CLAIMS

What is claimed is:

1. A method for protecting a plant against a bacterial, fungal or viral pathogen, comprising:

contacting the plant with an effective amount of a bismuth-thiol (BT) composition under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the bacterial, fungal or viral pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the bacterial, fungal or viral pathogen,

(iii) inhibition of biofilm formation by the bacterial, fungal or viral pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the bacterial, fungal or viral pathogen,

wherein the BT composition comprises a substantially monodisperse suspension of microparticles that comprise a BT compound, said microparticles having a volumetric mean diameter of from about 0.4 μm to about 10 μm.

2. The method of claim 1 wherein the bacterial pathogen comprises *Erwinia amylovora* cells.

3. The method of claim 1 wherein the bacterial pathogen is selected from the group consisting of *Erwinia amylovora*, *Xanthomonas campestris pv dieffenbachiae*, *Pseudomonas syringae, Xylella fastidiosa; Xylophylus ampelinus; Monilinia fructicola, Pantoea stewartii* subsp. *Stewartii, Ralstonia solanacearum, and Clavibacter michiganensis* subsp. *sepedonicus.*

4. The method of claim 1 wherein the bacterial pathogen exhibits antibiotic resistance.

5. The method of claim 1 wherein the bacterial pathogen exhibits streptomycin resistance.

6. The method of claim 1 wherein the plant is a food crop plant.

7. The method of claim 6 wherein the food crop plant is a fruit tree.

8. The method of claim 7 wherein the fruit tree is selected from the group consisting of an apple tree, a pear tree, a peach tree, a nectarine tree, a plum tree, an apricot tree.

9. The method of claim 6 wherein the food crop plant is a banana tree of genus *Musa*.

10. The method of claim 6 wherein the food crop plant is a plant selected from a tuberous plant, a leguminous plant, and a cereal grain plant.

11. The method of claim 10 wherein the tuberous plant is selected from the group consisting of *Solanum tuberosum* (potato), and *Ipomoea batatas* (sweet potato).

12. The method of claim 1 in which the step of contacting is performed one or a plurality of times.

13. The method of claim 12 in which at least one step of contacting comprises one of spraying, dipping, coating and painting the plant.

14. The method of claim 12 in which at least one step of contacting is performed at a flower blossom, green-tip or growth site of the plant.

15. The method of claim 12 in which at least one step of contacting is performed within 24, 48 or 72 hours of first flower blooming on the plant.

16. The method of claim 1 wherein the BT composition comprises one or more BT compounds selected from the group consisting of BisBAL, BisEDT, Bis-dimercaprol, Bis-DTT, Bis-2-mercaptoethanol, Bis-DTE, Bis-Pyr, Bis-Ery, Bis-Tol, Bis-BDT, Bis-PDT, Bis-Pyr/Bal, Bis-Pyr/BDT, Bis-Pyr/EDT, Bis-Pyr/PDT, Bis-Pyr/Tol, Bis-Pyr/Ery, bismuth-1-mercapto-2-propanol, and Bis-EDT/2-hydroxy-1-propanethiol.

17. The method of claim 1 wherein the bacterial pathogen exhibits antibiotic resistance.

18. The method of any one of claims 1-17 which further comprises contacting the plant with a synergizing or enhancing antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the plant with the BT composition.

19. The method of claim 18 wherein the synergizing or enhancing antibiotic comprises an antibiotic that is selected from the group consisting of an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a penicillinase-resistant penicillin antibiotic, and an aminopenicillin antibiotic.

20. The method of claim 19 wherein the synergizing or enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

21. A method for overcoming antibiotic resistance in a plant in or on which an antibiotic-resistant bacterial plant pathogen is present, comprising

(a) contacting the plant with an effective amount of a BT composition under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the antibiotic-resistant bacterial pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the antibiotic-resistant bacterial pathogen,

(iii) inhibition of biofilm formation by the antibiotic-resistant bacterial pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the antibiotic-resistant bacterial pathogen,

wherein the BT composition comprises a substantially monodisperse suspension of microparticles that comprise a BT compound, said microparticles having a volumetric mean diameter of from about 0.5 μm to about 10 μm; and

(b) contacting the plant with a synergizing or enhancing antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the plant with the BT composition.

22. The method of any one of claims 1-21 wherein the bismuth-thiol composition comprises a plurality of microparticles that comprise a bismuth-thiol (BT) compound, substantially all of said microparticles having a volumetric mean diameter of from about 0.4 μm to about 5 μm and being formed by a process that comprises:

(a) admixing, under conditions and for a time sufficient to obtain a solution that is substantially free of a solid precipitate, (i) an acidic aqueous solution that comprises a bismuth salt comprising bismuth at a

concentration of at least 50 mM and that lacks a hydrophilic, polar or organic solubilizer, with (ii) ethanol in an amount sufficient to obtain an admixture that comprises about 25% ethanol by volume; and

(b) adding to the admixture of (a) an ethanolic solution comprising a thiol-containing compound to obtain a reaction solution, wherein the thiol-containing compound is present in the reaction solution at a molar ratio of from about 1:3 to about 3:1 relative to the bismuth, under conditions and for a time sufficient for formation of a precipitate which comprises the microparticles comprising the BT compound.

23. The method of claim 22 wherein the bismuth salt is $Bi(NO_3)_3$.

24. The method of claim 22 wherein the acidic aqueous solution comprises at least 5%, 10%, 15%, 20%, 22% or 22.5% bismuth by weight.

25. The method of claim 22 wherein the acidic aqueous solution comprises at least 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5% or 5% nitric acid by weight.

26. The method of claim 22 wherein the thiol-containing compound comprises one or more agents selected from the group consisting of 1,2-ethane dithiol, 2,3-dimercaptopropanol, pyrithione, dithioerythritol, 3,4-dimercaptotoluene, 2,3-butanedithiol, 1,3-propanedithiol, 2-hydroxypropane thiol, 1-mercapto-2-propanol, dithioerythritol, alpha-lipoic acid, dithiothreitol, methanethiol (CH_3SH [m-mercaptan]), ethanethiol (C_2H_5SH [e- mercaptan]), 1-propanethiol (C_3H_7SH [n-P mercaptan]), 2-propanethiol ($CH_3CH(SH)CH_3$ [$2C_3$ mercaptan]), butanethiol (C_4H_9SH ([n-butyl mercaptan]), tert-butyl mercaptan ($C(CH_3)_3SH$ [t-butyl mercaptan]), pentanethiol ($C_5H_{11}SH$ [pentyl mercaptan]), coenzyme A, lipoamide, glutathione, cysteine, cystine, 2-mercaptoethanol, dithiothreitol, dithioerythritol, 2-mercaptoindole, transglutaminase, (11-mercaptoundecyl)hexa(ethylene glycol), (11-mercaptoundecyl)tetra(ethylene glycol), (11-mercaptoundecyl)tetra(ethylene glycol) functionalized gold nanoparticles, 1,1',4',1"-terphenyl-4-thiol, 1,11-undecanedithiol, 1,16-hexadecanedithiol, 1,2-ethanedithiol technical grade, 1,3-propanedithiol, 1,4-benzenedimethanethiol, 1,4-butanedithiol, 1,4-butanedithiol diacetate, 1,5-

pentanedithiol, 1,6-hexanedithiol, 1,8-octanedithiol, 1,9-nonanedithiol, adamantanethiol, 1-butanethiol, 1-decanethiol, 1-dodecanethiol, 1-heptanethiol, 1-heptanethiol purum, 1-hexadecanethiol, 1-hexanethiol, 1-mercapto-(triethylene glycol), 1-mercapto-(triethylene glycol) methyl ether functionalized gold nanoparticles, 1-mercapto-2-propanol, 1-nonanethiol, 1-octadecanethiol, 1-octanethiol, 1-octanethiol, 1-pentadecanethiol, 1-pentanethiol, 1-propanethiol, 1-tetradecanethiol, 1-tetradecanethiol purum, 1-undecanethiol, 11-(1*H*-pyrrol-1-yl)undecane-1-thiol, 11-amino-1-undecanethiol hydrochloride, 11-bromo-1-undecanethiol, 11-mercapto-1-undecanol, 11-mercapto-1-undecanol, 11-mercaptoundecanoic acid, 11-mercaptoundecanoic acid, 11-mercaptoundecyl trifluoroacetate, 11-mercaptoundecylphosphoric acid, 12-mercaptododecanoic acid, 12-mercaptododecanoic acid, 15-mercaptopentadecanoic acid, 16-mercaptohexadecanoic acid, 16-mercaptohexadecanoic acid, 1*H*,1*H*,2*H*,2*H*-perfluorodecanethiol, 2,2'-(ethylenedioxy)diethanethiol, 2,3-butanedithiol, 2-butanethiol, 2-ethylhexanethiol, 2-methyl-1-propanethiol, 2-methyl-2-propanethiol, 2-phenylethanethiol, 3,3,4,4,5,5,6,6,6-nonafluoro-1-hexanethiol purum, 3-(dimethoxymethylsilyl)-1-propanethiol, 3-chloro-1-propanethiol, 3-mercapto-1-propanol, 3-mercapto-2-butanol, 3-mercapto-*N*-nonylpropionamide, 3-mercaptopropionic acid, 3-mercaptopropyl-functionalized silica gel, 3-methyl-1-butanethiol, 4,4'-bis(mercaptomethyl)biphenyl, 4,4'-dimercaptostilbene, 4-(6-mercaptohexyloxy)benzyl alcohol, 4-cyano-1-butanethiol, 4-mercapto-1-butanol, 6-(ferrocenyl)hexanethiol, 6-mercapto-1-hexanol, 6-mercaptohexanoic acid, 8-mercapto-1-octanol, 8-mercaptooctanoic acid, 9-mercapto-1-nonanol, biphenyl-4,4'-dithiol, butyl 3-mercaptopropionate, copper(I) 1-butanethiolate, cyclohexanethiol, cyclopentanethiol, decanethiol functionalized silver nanoparticles, dodecanethiol functionalized gold nanoparticles, dodecanethiol functionalized silver nanoparticles, hexa(ethylene glycol)mono-11-(acetylthio)undecyl ether, mercaptosuccinic acid, methyl 3-mercaptopropionate, nanoTether BPA-HH, NanoThinks™ 18, NanoThinks™ 8, NanoThinks™ ACID11, NanoThinks™ ACID16, NanoThinks™ ALCO11, NanoThinks™ THIO8, octanethiol functionalized gold nanoparticles, PEG dithiol average M_n 8,000, PEG dithiol average mol wt 1,500, PEG dithiol average mol wt 3,400, *S*-(11-bromoundecyl)thioacetate, *S*-(4-cyanobutyl)thioacetate, thiophenol, triethylene glycol mono-11-mercaptoundecyl ether, trimethylolpropane tris(3-mercaptopropionate), [11-

(methylcarbonylthio)undecyl]tetra(ethylene glycol), *m*-carborane-9-thiol, *p*-terphenyl-4,4″-dithiol, *tert*-dodecylmercaptan, and *tert*-nonyl mercaptan.

27. The method of any one of claims 1-21 wherein the bacterial pathogen comprises at least one of:

(i) one or more gram-negative bacteria;

(ii) one or more gram-positive bacteria;

(iii) one or more antibiotic-sensitive bacteria;

(iv) one or more antibiotic-resistant bacteria;

(v) a bacterial pathogen that is selected from the group consisting of *Staphylococcus aureus (S. aureus)*, MRSA (methicillin-resistant *S. aureus*), *Staphylococcus epidermidis* , MRSE (methicillin-resistant *S. epidermidis*), *Mycobacterium tuberculosis, Mycobacterium avium, Pseudomonas aeruginosa,* drug-resistant *P. aeruginosa, Escherichia coli,* enterotoxigenic *E. coli,* enterohemorrhagic *E. coli, Klebsiella pneumoniae, Clostridium difficile, Heliobacter pylori, Legionella pneumophila, Enterococcus faecalis,* methicillin-susceptible *Enterococcus faecalis, Enterobacter cloacae, Salmonella typhimurium, Proteus vulgaris, Yersinia enterocolitica, Vibrio cholera, Shigella flexneri,* vancomycin-resistant *Enterococcus* (VRE), *Burkholderia cepacia* complex, *Francisella tularensis, Bacillus anthracis, Yersinia pestis, Pseudomonas aeruginosa, Streptococcus pneumonia,* penicillin-resistant *Streptococcus pneumonia, Escherichia coli, Burkholderia cepacia, Bukholderia multivorans, Mycobacterium smegmatis* and *Acinetobacter baumannii.*

28. The method of any one of claims 1-21 which comprises contacting the plant with at least one of (i) a synergizing antibiotic and (ii) a cooperative antimicrobial efficacy enhancing antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the surface with the BT composition.

29. The method of claim 28 wherein the synergizing antibiotic or the cooperative antimicrobial efficacy enhancing antibiotic comprises an antibiotic that is selected from the group consisting of an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a glycopeptide antibiotic, a lincosamide antibiotic, a penicillinase-resistant penicillin antibiotic, and an aminopenicillin antibiotic.

30. The method of claim 29 wherein the synergizing antibiotic or the cooperative antimicrobial efficacy enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

31. A method for overcoming antibiotic resistance in or on a plant where an antibiotic-resistant bacterial pathogen is present, comprising:

contacting the plant simultaneously or sequentially and in any order with an effective amount of (1) at least one bismuth-thiol (BT) composition and (2) at least one antibiotic that is capable of enhancing or acting synergistically with the at least one BT composition, under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the bacterial pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the bacterial pathogen,

(iii) inhibition of biofilm formation by the bacterial pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the bacterial pathogen,

wherein the BT composition comprises a plurality of microparticles that comprise a bismuth-thiol (BT) compound, substantially all of said microparticles having a volumetric mean diameter of from about 0.4 μm to about 5 μm; and thereby overcoming antibiotic resistance on the epithelial tissue surface.

32. The method of claim 31 wherein the bacterial pathogen exhibits resistance to an antibiotic that is selected from the group consisting of methicillin, vancomycin, naficilin, gentamicin, ampicillin, chloramphenicol, doxycycline, tobramycin, clindamicin and gatifloxacin.

33. The method of claim 31 wherein the BT composition comprises one or more BT compounds selected from the group consisting of BisBAL, BisEDT, Bis-dimercaprol, Bis-DTT, Bis-2-mercaptoethanol, Bis-DTE, Bis-Pyr, Bis-Ery, Bis-Tol, Bis-BDT, Bis-PDT, Bis-Pyr/Bal, Bis-Pyr/BDT, Bis-

Pyr/EDT, Bis-Pyr/PDT, Bis-Pyr/Tol, Bis-Pyr/Ery, bismuth-1-mercapto-2-propanol, and Bis-EDT/2-hydroxy-1-propanethiol.

34. The method of claim 33 wherein the synergizing or enhancing antibiotic comprises an antibiotic that is selected from the group consisting of clindamicin, gatifloxacin, an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a penicillinase-resistant penicillin antibiotic, and an aminopenicillin antibiotic.

35. The method of claim 34 wherein the synergizing or enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

CLAIMS

1. A method for protecting a plant against a bacterial, fungal or viral pathogen, comprising:

contacting the plant with an effective amount of a bismuth-thiol (BT) composition under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the bacterial, fungal or viral pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the bacterial, fungal or viral pathogen,

(iii) inhibition of biofilm formation by the bacterial, fungal or viral pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the bacterial, fungal or viral pathogen,

wherein the BT composition comprises a substantially monodisperse suspension of microparticles that comprise a BT compound, said microparticles having a volumetric mean diameter of from about 0.4 μm to about 10 μm.

2. The method of claim 1 wherein the bacterial pathogen comprises *Erwinia amylovora* cells.

3. The method of claim 1 wherein the bacterial pathogen is selected from the group consisting of *Erwinia amylovora, Xanthomonas campestris pv dieffenbachiae, Pseudomonas syringae, Xylella fastidiosa; Xylophylus ampelinus; Monilinia fructicola, Pantoea stewartii* subsp. *Stewartii, Ralstonia solanacearum, and Clavibacter michiganensis* subsp. *sepedonicus.*

4. The method of claim 1 wherein the bacterial pathogen exhibits antibiotic resistance.

5. The method of claim 1 wherein the bacterial pathogen exhibits streptomycin resistance.

6. The method of claim 1 wherein the plant is a food crop plant.

7. The method of claim 6 wherein the food crop plant is a fruit tree.

8. The method of claim 7 wherein the fruit tree is selected from the group consisting of an apple tree, a pear tree, a peach tree, a nectarine tree, a plum tree, an apricot tree.

9. The method of claim 6 wherein the food crop plant is a banana tree of genus *Musa.*

10. The method of claim 6 wherein the food crop plant is a plant selected from a tuberous plant, a leguminous plant, and a cereal grain plant.

11. The method of claim 10 wherein the tuberous plant is selected from the group consisting of *Solanum tuberosum* (potato), and *Ipomoea batatas* (sweet potato).

12. The method of claim 1 in which the step of contacting is performed one or a plurality of times.

13. The method of claim 12 in which at least one step of contacting comprises one of spraying, dipping, coating and painting the plant.

14. The method of claim 12 in which at least one step of contacting is performed at a flower blossom, green-tip or growth site of the plant.

15. The method of claim 12 in which at least one step of contacting is performed within 24, 48 or 72 hours of first flower blooming on the plant.

16. The method of claim 1 wherein the BT composition comprises one or more BT compounds selected from the group consisting of BisBAL, BisEDT, Bis-dimercaprol, Bis-DTT, Bis-2-mercaptoethanol, Bis-DTE, Bis-Pyr, Bis-Ery, Bis-Tol, Bis-BDT, Bis-PDT, Bis-Pyr/Bal, Bis-Pyr/BDT, BisPyr/EDT, Bis-Pyr/PDT, Bis-Pyr/Tol, Bis-Pyr/Ery, bismuth-1-mercapto-2- propanol, and Bis-EDT /2-hydroxy-1-propanethiol.

17. The method of any one of claims 1-16 which further comprises contacting the plant with a synergizing or enhancing antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the plant with the BT composition.

18. The method of claim 17 wherein the synergizing or enhancing antibiotic comprises an antibiotic that is selected from the group consisting of an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a penicillinase-resistant penicillin antibiotic, and an aminopenicillin antibiotic.

19. The method of claim 18 wherein the synergizing or enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

20. A method for overcoming antibiotic resistance in a plant in or on which an antibiotic-resistant bacterial plant pathogen is present, comprising

(a) contacting the plant with an effective amount of a BT composition under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the antibioticresistant bacterial pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the antibiotic-resistant bacterial pathogen,

(iii) inhibition of biofilm formation by the antibioticresistant bacterial pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the antibiotic-resistant bacterial pathogen,

wherein the BT composition comprises a substantially monodisperse suspension of microparticles that comprise a BT compound, said microparticles having a volumetric mean diameter of from about 0.5 μm to about 10 μm; and

(b) contacting the plant with a synergizing or enhancing antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the plant with the BT composition.

21. The method of any one of claims 1-20 wherein the bismuth-thiol composition comprises a plurality of microparticles that comprise a bismuth-thiol (BT) compound, substantially all of said microparticles having a volumetric mean diameter of from about 0.4 μm to about 5 μm and being formed by a process that comprises:

(a) admixing, under conditions and for a time sufficient to obtain a solution that is substantially free of a solid precipitate, (i) an acidic aqueous solution that comprises a bismuth salt comprising bismuth at aconcentration of at least 50 mM and that lacks a hydrophilic, polar or organic solubilizer, with (ii) ethanol in an amount sufficient to obtain an admixture that comprises about 25% ethanol by volume; and

(b) adding to the admixture of (a) an ethanolic solution comprising a thiol-containing compound to obtain a reaction solution, wherein the thiol-containing compound is present in the reaction solution at a molar ratio of from about 1:3 to about 3:1 relative to the bismuth, under conditions and for a time sufficient for formation of a precipitate which comprises the microparticles comprising the BT compound.

22. The method of claim 21 wherein the bismuth salt is $Bi(NO_3)_3$.

23. The method of claim 21 wherein the acidic aqueous solution comprises at least 5%, 10%, 15%, 20%, 22% or 22.5% bismuth by weight.

24. The method of claim 21 wherein the acidic aqueous solution comprises at least 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5% or 5% nitric acid by weight.

25. The method of claim 21 wherein the thiol-containing compound comprises one or more agents selected from the group consisting of 1,2-ethane dithiol, 2,3-dimercaptopropanol, pyrithione, dithioerythritol, 3,4-dimercaptotoluene, 2,3-butanedithiol, 1,3-propanedithiol, 2-hydroxypropane thiol, 1-mercapto-2-propanol, dithioerythritol, alpha-lipoic acid, dithiothreitol,methanethiol (CH_3SH [m-mercaptan]), ethanethiol (C_2H_5SH [e- mercaptan]), 1-propanethiol (C3H7SH [n-P mercaptan]), 2-propanethiol ($CH_3CH(SH)CH_3$ [$2C_3$ mercaptan]), butanethiol (C_4H_9SH ([n-butyl mercaptan]), tert-butyl mercaptan ($C(CH_3)_3SH$ [t-butyl mercaptan]), pentanethiol ($C_5H_{11}SH$ [pentyl mercaptan]), coenzyme A, lipoamide, glutathione, cysteine, cystine, 2-mercaptoethanol, dithiothreitol, dithioerythritol, 2-mercaptoindole, transglutaminase, (11-mercaptoundecyl)hexa(ethylene glycol), (11-mercaptoundecyl)tetra(ethylene glycol), (11-mercaptoundecyl)tetra(ethylene glycol) functionalized gold nanoparticles, 1,1',4',1"-terphenyl-4-thiol, 1,11-undecanedithiol, 1,16-hexadecanedithiol, 1,2-ethanedithiol technical grade, 1 ,3-propanedithiol, 1,4-benzenedimethanethiol, 1,4-butanedithiol, 1,4-butanedithiol diacetate, 1,5- adamantanethiol, 1-butanethiol, 1-decanethiol, 1-dodecanethiol, 1- heptanethiol, 1-heptanethiol purum, 1-hexadecanethiol, 1-hexanethiol, 1-mercapto-(triethylene glycol), 1-mercapto-(triethylene glycol) methyl ether functionalized gold nanoparticles, 1-mercapto-2-propanol, 1-nonanethiol, 1-octadecanethiol, 1-octanethiol, 1-octanethiol, 1-pentadecanethiol, 1-pentanethiol, 1-propanethiol, 1-tetradecanethiol, 1-tetradecanethiol purum, 1-undecanethiol, 11-(1*H*-pyrrol-1-yl)undecane-1-thiol, 11-amino-1-undecanethiol hydrochloride, 11-bromo-1-undecanethiol, 11-mercapto-1-undecanol, 11-mercapto-1-undecanol, 11-mercaptoundecanoic acid, 11-mercaptoundecanoic acid, 11-mercaptoundecyl trifluoroacetate, 11-mercaptoundecylphosphoric acid, 12-mercaptododecanoic acid, 12-mercaptododecanoic acid, 15-mercaptopentadecanoic acid, 16-mercaptohexadecanoic acid, 16-mercaptohexadecanoic acid, 1*H*,1*H*,2*H*,2*H*-perfluorodecanethiol, 2,2'(ethylenedioxy)diethanethiol, 2,3-butanedithiol, 2-butanethiol, 2-ethylhexanethiol, 2-methyl-1-propanethiol, 2-methyl-2-propanethiol, 2-phenylethanethiol, 3,3,4,4,5,5,6,6,6-nonafluoro-1-hexanethiol purum, 3-(dimethoxymethylsilyl)-1-propanethiol, 3-chloro-1-propanethiol, 3-mercapto-1-propanol, 3-mercapto-2-butanol, 3-mercapto-N-nonylpropionamide, 3-mercaptopropionic acid, 3-mercaptopropyl-functionalized silica gel, 3-methyl-1-butanethiol, 4,4'-bis(mercaptomethyl)biphenyl, 4,4'-dimercaptostilbene, 4-(6-mercaptohexyloxy)benzyl alcohol, 4-cyano-1-butanethiol, 4-mercapto-1-butanol, 6-

(ferrocenyl)hexanethiol, 6-mercapto-1-hexanol, 6-mercaptohexanoic acid, 8-mercapto-1-octanol, 8-mercaptooctanoic acid, 9-mercapto-1-nonanol, biphenyl-4,4'-dithiol, butyl 3-mercaptopropionate, copper(I) 1-butanethiolate, cyclohexanethiol, cyclopentanethiol, decanethiol functionalized silver nanoparticles, dodecanethiol functionalized gold nanoparticles, dodecanethiol functionalized silver nanoparticles, hexa(ethylene glycol)mono-11-(acetylthio)undecyl ether, mercaptosuccinic acid, methyl 3-mercaptopropionate, nanoTether BPA-HH, NanoThinks™ 18, NanoThinks™ 8, NanoThinks™ ACID11, NanoThinks™ ACID16, NanoThinks™ ALCO11, NanoThinks™ THIO8, octanethiol functionalized gold nanoparticles, PEG dithiol average M_n 8,000, PEG dithiol average mol wt 1,500, PEG dithiol average mol wt 3,400, *S*-(11-bromoundecyl)thioacetate, *S*-(4-cyanobutyl)thioacetate, thiophenol, triethylene glycol mono-11-mercaptoundecyl ether, trimethylolpropane tris(3-mercaptopropionate), [11-(methylcarbonylthio)undecyl]tetra(ethylene glycol), m-carborane-9-thiol, *p*terphenyl-4,4"-dithiol, terl-dodecylmercaptan, and terl-nonyl mercaptan.

26. The method of any one of claims 1-20 wherein the bacterial pathogen comprises at least one of:

(i) one or more gram-negative bacteria;

(ii) one or more gram-positive bacteria;

(iii) one or more antibiotic-sensitive bacteria;

(iv) one or more antibiotic-resistant bacteria;

(v) a bacterial pathogen that is selected from the group consisting of *Staphylococcus aureus (S. aureus),* MRSA (methicillin-resistant *S. aureus), Staphylococcus epidermidis,* MRSE (methicillin-resistant *S. epidermidis), Mycobacterium tuberculosis, Mycobacterium avium, Pseudomonas aeruginosa,* drug-resistant *P. aeruginosa, Escherichia coli,* enterotoxigenic *E. coli,* enterohemorrhagic *E. coli, Klebsiella pneumoniae, Clostridium difficile, Heliobacter pylori, Legionella pneumophila, Enterococcus faecalis,* methicillin-susceptible *Enterococcus faecalis, Enterobacter cloacae, Salmonella typhimurium, Proteus vulgaris, Yersinia enterocolitica, Vibrio cholera, Shigella flexneri,* vancomycin-resistant *Enterococcus* (VRE), *Burkholderia cepacia* complex, *Francisella tularensis, Bacillus anthracis, Yersinia pestis, Pseudomonas aeruginosa, Streptococcus pneumonia,* penicillin-resistant *Streptococcus pneumonia, Escherichia coli, Burkholderia cepacia, Bukholderia multivorans, Mycobacterium smegmatis* and *Acinetobacter baumannii.*

27. The method of any one of claims 1-20 which comprises contacting the plant with at least one of (i) a synergizing antibiotic and (ii) a cooperative antimicrobial efficacy enhancing

antibiotic, simultaneously or sequentially and in any order with respect to the step of contacting the surface with the BT composition.

28. The method of claim 27 wherein the synergizing antibiotic or the cooperative antimicrobial efficacy enhancing antibiotic comprises an antibiotic that is selected from the group consisting of an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a glycopeptide antibiotic, a lincosamide antibiotic, a penicillinaseresistant penicillin antibiotic, and an aminopenicillin antibiotic.

29. The method of claim 28 wherein the synergizing antibiotic or the cooperative antimicrobial efficacy enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

30. A method for overcoming antibiotic resistance in or on a plant where an antibiotic-resistant bacterial pathogen is present, comprising:

contacting the plant simultaneously or sequentially and in any order with an effective amount of (1) at least one bismuth-thiol (BT) composition and (2) at least one antibiotic that is capable of enhancing or acting synergistically with the at least one BT composition, under conditions and for a time sufficient for one or more of:

(i) prevention of infection of the plant by the bacterial pathogen,

(ii) inhibition of cell viability or cell growth of substantially all planktonic cells of the bacterial pathogen,

(iii) inhibition of biofilm formation by the bacterial pathogen, and

(iv) inhibition of biofilm viability or biofilm growth of substantially all biofilm-form cells of the bacterial pathogen,

wherein the BT composition comprises a plurality of microparticles that comprise a bismuth-thiol (BT) compound, substantially all of said microparticles having a volumetric mean diameter of from about 0.4 μm to about 5 μm; and thereby overcoming antibiotic resistance on the epithelial tissue surface.

31. The method of claim 30 wherein the bacterial pathogen exhibits resistance to an antibiotic that is selected from the group consisting of methicillin, vancomycin, naficilin, gentamicin, ampicillin, chloramphenicol, doxycycline, tobramycin, clindamicin and gatifloxacin.

32. The method of claim 30 wherein the BT composition comprises one or more BT compounds selected from the group consisting of BisBAL, BisEDT, Bis-dimercaprol, Bis-DTT,

Bis-2-mercaptoethanol, Bis-DTE, Bis-Pyr, Bis-Ery, Bis-Tol, Bis-BDT, Bis-PDT, Bis-Pyr/Bal, Bis-Pyr/BDT, Bis- Pyr/EDT, Bis-Pyr/PDT, Bis-Pyr/Tol, Bis-Pyr/Ery, bismuth-1-mercapto-2-propanol, and Bis-EDT /2-hydroxy-1-propanethiol.

33. The method of claim 32 wherein the synergizing or enhancing antibiotic comprises an antibiotic that is selected from the group consisting of clindamicin, gatifloxacin, an aminoglycoside antibiotic, a carbapenem antibiotic, a cephalosporin antibiotic, a fluoroquinolone antibiotic, a penicillinase-resistant penicillin antibiotic, and an aminopenicillin antibiotic.

34. The method of claim 33 wherein the synergizing or enhancing antibiotic is an aminoglycoside antibiotic that is selected from the group consisting of amikacin, arbekacin, gentamicin, kanamycin, neomycin, netilmicin, paromomycin, rhodostreptomycin, streptomycin, tobramycin and apramycin.

35. A method for protecting a plant against a bacterial, fungal or viral pathogen, or for overcoming antibiotic resistance in a plant in or on which an antibiotic-resistant bacterial plant pathogen is present, substantially as herein described with reference to any one of the examples but excluding the comparative examples, and as illustrated by the accompanying drawings.