

Antimicrobial use in plants

Virginia Stockwell
Department of Botany and Plant Pathology
Oregon State University
Corvallis, Oregon USA

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Outline

- Antimicrobials used on plants
 - Putative risk factors
 - Development of resistance in plant pathogenic bacteria
 - Resistance mitigation
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Antimicrobials used on plants

Aminoglycosides

- Streptomycin
- Gentamicin
- Kasugamycin

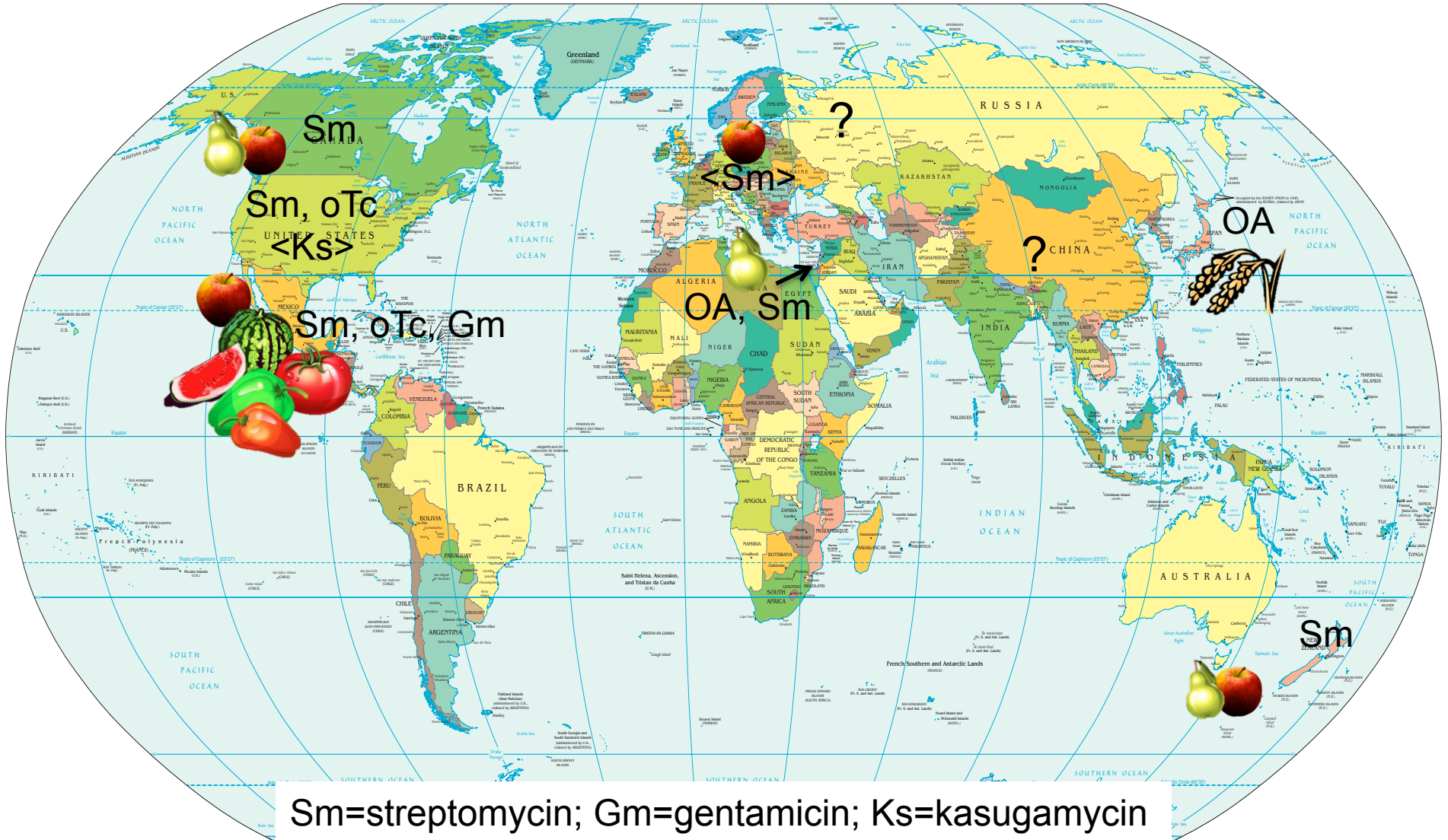
Quinolone (first generation)

- Oxolinic acid

Tetracycline

- Oxytetracycline
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Worldwide use of antibiotics on plants



Sm=streptomycin; Gm=gentamicin; Ks=kasugamycin
OA=oxolinic acid; oTc=oxytetracycline

Quantities of antibiotics used on plants

- Very difficult to obtain worldwide data on quantities of antibiotics used on plants.
- In the USA, data on all materials used for plant production, including antibiotics, are reported to the federal government.
Compiled data is available on the website:

www.nass.usda.gov

Antibiotic use on tree fruit crops in the USA

Apple: ~142,000 HA

12 to 16% of acreage sprayed

Average 1 to 2 sprays during bloom

Streptomycin: 6,169 kg

Oxytetracycline: 3,084 kg

Pear: ~27,000 HA

30 to 41% of of acreage sprayed

Average 3 to 4 sprays during bloom

Streptomycin: 1,905 kg

Oxytetracycline: 3,901 kg

Peach: ~50,000 HA

10% of of acreage sprayed

Average 2 to 3 sprays annually

Streptomycin: Not registered

Oxytetracycline: 1,406 kg



Data from US National Agricultural Statistics Service

Amount of antibiotics used on plants relative to amount in animal agriculture in the USA

- 16,465 kg of antibiotics applied to trees. Less than half of the acreage was treated.
 - 90% of the antibiotics were used on pear and apple trees during bloom for prevention of the disease fire blight.
 - In animal agriculture, 13 million kg of antibiotics were dispensed. Plant agriculture accounts for 0.12% of total antibiotics used in agriculture.
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Putative risk factors with antibiotic use on plants

Are plant-grade antibiotics contaminated with resistance genes?

Do antibiotic sprays increase prevalence of resistant clinical bacteria on plants?



How long are antibiotics active on plants and soils?
Are significant residues found on fruit?



Putative risk factors with antibiotic use on plants

Are plant-grade antibiotics contaminated with resistance genes?

None detected



No bacterial DNA or resistance genes were detected with qPCR in plant-grade formulations from the EU, USA, Canada, or New Zealand.

Rezzonico, Stockwell & Duffy. 2009. Antimicrob. Agents Chemother. 56: 3173-3177.

Putative risk factors with antibiotic use on plants

Do antibiotic sprays increase prevalence of resistant clinical bacteria on plants?



No evidence indicating that this is true, but more research is needed.

- Metagenomic study: major genera on apple trees were *Massilia*, *Pantoea*, *Methylobacterium*, *Pseudomonas*, and *Sphingomonas*. No human pathogens.
- Bacterial communities from apple orchards with long-term history (10 yr) of Sm sprays were similar to those in non-sprayed orchards.
- Incidence of antibiotic resistant bacteria (~50%) was similar in sprayed and non-sprayed orchards.

Putative risk factors with antibiotic use on plants

How long are antibiotics active on plants and soils? Are significant residues found on fruit?



Antibiotic activity short-lived on plants and in soil. Residues are often below detection.

- Antibiotics are active on plant surfaces for less than five days.
- Rainfall reduces concentrations rapidly.
- Sunlight can degrade antibiotics.
- Soil inactivates antibiotics used on plants.
- No reports of fruit with antibiotic chemical residues at or above the residue tolerance concentration of 0.25 ppm.

Christiano *et al.* 2010. *Plant Dis.* 94:1213-1218.; Stockwell *et al.* 2008. *Acta Hort.* 793:383-390.
Subbiah *et al.* 2011. *Appl. Environ. Microbiol.* 77:7255-7260.

Development of resistance in plant pathogenic bacteria

- Streptomycin was registered in the USA as a prophylaxis treatment for fire blight in the 1950s.
 - Growers applied the antibiotic on a calendar-basis, with up to 20 applications per year.
 - By the 1970s, resistance to streptomycin was detected in the pathogen in California.
 - Understanding the disease cycle has reduced number of antibiotic applications.
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Fire blight: bacterial disease of pear and apple caused by *Erwinia amylovora*

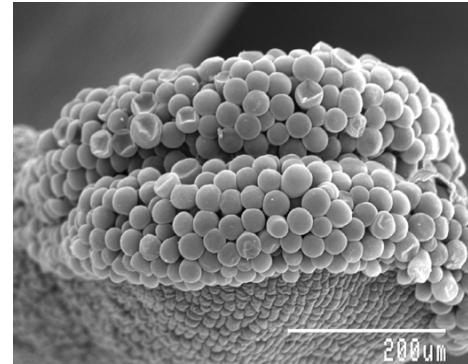


Fire blight epidemics occur sporadically, resulting in losses of tens of millions of dollars to growers.

Infection of flowers by *Erwinia amylovora*



Establishment



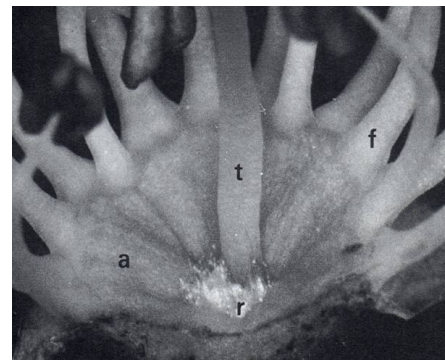
Pathogen multiplies on stigmas to 10^7 cells.

Prevent disease by suppressing epiphytic growth of pathogen on stigmas.

Migration to nectary

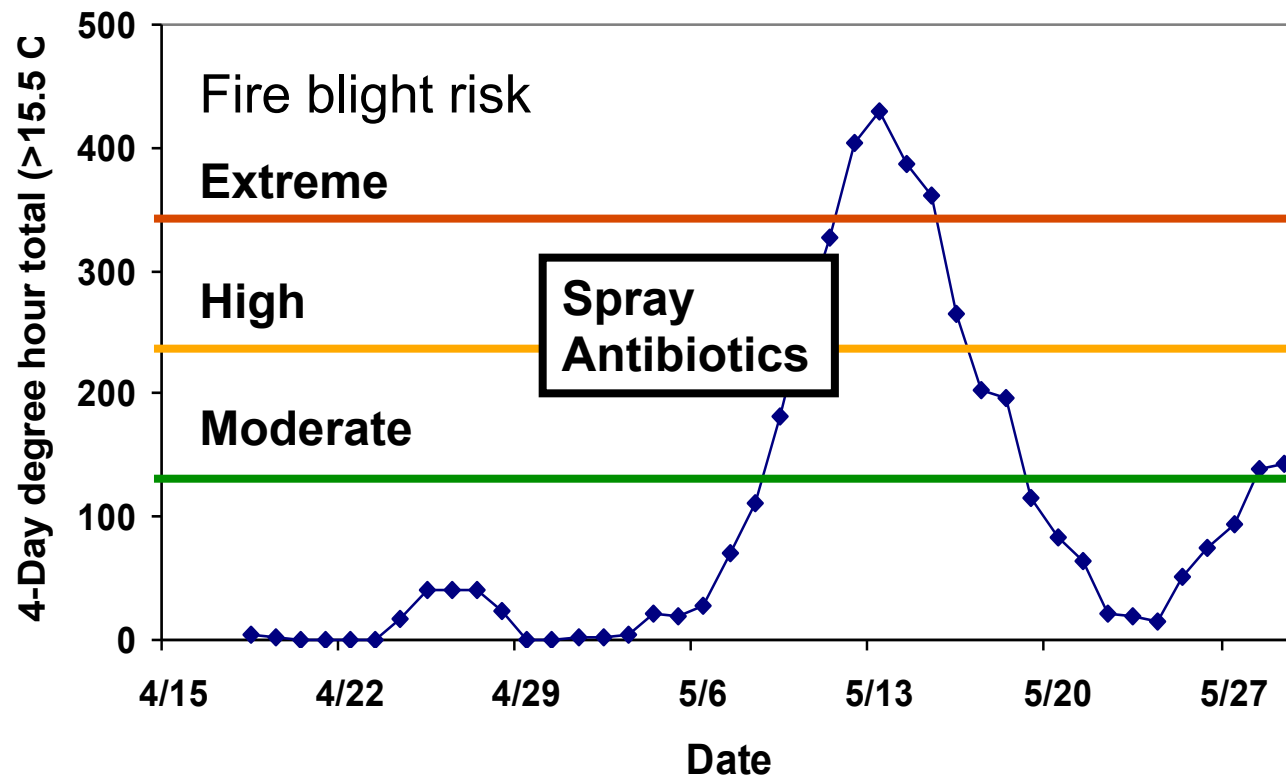


Infection



Disease risk models inform growers when to spray antibiotics

Daily Fire Blight Risk - COUGARBLIGHT Model



Growers monitor temperatures and forecasts to assess risk and need for intervention.

Models have reduced antibiotic applications.

Resistance management strategies

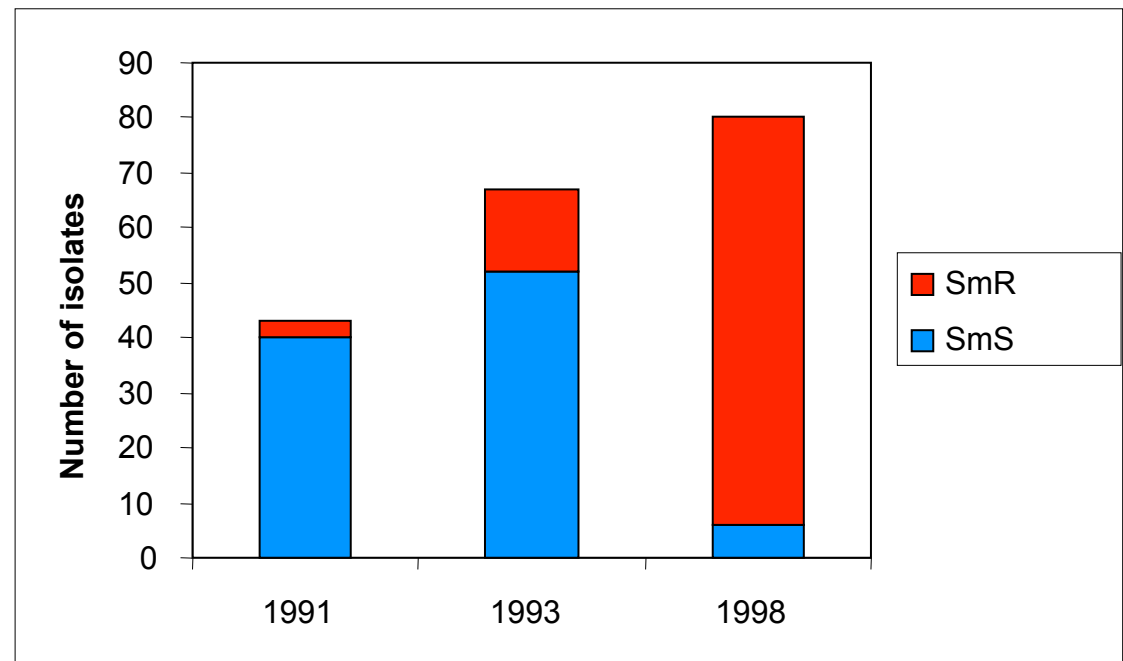
- Sanitation: remove diseased tissues in orchards.
- Use disease risk models to minimize number of applications of antibiotics.

Resistance can emerge quickly.

Orchards sprayed 0 to 3 times with streptomycin.

Resistance due to single point mutation of chromosomal gene.

Timeline of emergence of streptomycin resistant *E. amylovora* in northern Oregon



Additional resistance management strategies

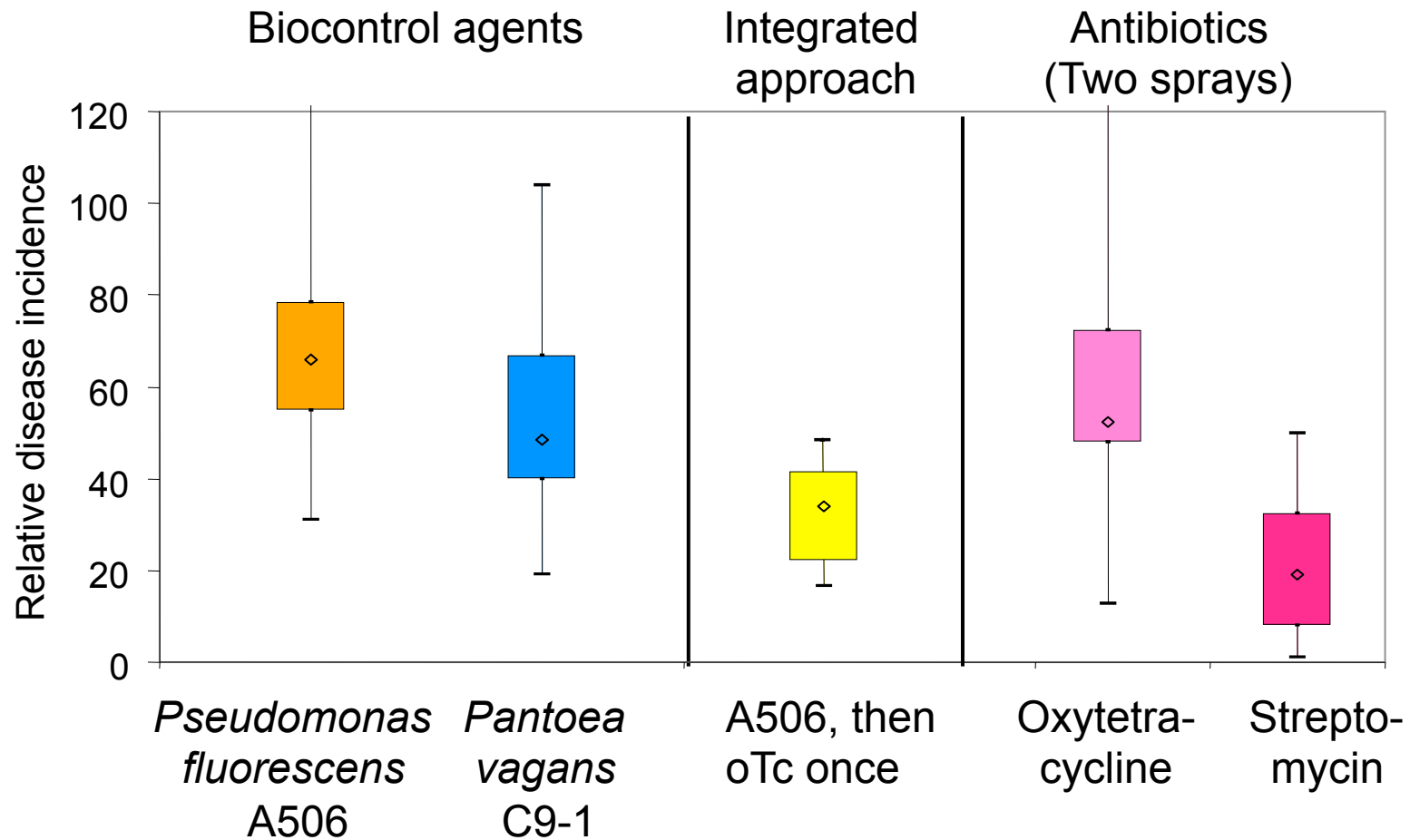
Combine antibiotics

- In USA, growers mix streptomycin with oxytetracycline. This approach is moderately successful if streptomycin resistance is not present.

Integrate biological control agents with antibiotics

- Similar to 'probiotic' approach.
 - Biological control agents established on flowers in early bloom suppress the establishment and growth of the fire blight pathogen.
 - If disease risk is high, a single late bloom antibiotic spray is applied.
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Fire blight control in pathogen-inoculated experimental orchard trials in Oregon



Summary

- Antibiotics have been used in plant agriculture for more than 60 years without documented adverse affects on the environment or human health.
- Antibiotics are primarily used for the management of fire blight, the most severe bacterial disease of pear and apple.
- Prudent and integrated uses of antibiotics in plant agriculture are critical tools for resistance management and long-term efficacy.



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