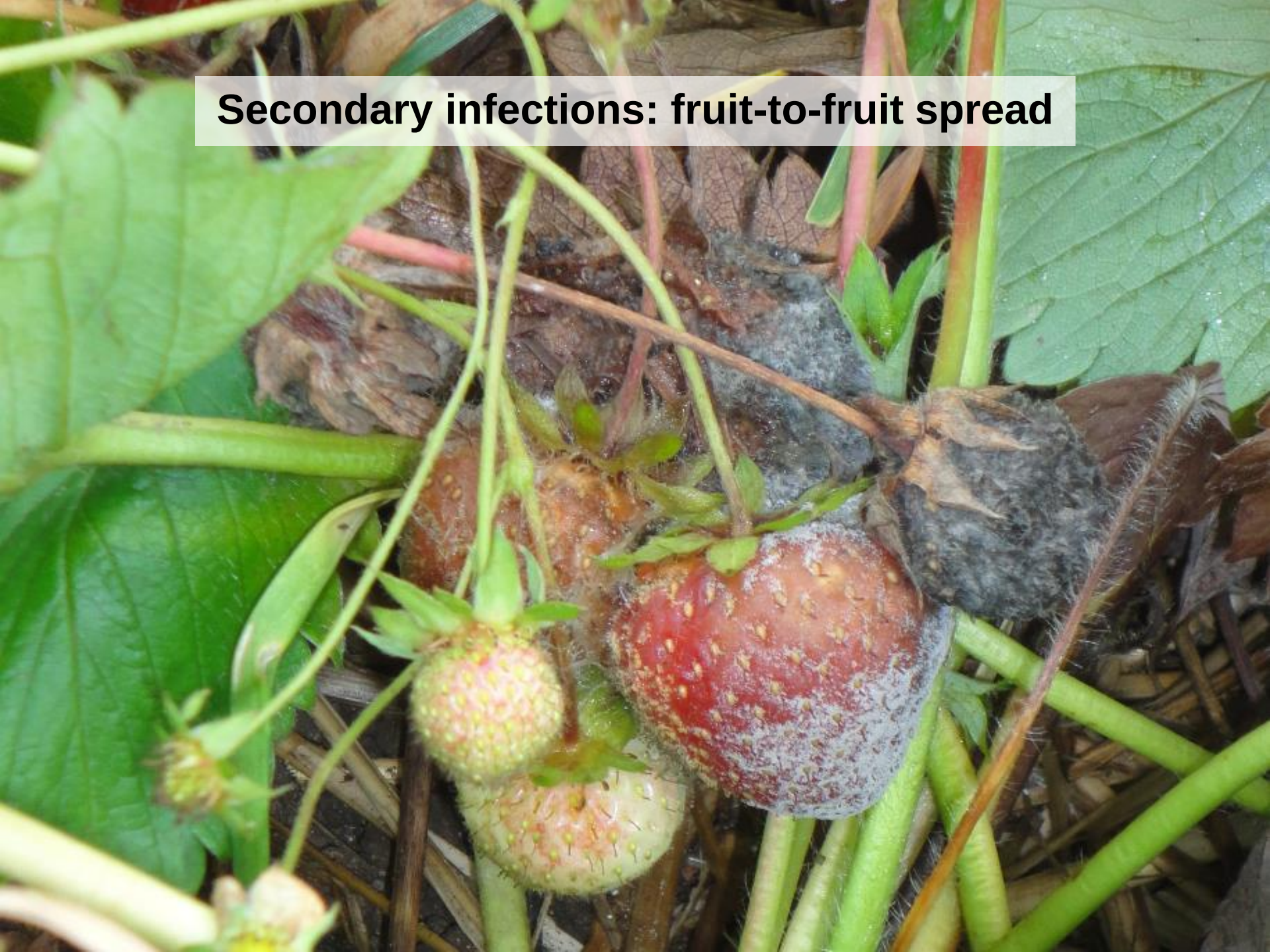
Primary infection at flowering

→ State of latency in receptacle of flower

→ Fruit rot (primary infection) at onset of fruit ripening

→ Secondary infections of further ripening fruits

→ Uncontrollable epidemic


Secondary infections: fruit-to-fruit spread

Fungicides with *Botrytis* activity

Teldor	**Fenhexamid**
Prolectus	**Fenpyrazamin**
Switch	**Cyprodinil** + **Fludioxonil**
Scala	**Pyrimethanil**
Frupica SC	**Mepanipyrim**
Geoxe	**Fludioxonil**
Amistar	**Azoxystrobin**
Candit	**Kresoxim-methyl**
Signum	**Pyraclostrobin** + **Boscalid**
Luna Sensation*	**Trifloxystrobin** + **Fluopyram**

* Pending registration

All 5 groups are specific fungicides → risk of resistance development!

	Type of resistance
Hydroxyanilid	target mutation
Strobilurin / QoI	target mutation
Carboxamide / SDHI	target mutation **(incomplete cross-resistance)**
Anilino-Pyrimidine	target mutation and multi-drug resistance
Phenylpyrrole	multi-drug resistance only

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Fenhexamid
2011 and 2012
(strawberries)
Kiel
Rostock
Hamburg
Oldenburg
Bremen
Osnabrück
Hannover
Braunschweig
Magdeburg
Münster

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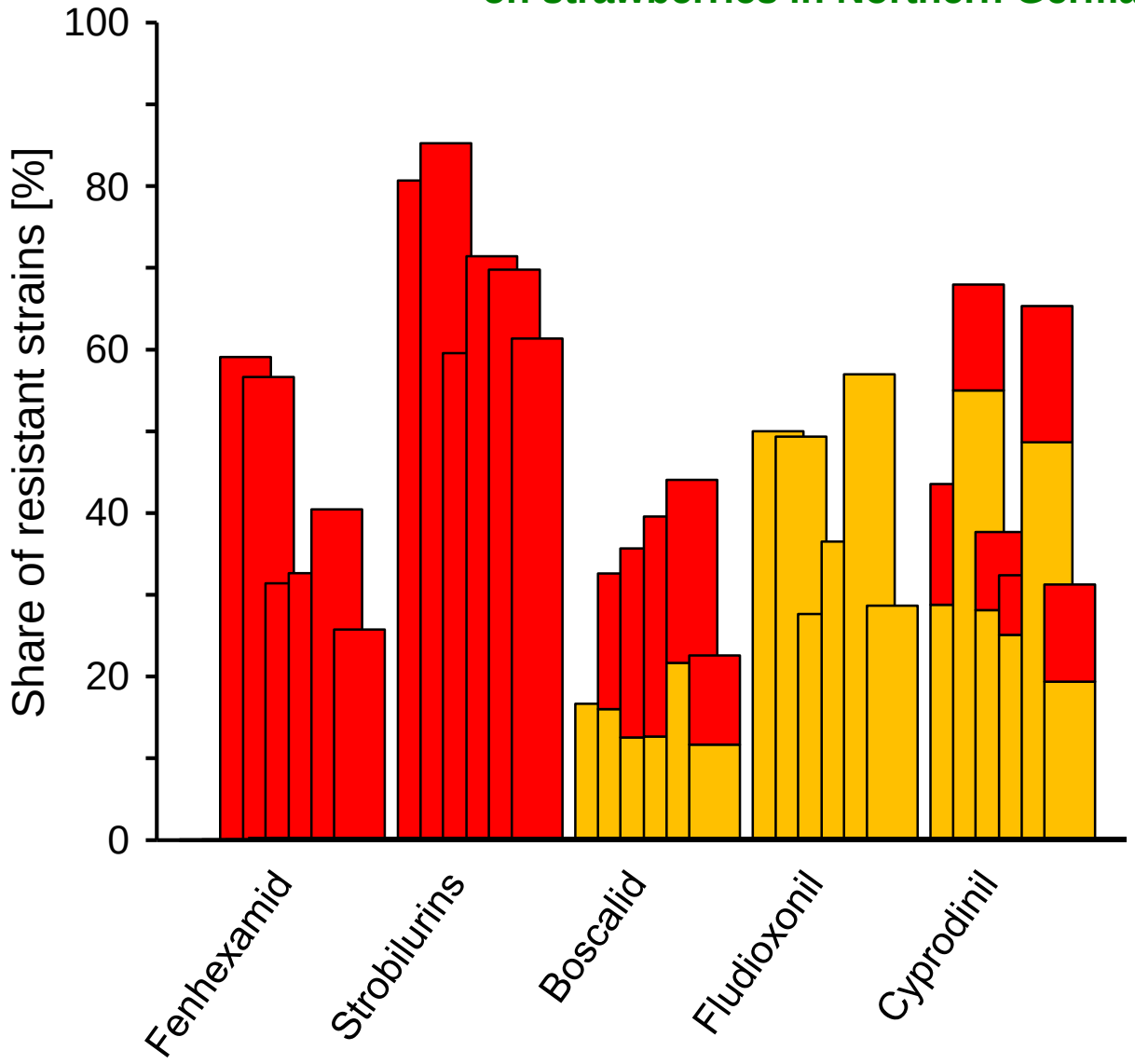
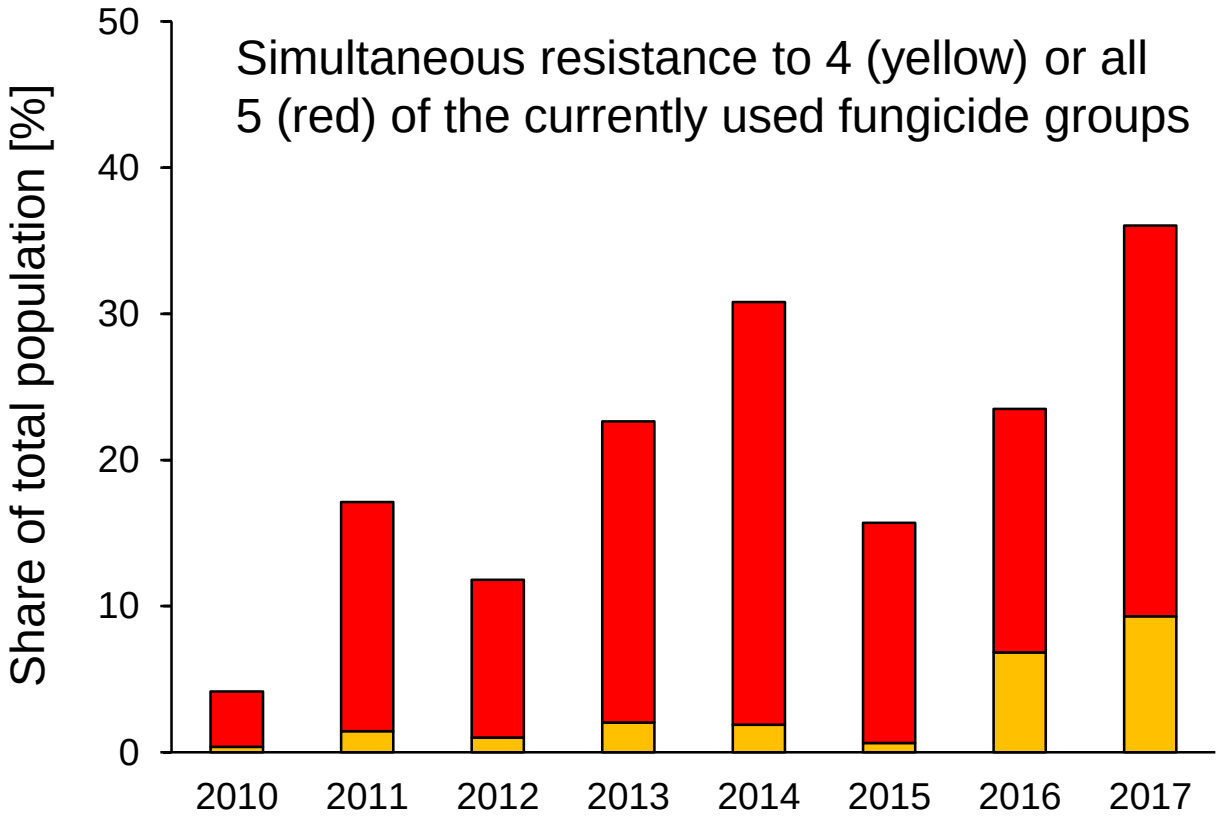
Single resistances 2010 2011 2012 2013 2014 2015

on strawberries in Northern Germany



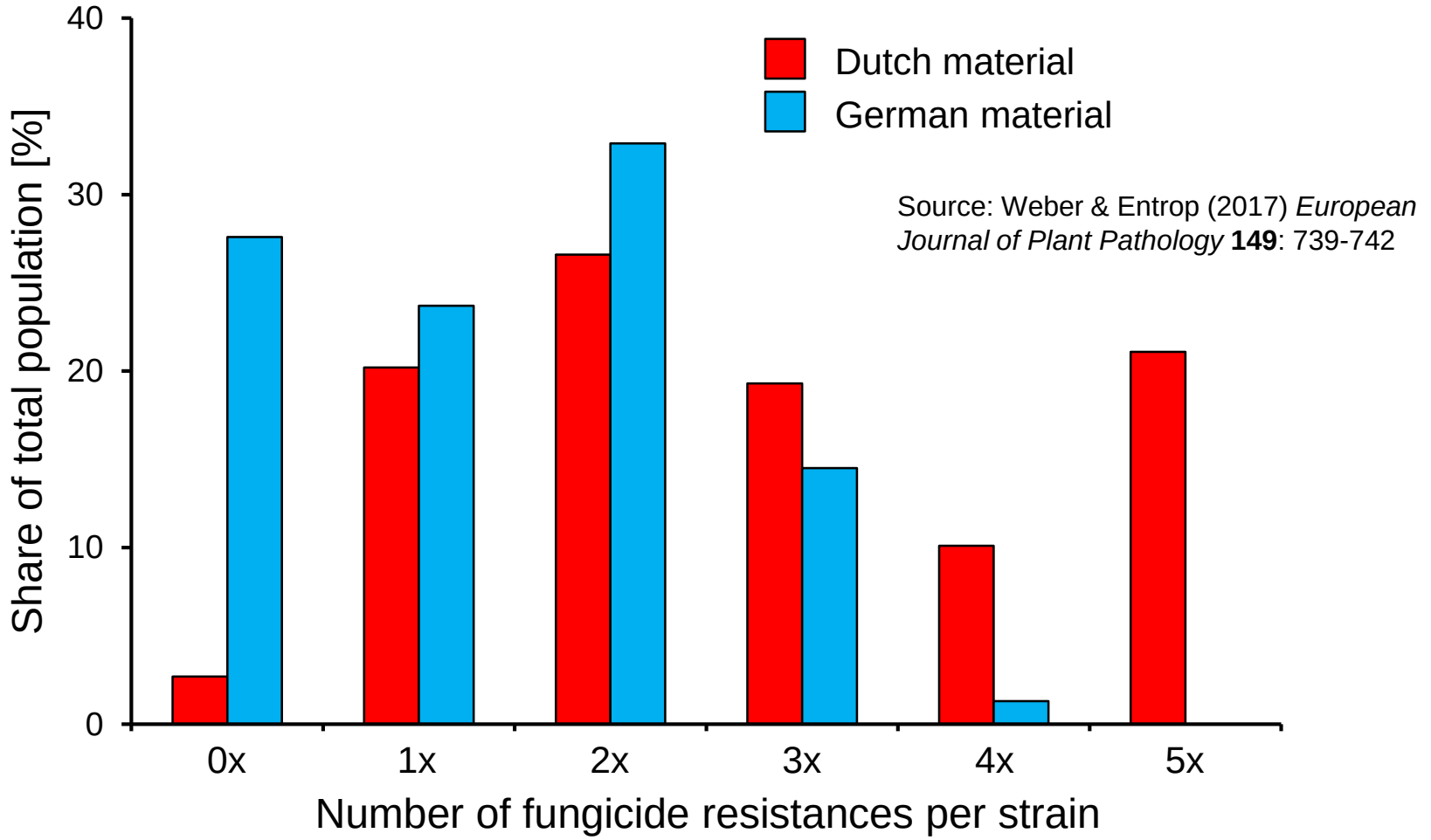
Strains with multiple resistance on strawberries in Northern Germany



Spread of multi-resistant strains

1. Stepwise acquisition of resistances to all fungicides somewhere
2. Spread by contaminated nursery material or immigration from outside
3. Local selection by intensive fungicide use

Multiple resistance in strawberry nursery material: Netherlands *versus* Germany 2014



Multi-resistant strains in raspberry longcanes

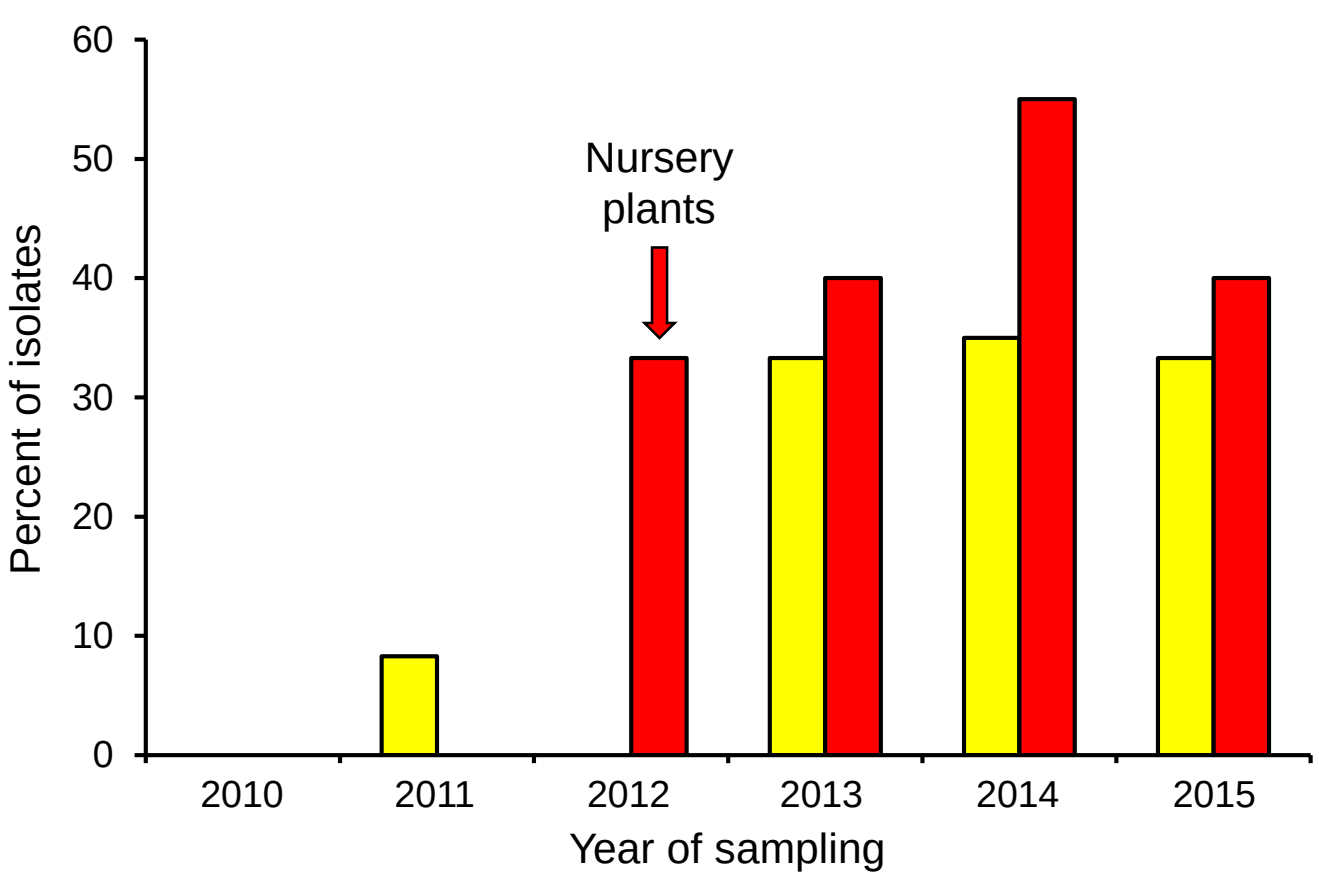
Origin	Batches	0x res.	1x res.	2x res.	3x res.	4x res.	5x res.
1	3 (n=37)	-	-	19	2	2	14
2	3 (n=45)	-	-	1	5	6	33
3	3 (n=37)	5	1	11	5	6	9
4	1 (n=15)	-	3	9	-	-	3
Total	10 (n=134)	3.7%	3.0%	29.9%	9.0%	10.4%	44.0%

Longcane nursery plants may be heavily contaminated with *Botrytis* strains possessing multiple resistance

→ caution when planting a long-term field

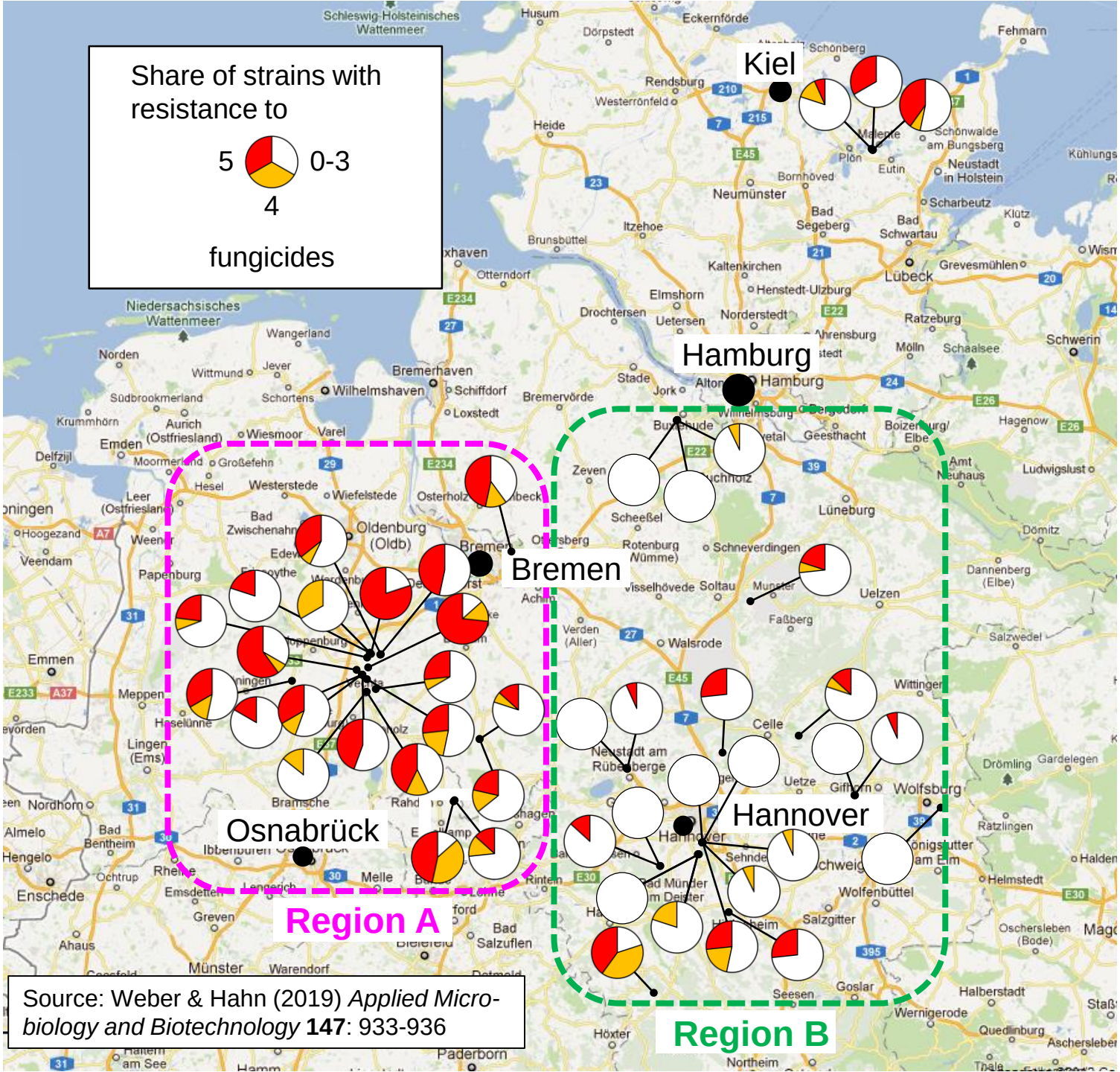
Source: Weber & Entrop (2017) *European Journal of Plant Pathology* **147**: 933-936

Spread of multi-resistant strains from nursery material to an adjacent established field



Assay: c. 15 over-wintered cane lesions each spring

Source: Weber & Entrop (2017) *European Journal of Plant Pathology* **147**: 933-936



Source: Weber & Hahn (2019) *Applied Microbiology and Biotechnology* **147**: 933-936

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The situation in Norway 2016

Strong correlation between the total number of sprays with any of the 5 fungicide classes and

- Resistance to individual fungicides
- Multi-resistance to all fungicides

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Effects of excessive spray sequences

If strains with multiple resistance are present in a field…

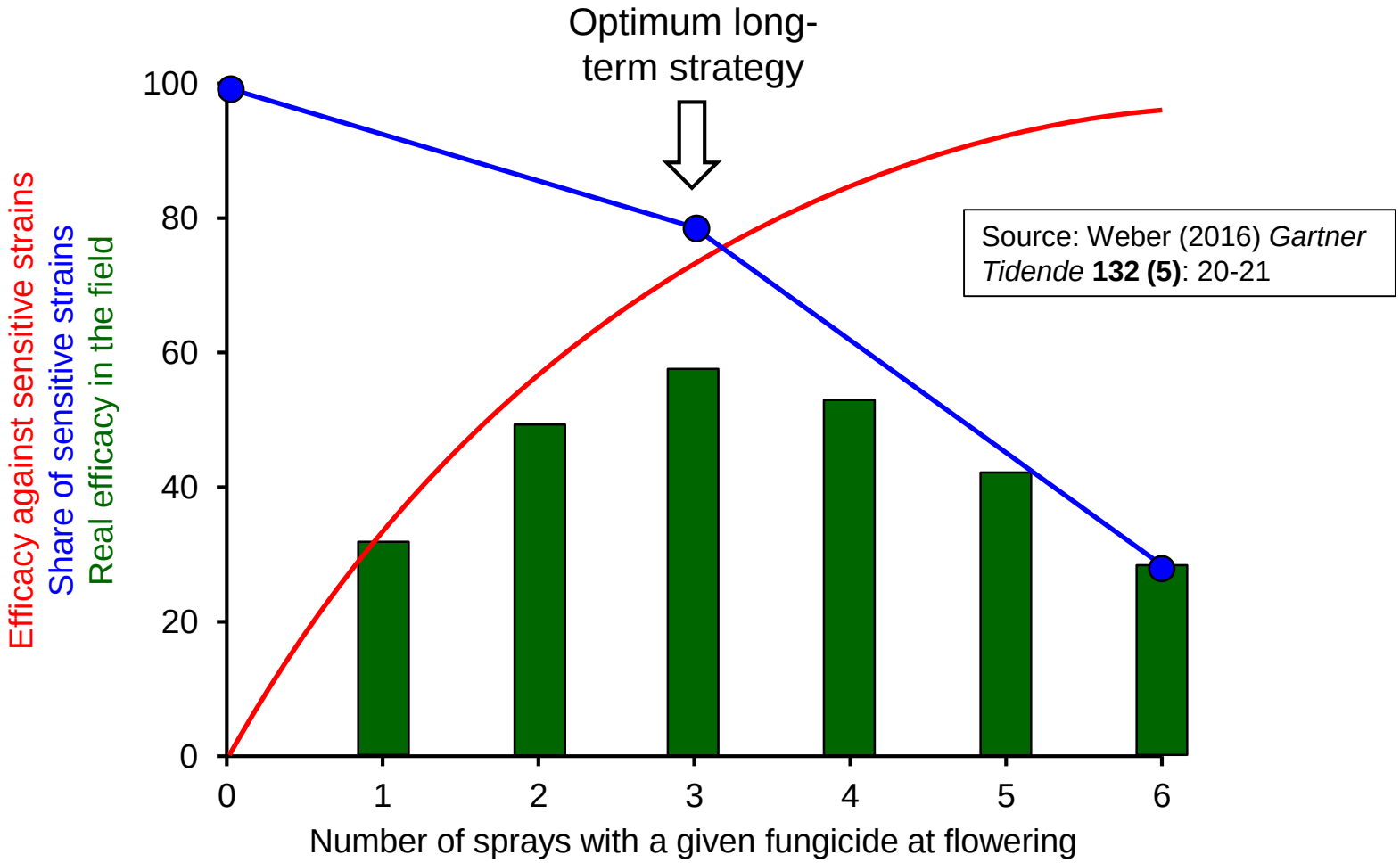
… the application of any fungicide will further select multi-resistant strains

… the more we spray, the more resistance we get

… but is the reverse also true?

A **less** frequent fungicide may reduce the selective advantage of multi-resistant strains and **means more** fungicide efficacy in the long-term

How many sprays to give the optimum efficacy?



Non-chemical control of *Botrytis*

Picking and removal of infected fruit (especially at beginning of harvest!)

Moderate fertilisation

Sufficient planting distance

Ventilation (tunnel, protective coverings)

Drip irrigation instead of overhead irrigation

Modest use of fungicides
(3 or max. 4 sprays)

+ removal of rotten fruit at harvest

= high yield security

Literature

1. Weber, R.W.S. (2015). Masser af resistens i gråskimmel på jordbær. *Gartner Tidende* **7/2015**: 20-21.
2. Weber, R.W.S. & Entrop, A.-P. (2015). Undgå resistens mod gråskimmel. *Gartner Tidende* **8/2015**: 8-9.
3. Weber, R.W.S. (2016). Resistent gråskimmel i danske jordbær. *Gartner Tidende* **5/2016**: 20-21.

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Thank you
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