A GUIDE TO NUFARM SOLUTIONS

BACTERIAL DISEASES OF TREE NUT, VINES AND VEGETABLES
A GUIDE TO NUFRM SOLUTIONS FOR BACTERIAL DISEASES
Bacterial diseases can be devastating — especially to tree fruit, citrus and potato crops. And, as new threats such as HLB and Zebra Chip emerge, Nufarm is dedicating more research and more resources than ever to help growers prevent, suppress or control as many of these diseases as possible.

At Nufarm, our goal is to arm growers with available crop and disease information, growing tips and product chemistries to give growers and their crops the best chance for success.

In this guide, find at-a-glance summaries for many Nufarm disease control chemistries as well as helpful identification tips for the most common bacterial diseases.

HLB and Zebra Chip disease information follows. Although disease control products for HLB and Zebra Chip are not yet available, Nufarm is working hard to develop new solutions. Visit www.nufarm.com/USAG to stay informed on the most recent news and control developments.

▸ Nufarm Chemistries — at-a-glance summaries of Nufarm fungicide, bactericide and microbial pesticide products.

▸ Bacterial Diseases — key information and identification tips for the most common bacterial diseases.

▸ Emerging Threats — disease overview, detection signs and economic impacts of HLB and Zebra Chip.
COPPER: THE FIRST BACTERICIDE

FROM WHEAT SMUT TO DOWNY MILDEW IN GRAPES, COPPER HAS BEEN USED TO PREVENT A VARIETY OF PLANT DISEASES DATING AS FAR BACK AS 1807 FRANCE.

In 1807, Swiss scientist Isaac Bénédict Prévost was researching why some French farmers were able to control smut of wheat when he discovered that copper vessels were the key. Much to Prévost’s surprise, the farmers that kept wheat seed in copper vessels had smut-free fields. Prévost validated the use of copper by conducting a large-scale field test, and later developed a fungicide for wheat seed that was made with copper sulfate.

Seventy years later, French botanist Pierre Marie Alexis Millardet made a similar discovery in vineyards in Bordeaux, France. Millardet noticed that the vines closest to the road did not have downy mildew. These vines were often covered with a mixture of copper and lime, which made the grapes look poisonous and taste sour to hungry passer-byers – it also protected the grapes from downy mildew.

Millardet used this discovery to develop the Bordeaux Mixture – the first fungicide used worldwide.

COPPER IONS HELP PREVENT DISEASE: Cu²⁺ ions (copper ions) are a powerful fungicide agent that are effective against a host of diseases that attack ornamentals, fruit trees, vegetables and tubers. The copper forms a coating over the leaf to provide the plant with a protective barrier. The bioavailable ions – ions that the plant is able to absorb – protect the plant by disrupting cell processes in bacteria and fungi.

The Cu²⁺ ions destroy bacterial organisms by entering the organism and killing the enzyme system. Likewise, Cu²⁺ ions prevent fungal spores from germinating and spreading.

Unlike some fungicides, copper is not altered by sun or heat, however it relies on adequate amounts of moisture to activate. Copper works best against diseases that occur during wet seasons or that occur during heavy irrigation.

IMPROVEMENTS IN COPPER USE: Since the 1800’s, improvements such as smaller particle sizes, which cover the leaf more completely, have made copper a more effective ingredient in fungicides. Gains in research, such as the correct amount to apply, have made copper application safer for plants and soil. And the use of copper worldwide has promoted plant production.
**Champ® ION™**

Better coverage and disease control with the smallest, most consistent copper particles of any WG copper. The lower use rates result in less environmental load than high dose copper products.

**KEY PERFORMANCE BENEFITS**
- Small particle size delivers excellent coverage
- Stable WG formula pours and disperses easily
- Low use rates and OMRI Listed®
- Controls plant pathogenic fungi and bacteria (non-public health bacteria)

**KEY USES**
Berries, field crops, tree crops (almond, apple, citrus, peach, pear), vegetables (bean, cucurbits, pepper, potato, tomato), vines and hops

**KEY DISEASES CONTROLLED**
Bacterial blast, bacterial blight, bacterial canker, black spot, blossom brown rot, dead bud, early blight, fire blight, late blight, leaf spots, shoot blast *(see label for complete list)*

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**Champ® Dry Prill**

The only dry prill copper available for no-dust mixing and handling.

**KEY PERFORMANCE BENEFITS**
- Only dry prill copper product on the market
- Made using a unique polymer process that results in a virtually dust-free formula
- Mixes fast and easily

**KEY USES**
Citrus crops, field crops, small fruits, tree crops, vegetables and vines

**KEY DISEASES CONTROLLED**
Bacterial blast, bacterial blight, bacterial canker, black spot, blossom brown rot, dead bud, early blight, fire blight, late blight, leaf spots, shoot blast *(see label for complete list)*

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**Champ® Formula 2 Flowable**

An advanced copper formulation that delivers excellent disease control. Its small particle size stays in suspension longer, mixes easier in water and covers plants better.

**KEY PERFORMANCE BENEFITS**
- Mixes fast and easily

**KEY USES**
Citrus crops, field crops, small fruits, tree crops, vegetables and vines

**KEY DISEASES CONTROLLED**
Bacterial blast, bacterial blight, bacterial canker, black spot, blossom blast, blossom brown rot, dead bud, early blight, fire blight, late blight, leaf spots, shoot blast *(see label for complete list)*
FUNGICIDES / BACTERICIDES

Champ® WG

An effective copper hydroxide formulation that is easy and efficient to use. As a water dispersible granule, it provides surface area coverage and fungicidal protection.

**KEY PERFORMANCE BENEFITS**
- Actively controls several disease causing fungi
- Multi-site mode of action
- Resistance management for strobilurins and sterol-inhibitors

**KEY USES**
Berries, field crops, tree crops (almond, apple, citrus, peach, pear), vegetables (bean, cucurbits, pepper, potato, tomato), vines and hops

**KEY DISEASES CONTROLLED**
Blossom blast, early blight, fire blight, late blight, leaf spots, shoot blast *(see label for complete list)*

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Mycoshield®

Controls fire blight in apples and pears and bacterial spot in nectarines and peaches. May rotate with Agri-Mycin® and other bactericides in applicable crops. Compatible with most pesticides.

**KEY PERFORMANCE BENEFITS**
- Essential part of resistance management programs
- Gentle protectant bactericide – does not alter appearance or growth of fruit

**KEY USES**
Apples, nectarines, peaches, pears

**KEY DISEASES CONTROLLED**
Bacterial spot, fire blight *(see label for complete list)*

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Agri-Mycin® 50

Protect apples, pears, tomatoes and other crops against bacterial diseases such as fire blight.

**KEY PERFORMANCE BENEFITS**
- Protectant bactericide
- Provides 3-4 days of dependable protection
- Easy on plants and animals
- Compatible with most pesticides

**KEY USES**
Apples, celery, pears, pepper, potatoes, tobacco, tomatoes, tree crops

**KEY DISEASES CONTROLLED**
Bacterial blight, bacterial spot, fire blight, soft rot blackleg, wildfire blue mold *(see label for complete list)*
BlightBan® A506

Protect crops from fire blight and reduce russetting. OMRI Listed® for use in organic agriculture, BlightBan A506 offers outstanding crop safety.

KEY PERFORMANCE BENEFITS
- Provides fire blight and russet suppression in pears and apples
- Offers frost protection for a variety of crops
- Essential part of resistance management programs
- Gentle on crops

KEY USES
- FIRE BLIGHT SUPPRESSION: Apples, pears
- FROST PROTECTION: Almonds, cherries, peaches, potatoes, strawberries, tomatoes
- SOUR ROT PROTECTION: Grapes

KEY DISEASES CONTROLLED
Fire blight, reduces russetting, frost protection (see label for complete list)
FIRE BLIGHT:
A DESTRUCTIVE ENEMY

Fire blight is a serious disease caused by the bacterium *Erwinia amylovora*. The disease damages blossoms and shoots, reducing yields, disfiguring fruit and diminishing the vigor of the trees it attacks. Severe infections may also compromise scaffold limbs, trunks and root systems, and can eventually cause tree death.

Bacteria lie dormant in the winter at the edges of cankers formed on twigs, branches, scaffolds and trunks during the previous growing season. Bacteria in cankers begin to multiply in the spring, just after new growth has begun. The canker also begins to produce exudates containing millions of bacteria.

Insects and rain are the primary transporters of fire blight bacteria. Flying and crawling insects, attracted to exudates, carry the bacteria to open blossoms and from tree to tree. Rain spreads bacteria from cankers or other infected areas of a tree to new sites. Upwards of 10 million bacteria can be present inside a single blossom by the time fire blight symptoms become visible.

Fire blight infection can spread beyond the blossom into the branch and even farther, causing green plant tissue to wither and die. Bacteria can also infect vegetation, fruit and bark through wounds caused by rain, hail and wind. All this time, more bacteria-laden exudates are forming and being dispersed.

Plant tissue is vulnerable to infection during the growth period; fruit is susceptible until just before harvest. Once growth has stopped, overwintering cankers start to form and the cycle begins again.
PREVENTION IS KEY

Plant pathologists recommend three approaches to fire blight prevention: reduce susceptibility, reduce the amount of the exudates and prevent bacteria from developing.

HOW TO REDUCE FIRE BLIGHT PATHOGENS:

• Reduce susceptibility: Select an appropriate orchard site and resistant tree varieties. Prune young orchards annually if possible. Do not increase nitrogen supply suddenly. Cut root sprouts and suckers above the soil line when trees are dormant, and remove spurs on trunks and scaffold limbs.

• Reduce fire blight exudate: remove overwintering cankers on blighted tissue and minimize non-orchard sources of exudates.

• Prevent development of bacteria: use a resistance-management program.

WHAT TO LOOK FOR:

• Damaged blossoms, shoots, trunk and root stock

• Cankers on twigs, branches, scaffolds and trunks

• Diminished tree vigor, reduced yields and disfigured fruit
**BACTERIAL SPOT: A COSTLY DISEASE**

Bacterial spot can be a formidable problem for peach and nectarine growers. The disease is caused by the bacterium *Xanthomonas arboricola pv. pruni*, which damages leaves, fruit and growing shoots, causing defoliation and making fruit unmarketable. Bacterial spot has a three-phase life cycle: dormancy, a primary cycle and a secondary cycle.

Bacteria overwinter in spring cankers on young twigs. When growth resumes, the bacteria multiply and form exudate. The bacteria thrive in the exudate, which seeps out of the canker. Dew, fog, rain, wind and foraging insects carry the exudate to leaves, fruit and shoots. Driving rain is a particularly harmful means of spreading bacterial spot.

Bacterial spot infections blacken blossoms, leaves and branches, leave brown or black blemishes on fruit, cause early leaf drop and contribute to loss of vigor. Tree death can result.

As the growth season ends, bacteria become dormant in existing spring cankers, ready to fuel the life cycle again in the following season.
**PREVENTION IS KEY**

Plant pathologists favor prevention programs that emphasize sound cultural practices and use of bactericide sprays to reduce the presence of bacterial spot.

**HOW TO REDUCE BACTERIAL SPOT PATHOGENS:**
- Select resistant varieties for orchards
- Plant new trees far from susceptible varieties
- Avoid excess nitrogen
- Prune new infection promptly
- Use Nufarm bactericides

**WHAT TO LOOK FOR:**
- Damaged leaves, fruit and growing shoots
- Cankers on twigs, buds may fail to open
- Water-soaked spots on leaves turn to shot holes
- Defoliation and unmarketable fruit
- Three-phase life cycle: dormancy, a primary cycle and a secondary cycle
BACTERIAL BLAST

*Pseudomonas syringae*

Named for its fire-blight appearance of yellow and brown halos on the leaves, bacterial blast is economically damaging with its ability to kill both young and adult trees. The pathogen thrives in rainy conditions.

**WHAT TO LOOK FOR:**
- Bacteria attacks shortly before or during bloom
- Kills blossoms, buds, young leaves and shoots
- Blossoms turn black, stay fixed on the tree
- Leaves darken with spots that eventually hole open
- The right conditions can cause complete crop loss

Photo: Daren Mueller, Iowa State University, Bugwood.org

BACTERIAL SPECK

*Pseudomonas syringae pv. tomato*

Named for the black and brown specks found on infected tomatoes and leaves, bacterial speck lowers the value of fruit. Bacterial speck thrives in cool (below 70 degrees Fahrenheit) and moist weather conditions.

**WHAT TO LOOK FOR:**
- Infects leaves and fruit
- Heavy infection can cause defoliation
- Mainly reduces fruit quality
- Lesions are black and normally surrounded by yellow halo
- Lesions are also slightly raised, but unlike bacterial spot, do not crack or become scaly

Photo: Chris Smart, NYSAES, Geneva NY, Wikimedia Commons
BACTERIAL SPOT OF PEPPER AND TOMATO
_Xanthomonas campestris pv. vesicatoria_

Warm, humid conditions may be ideal for tomato and pepper crops, but they also favor bacterial spot disease progression. Bacterial spot attacks the plant foliage, stems and fruit causing leaf and fruit spots and crop loss from blossom and young fruit shed. Fruit that does mature is most often unmarketable due to poor quality.

**WHAT TO LOOK FOR:**
- Pale green spots on fruit which progress to rough, raised brown spots
- Yellow-green lesions on young leaves, changing to darker, greasy, water-soaked lesions on mature leaves
- Leaf lesions tend be angular in shape following leaf veinlets and more numerous at the leaf tip or margin
- Diseased leaves may drop prematurely, especially in pepper crops

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

CITRUS CANKER
_Xanthomonas axonopodis pv. citri_

Known for its blemishes on leaves, stems and fruit on citrus trees, citrus canker is difficult to control during wet weather conditions. The bacterium spreads through wind-blown rain that is at least 20 miles per hour.

**WHAT TO LOOK FOR:**
- Infects fruit, leaves and twigs
- Tell-tale lesions are small, round and blister like
- Lesions are scabby or corky on fruit
- Effects include defoliation, dieback and severely blemished fruit
- Reduces fruit quality and can cause premature fruit drop
- A severe infection can destroy an entire crop

Photo: Scot Nelson, Honolulu HI, flickr.com
COMMON BACTERIAL BLIGHT
Xanthomonas campestris pv. phaseoli

Commonly found in snap beans and dry beans, common bacterial blight thrives in humid conditions with heavy rainfall. Severe infections may result in the loss of entire pods.

WHAT TO LOOK FOR:
• Bacteria commonly spread by wind, infesting wounds and other openings
• Small water-soaked spots form, dry, turn brown and are encircled by a band of lemon yellow
• When wind whips, heavily infected leaves may become tattered
• Leaves may even die and yet remain attached to the plant

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

FRUIT RUSSETING

Commonly known for damaging the appearance of fruit and lowering the marketability, fruit russetting is a costly problem. The appearance of affected fruit lowers the yield value.

WHAT TO LOOK FOR:
• Fruit blemish of brown, corky appearance
• Typical causal agents are weather, spray injury and pathogens
• Fruit is most at risk immediately after blossom stage
• Ice nucleating bacteria can also be primary causal agents
• Decreases value of yield
• Can devastate whole crops

Photo: N.S. Luepschen, Bugwood.org
WALNUT BLIGHT
Xanthomonas campestris pv. juglandis

Overwintering bacteria, primarily in dormant buds, can infect all green developing tissue including leaves, shoots, catkins, flowers, and fruit. Rain and wet conditions increase the spread of bacteria.

WHAT TO LOOK FOR:
- Water-soaked spots on leaves turn blackish, greasy - lesions may be surrounded with a yellow-green halo
- Florets blacken and catkins become twisted
- Black, oily spots and necrotic lesions develop on fruit
- Nuts infected prior to shell-hardening shrivel and prematurely drop
- Infected nuts reaching full size are blackened and not marketable
- Downward spreading bacteria can cause stem cankers and dieback

Photo: H. Zell, Wikimedia Commons
The Nufarm research and development team is working tirelessly toward new solutions in the fight against HLB and Zebra Chip. As a grower, it is important to understand these emerging threats and take proactive measures to help stop the spread of these diseases. Check www.nufarm.com/USAG regularly to stay on top of disease and treatment updates as they evolve.
HLB

WHAT YOU NEED TO KNOW ABOUT HLB:
Citrus Greening, also known as Asiatic Huanglongbing (HLB), is one of the most destructive diseases to attack citrus. The disease, *Candidatus Liberibacter asiaticus*, is called citrus greening due to part of the fruit retaining its green color at maturity.

Since first being detected in Florida in 2005, the disease has since caused $1.3 billion in damages to the Florida citrus industry and has been detected in several southern states and Mexico.

Fruit from trees infected gradually decline in production. Fruit may drop prematurely, fail to ripen, and have little to no value due to poor size and flavor. Within three to five years, an infected tree may stop bearing fruit and die.

While HLB can kill a tree in as little as five years, it takes at least one to two years for the plant to show symptoms of infection. HLB can infect most citrus cultivars, species and hybrids. The disease is spread by the Asian citrus psyllid, whose reproduction cycle correlates with flush. The psyllid lays its eggs on emerging leaves and transmits bacteria from infected trees as it feeds.

HOW TO DETECT HLB: Identifying HLB can be tricky, with symptoms taking one to two years to appear. One symptom to watch for is leaf yellowing. Look for blotchy yellowing on the leaf, with one side appearing green and the other side yellow. Leaf yellowing ranges from small spots on the leaf to the leaf turning completely yellow. The fruit from infected trees tends to be smaller, lopsided, and drop prematurely.

Because the symptoms of HLB in citrus plants are similar to symptoms from other pathogens and deficiencies, diagnostic laboratories are needed to confirm its presence.

ECONOMIC EFFECTS: HLB affects the marketable yield of citrus fruit due to poor visual and taste characteristics. The loss in marketability increases as the disease progresses to the point that the tree stops bearing fruit and dies.

*Photos: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org*
ZEBRA CHIP

WHAT YOU NEED TO KNOW: Zebra Chip has cost US potato producers millions of dollars annually since the pathogen was first detected in South Texas in 2000. The pathogen, caused by the bacterium Candidatus Liberibacter solanacearum (Lso), has spread to every major potato production region in the southwestern part of the US, Mexico, Guatemala, Honduras, and New Zealand.

All varieties of potatoes are at risk of infection, which alters the taste and appearance of the tuber and kills the plant. Zebra Chip manipulates the level of sugar in potato tubers; this gives the chips a burnt look when fried. The taste is also altered, making the potatoes less palatable.

Zebra Chip is spread by adult potato psyllids as they feed. Once a psyllid feeds on an infected plant, that psyllid carries the bacterium for life and can spread Lso onto its offspring. Psyllid movement and Zebra Chip infections thrive in mild summer conditions. Potato psyllids tend to start feeding at the edges of fields and migrate inward.

HOW TO DETECT ZEBRA CHIP: Plants with Zebra Chip start showing symptoms as early as three weeks after infection. Early signs include leaf curling and purple or yellow leaf discoloration, and can include aerial tubers and stunted growth. As the disease progresses, plants will show signs of scorching and eventually die.

Below-ground symptoms include enlarged lenticels, shortened or collapsed stolons, excessive numbers of misshapen potato tubers, and chain tubers.

ECONOMIC EFFECTS: The economic losses from Zebra Chip are twofold: the loss of marketable potatoes and the loss of plants. Infected plants produce little to no yield; harvested tubers have low market value and are unacceptable for planting. It’s estimated that Zebra Chip has infected more than 35 percent of the acreage used for commercial potato production in Texas alone, and has cost Texas potato producers more than $25 million annually in losses.

Photos: zebrachipscri.tamu.edu/image-gallery/symptom-gallery
photographer unknown (top); Jianchi Chen, 2010 (middle); photographer unknown (bottom)
OUR COPPER HAS YOU COVERED.

Nothing fights disease like ChampION++™ Fungicide/Bactericide*. A new formulation gives you the smallest, most consistently-sized copper particles, more thorough leaf coverage, better absorption and more effective disease control. All this with reduced soil loading, compared to other coppers.

WWW.NUFARM.COM/USAG

*Non-public health bacteria
Nufarm Has Your Back.

As new disease threats emerge, Nufarm is working harder than ever to help you protect your crops. With new chemistries and new use labeling for existing products underway, Nufarm is delivering more solutions to grow a better tomorrow.

Learn more about our most recent disease protection developments.

www.nufarm.com/USAG