PEST CONTROL COMPOSITIONS AND USES THEREOF

BACKGROUND

Plant pests, including plant pathogens (e.g., bacteria or fungi), invertebrate pests (e.g., insects, mollusks, and nematodes), and weeds are pervasive in the human environment. Although a multitude of means have been utilized for attempting to control infestations by these pests, the demand for safe and effective pest control strategies is increasing. Thus, there is need in the art for new methods and compositions to control plant pests.

SUMMARY ~~OF THE INVENTION~~

Disclosed herein are pest control (e.g., biopesticide or biorepellent) compositions including a plurality of plant messenger packs (PMPs) that are useful in methods for decreasing the fitness of pests (e.g., agriculture pests) and/or increasing the fitness of a plant.

In one ~~aspect~~example, the disclosure features a pest control composition including a plurality of plant messenger packs (PMPs), wherein the composition is formulated for delivery to a plant and wherein the composition includes at least 5% PMPs as measured by wt/vol, percent PMP protein composition, and/or percent lipid composition (e.g., by measuring fluorescently labelled lipids)

In another ~~aspect~~example, the disclosure features a pest control composition including a plurality of PMPs, wherein the composition is formulated for delivery to a plant pest and wherein the composition includes at least 5% PMPs.

In some ~~embodiment~~examples of the pest control composition, the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C. In other ~~embodiment~~examples, the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C. In some ~~embodiment~~examples, the composition is formulated for delivery to a plant. In some ~~embodiment~~examples, the composition is formulated for delivery to a plant pest. In some ~~embodiment~~examples, the PMPs are stable for at least 24 hours, 48 hours, seven days, or 30 days. In other ~~embodiment~~examples, the PMPs are stable at a temperature of at least 24°C, 20°C, or 4°C. In still other ~~embodiment~~examples, the plurality of PMPs in the composition is at a concentration effective to decrease the fitness of a plant pest.

In another ~~aspect~~example, the disclosure features a pest control composition including a plurality of PMPs, wherein the plurality of PMPs in the composition is at a concentration effective to decrease the fitness of a plant pest.

In some ~~embodiment~~examples, the composition is formulated for delivery to a plant. In some ~~embodiment~~examples, the composition is formulated for delivery to a plant pest. In some ~~embodiment~~examples, the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C. In some ~~embodiment~~examples, the PMP includes a plurality of PMP proteins, and the concentration of PMPs is the concentration of PMP proteins therein. In other ~~embodiment~~examples, the plurality of PMPs in the composition is at a concentration of at least 0.01 ng, 0.1 ng, 1 ng, 2 ng, 3 ng, 4 ng, 5 ng, 10 ng, 50 ng, 100 ng, 250 ng, 500 ng, 750 ng, 1 µg, 10 µg, 50 µg, 100 µg, or 250 µg PMP protein/ml. In yet other ~~embodiment~~examples, the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C.

In some ~~embodiment~~examples, the plurality of PMPs in the composition is at a concentration effective to decrease the fitness of a plant pest. In some ~~embodiment~~examples, the plant EV is a modified plant extracellular vesicle (EV). In some ~~embodiment~~examples, the plant EV is a plant exosome or a plant microvesicle. In some ~~embodiment~~examples, the plurality of PMPs further includes a pest repellent.

In one aspect, the disclosure provides a pest control composition comprising a plurality of PMPs, wherein each of the plurality of PMPs comprises a heterologous pesticidal agent and wherein the composition is formulated for delivery to a plant or a plant pest. In another ~~aspect~~example, the disclosure features a pest control composition including a plurality of PMPs, wherein each of the plurality of PMPs includes a heterologous pesticidal agent and wherein the composition is formulated for delivery to a plant or a plant pest.

In some ~~embodiment~~examples, the heterologous pesticidal agent is an herbicidal agent, an antibacterial agent, an antifungal agent, an insecticidal agent, a molluscicidal agent, or a nematicidal agent.

In some ~~embodiment~~examples, the herbicidal agent is doxorubicin. In other ~~embodiment~~examples, the herbicidal agent is glufosinate, glyphosate, propaquizafop, metamitron, metazachlor, pendimethalin, flufenacet, diflufenican, clomazone, nicosulfuron, mesotrione, pinoxaden, sulcotrione, prosulfocarb, sulfentrazone, bifenox, quinmerac, triallate, terbuthylazine, atrazine, oxyfluorfen, diuron, trifluralin, or chlorotoluron.

In some ~~embodiment~~examples, the antibacterial agent is doxorubicin. In some ~~embodiment~~examples, the antibacterial agent is an antibiotic. In some ~~embodiment~~examples, the antibiotic is vancomycin. In other ~~embodiment~~examples, the antibiotic is a penicillin, a cephalosporin, a tetracycline, a macrolide, a sulfonamide, vancomycin, polymixin, gramicidin, chloramphenicol, clindamycin, spectinomycin, ciprofloxacin, isoniazid, rifampicin, pyrazinamide, ethambutol, myambutol, or streptomycin. In some ~~embodiment~~examples, the antifungal agent is azoxystrobin, mancozeb, prothioconazole, folpet, tebuconazole, difenoconazole, captan, bupirimate, or fosetyl-Al. In some ~~embodiment~~examples, the insecticidal agent is a chloronicotinyl, a neonicotinoid, a carbamate, an organophosphate, a pyrethroid, an oxadiazine, a spinosyn, a cyclodiene, an organochlorine, a fiprole, a mectin, a diacylhydrazine, a benzoylurea, an organotin, a pyrrole, a dinitroterpenol, a METI, a tetronic acid, a tetramic acid, or a pthalamide. In some ~~embodiment~~examples, the heterologous pesticidal agent is a small molecule, a nucleic acid, or a polypeptide. In some ~~embodiment~~examples, the small molecule is an antibiotic or a secondary metabolite. In some ~~embodiment~~examples, the nucleic acid is an inhibitory RNA. In some ~~embodiment~~examples, the heterologous pesticidal agent is encapsulated by each of the plurality of PMPs; embedded on the surface of each of the plurality of PMPs; or conjugated to the surface of each of the plurality of PMPs.

In some ~~embodiment~~examples, each of the plurality of PMPs further includes a pest repellent. In some ~~embodiment~~examples, each of the plurality of PMPs further includes an additional heterologous pesticidal agent.

In some ~~embodiment~~examples, the plant pest is a bacterium or a fungus. In some ~~embodiment~~examples, the bacterium is a *Pseudomonas* species, e.g., *Pseudomonas aeruginosa* or *Pseudomonas syringae.* In some ~~embodiment~~examples, the fungus is a *Sclerotinia* species, a *Botrytis* species, an *Aspergillus* species, a *Fusarium* species, or a *Penicillium* species. In other ~~embodiment~~examples, the plant pest is an insect, e.g. an aphid or a lepidopteran; a mollusk; or a nematode, e.g., a corn root-knot nematode.

In some ~~embodiment~~examples, the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C. In some ~~embodiment~~examples, the PMPs are stable for at least 24 hours, 48 hours, seven days, or 30 days at 4°C. In other ~~embodiment~~examples, the PMPs are stable at a temperature of at least 20°C, 24°C, or 37°C.

In some ~~embodiment~~examples, the plurality of PMPs in the composition is at a concentration effective to decrease the fitness of a plant pest.

In some ~~embodiment~~examples, the plurality of PMPs in the composition is at a concentration of at least least 0.01 ng, 0.1 ng, 1 ng, 2 ng, 3 ng, 4 ng, 5 ng, 10 ng, 50 ng, 100 ng, 250 ng, 500 ng, 750 ng, 1 µg, 10 µg, 50 µg, 100 µg, or 250 µg PMP protein/mL.

In some ~~embodiment~~examples, the composition includes an agriculturally acceptable carrier; formulated to stabilize the PMPs; or formulated as a liquid, a solid, an aerosol, a paste, a gel, or a gas composition.

In some ~~embodiment~~examples, the composition includes at least 5% PMPs.

In one aspect, the disclosure provides a pest control composition comprising a plurality of PMPs, wherein the PMPs are isolated from a plant by a process which comprises the steps of: (a) providing an initial sample from a plant, or a part thereof, wherein the plant or part thereof comprises EVs; (b) isolating a crude PMP fraction from the initial sample, wherein the crude PMP fraction has a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the initial sample; (c) purifying the crude PMP fraction, thereby producing a plurality of pure PMPs, wherein the plurality of pure PMPs have a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the crude EV fraction; (d) loading the plurality of pure PMPs with a pest control agent; and (e) formulating the PMPs of step (d) for delivery to a plant or a plant pest. In another ~~aspect~~example, the disclosure features a pest control composition including a plurality of PMPs, wherein the PMPs are isolated from a plant by a process which includes the steps of (a) providing an initial sample from a plant, or a part thereof, wherein the plant or part thereof includes EVs; (b) isolating a crude PMP fraction from the initial sample, wherein the crude PMP fraction has a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the initial sample; (c) purifying the crude PMP fraction, thereby producing a plurality of pure PMPs, wherein the plurality of pure PMPs have a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the crude EV fraction; (d) loading the plurality of pure PMPs with a pest control agent; and (e) formulating the PMPs of step (d) for delivery to a plant or a plant pest.

In another aspect, the disclosure provides a plant comprising the pest control composition disclosed herein. In another ~~aspect~~example, the disclosure features a plant including any one of the pest control compositions provided herein.

In another aspect, the disclosure provides a plant pest comprising the pest control composition disclosed herein. In yet another ~~aspect~~example, the disclosure features a plant pest including any one of the pest control compositions provided herein.

In another aspect, the disclosure provides a method of delivering a pest control composition to a plant comprising contacting the plant with the composition disclosed herein. In still another ~~aspect~~example, the disclosure features a method of delivering a pest control composition to a plant including contacting the plant with any one of the compositions described herein.

In yet another aspect, the disclosure provides a method of increasing the fitness of a plant, the method comprising delivering to the plant the composition disclosed herein, wherein the method increases the fitness of the plant relative to an untreated plant. And in still another ~~aspect~~example, the disclosure features a method of increasing the fitness of a plant, the method including delivering to the plant any one of the compositions described herein, wherein the method increases the fitness of the plant relative to an untreated plant.

In some ~~embodiment~~examples, the plant has an infestation by a plant pest. In some ~~embodiment~~examples, the method decreases the infestation relative to the infestation in an untreated plant. In some ~~embodiment~~examples, the method substantially eliminates the infestation relative to the infestation in an untreated plant.

In some ~~embodiment~~examples, the plant is susceptible to infestation by a plant pest. In some ~~embodiment~~examples, the method decreases the likelihood of infestation in the plant relative to the likelihood of infestation in an untreated plant.

In some ~~embodiment~~examples, the plant pest is a bacterium, e.g., a *Pseudomonas* species; or a fungus, e.g., a *Sclerotinia* species, a *Botrytis* species, an *Aspergillus* species, a *Fusarium* species, or a *Penicillium* species.

In other ~~embodiment~~examples, the plant pest is an insect, e.g., an aphid or a lepidopteran; a mollusk; or a nematode, e.g., a corn root-knot nematode.

In some ~~embodiment~~examples, the pest control composition is delivered as a liquid, a solid, an aerosol, a paste, a gel, or a gas.

In one aspect, the disclosure provides a method of delivering a pest control composition to a plant pest comprising contacting the plant pest with the composition disclosed herein. In another ~~aspect~~example, the disclosure features a method of delivering a pest control composition to a plant pest including contacting the plant pest with any one of the compositions described herein.

In another aspect, the disclosure provides a method of decreasing the fitness of a plant pest, the method comprising delivering to the plant pest the composition disclosed herein, wherein the method decreases the fitness of the plant pest relative to an untreated plant pest. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of a plant pest, the method including delivering to the plant pest any one of the compositions described herein, wherein the method decreases the fitness of the plant pest relative to an untreated plant pest.

In some ~~embodiment~~examples, the method includes delivering the composition to at least one habitat where the plant pest grows, lives, reproduces, feeds, or infests. In some ~~embodiment~~examples, the composition is delivered as a plant pest comestible composition for ingestion by the plant pest.

In some ~~embodiment~~examples, the plant pest is a bacterium or a fungus. In other ~~embodiment~~examples, the plant pest is an insect, e.g., an aphid or a lepidopteran; a mollusk; or a nematode, e.g., a corn root-knot nematode. In some ~~embodiment~~examples, the composition is delivered as a liquid, a solid, an aerosol, a paste, a gel, or a gas.

In one aspect, the disclosure provides a method of treating a plant having a fungal infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs. In another ~~aspect~~example, the disclosure features a method of treating a plant having a fungal infection, wherein the method includes delivering to the plant a pest control composition including a plurality of PMPs.

In another aspect, the disclosure provides a method of treating a plant having a fungal infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an antifungal agent. In still another ~~aspect~~example, the disclosure features a method of treating a plant having a fungal infection, wherein the method includes delivering to the plant a pest control composition including a plurality of PMPs, and wherein each of the plurality of PMPs includes an antifungal agent. In some ~~embodiment~~examples, the antifungal agent is a nucleic acid that inhibits expression of a gene in a fungus that causes the fungal infection. In some ~~embodiment~~examples, the gene is *dcl1* and/or *dcl2*. In some ~~embodiment~~examples, the fungal infection is caused by a fungus belonging to a *Sclerotinia* species, e.g., *Sclerotinia sclerotiorum*; a *Botrytis* species, e.g., *Botrytis cinerea*; an *Aspergillus* species; a *Fusarium* species; or a *Penicillium* species. In some ~~embodiment~~examples, the composition includes a PMP derived from Arabidopsis. In some ~~embodiment~~examples, the method decreases or substantially eliminates the fungal infection.

In one aspect, the disclosure provides a method of treating a plant having a bacterial infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs. In another ~~aspect~~example, the disclosure features a method of treating a plant having a bacterial infection, wherein the method includes delivering to the plant a pest control composition including a plurality of PMPs.

In another aspect, the disclosure provides a method of treating a plant having a bacterial infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an antibacterial agent. In still another ~~aspect~~example, the disclosure features a method of treating a plant having a bacterial infection, wherein the method includes delivering to the plant a pest control composition including a plurality of PMPs, and wherein each of the plurality of PMPs includes an antibacterial agent. In some ~~embodiment~~examples, the antibacterial agent is doxorubicin. In some ~~embodiment~~examples, the bacterial infection is caused by a bacterium belonging to a *Pseudomonas* species, e.g., *Pseudomonas syringae*. In some ~~embodiment~~examples, the composition includes a PMP derived from Arabidopsis. In some ~~embodiment~~examples, the method decreases or substantially eliminates the bacterial infection.

In one aspect, the disclosure provides a method of decreasing the fitness of an insect plant pest, wherein the method comprises delivering to the insect plant pest a pest control composition comprising a plurality of PMPs. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of an insect plant pest, wherein the method includes delivering to the insect plant pest a pest control composition including a plurality of PMPs.

In another aspect, the disclosure provides a method of decreasing the fitness of an insect plant pest, wherein the method comprises delivering to the insect plant pest a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an insecticidal agent. In yet another ~~aspect~~example, the disclosure features a method of decreasing the fitness of an insect plant pest, wherein the method includes delivering to the insect plant pest a pest control composition including a plurality of PMPs, and wherein each of the plurality of PMPs includes an insecticidal agent. In some ~~embodiment~~examples, the insecticidal agent is a peptide nucleic acid.

In some ~~embodiment~~examples, the insect plant pest is an aphid. In some ~~embodiment~~examples, the insect plant pest is a lepidopteran, e.g., *Spodoptera frugiperda*. In some ~~embodiment~~examples, the method decreases the fitness of the insect plant pest relative to an untreated insect plant pest.

In one aspect, the disclosure provides a method of decreasing the fitness of a nematode plant pest, wherein the method comprises delivering to the nematode plant pest a pest control composition comprising a plurality of PMPs. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of a nematode plant pest, wherein the method includes delivering to the nematode plant pest a pest control composition including a plurality of PMPs.

In another aspect, the disclosure provides a method of decreasing the fitness of a nematode plant pest, wherein the method comprises delivering to the nematode plant pest a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises a nematicidal agent. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of a nematode plant pest, wherein the method includes delivering to the nematode plant pest a pest control composition including a plurality of PMPs, and wherein each of the plurality of PMPs includes a nematicidal agent.

In some ~~embodiment~~examples, the nematicidal agent is a peptide, e.g., Mi-NLP-15b. In some ~~embodiment~~examples, the nematode plant pest is a corn root-knot nematode. In some ~~embodiment~~examples, the method decreases the fitness of the nematode plant pest relative to an untreated nematode plant pest.

In one aspect, the disclosure provides a method of decreasing the fitness of a weed, wherein the method comprises delivering to the weed a pest control composition comprising a plurality of PMPs. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of a weed, wherein the method includes delivering to the weed a pest control composition including a plurality of PMPs.

In another aspect, the disclosure provides a method of decreasing the fitness of a weed, wherein the method comprises delivering to the weed a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an herbicidal agent. In another ~~aspect~~example, the disclosure features a method of decreasing the fitness of a weed, wherein the method includes delivering to the weed a pest control composition including a plurality of PMPs, and wherein each of the plurality of PMPs includes an herbicidal agent. In some ~~embodiment~~examples, the method decreases the fitness of the weed relative to an untreated weed. Other features and advantages of the ~~invention~~disclosure will be apparent from the following Detailed Description and the Claims.

Definitions

As used herein, the term “pest control composition” refers to a biopesticide or biorepellent composition that includes a plurality of plant messenger (PMP) packs. Each of the plurality of PMPs may include a pesticidal agent, e.g., a heterologous pesticidal agent.

As used herein, the term “biopesticide composition” refers to a pesticidal composition that includes a plurality of plant messenger (PMP) packs.

As used herein, the term “biorepellent composition” refers to a pest repellent composition that includes a plurality of plant messenger (PMP) packs.

As used herein, “delivering” or “contacting” refers to applying to a plant or plant pest, a pest control (e.g., biopesticide or biorepellent) composition either directly on the plant or plant pest, or adjacent to the plant or plant pest, in a region where the composition is effective to alter the fitness of the plant or plant pest. In methods where the composition is directly contacted with a plant, the composition may be contacted with the entire plant or with only a portion of the plant.

As used herein, “decreasing the fitness of a plant pest” refers to any disruption to pest physiology, or any activity carried out by said pest, as a consequence of administration of a pest control (e.g., biopesticide or biorepellent) composition described herein, including, but not limited to, any one or more of the following desired effects: (1) decreasing a population of a pest by about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 99%, 100% or more; (2) decreasing the reproductive rate of a pest (e.g., insect) by about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 99%, 100% or more; (3) decreasing the mobility of a pest by about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 99%, 100% or more; (4) decreasing the body weight of a pest by about 10%, 20%, 30%, 40%, 50%, 60%,

at least 50% pure, at least 60% pure, at least 70% pure, at least 80% pure, at least 90% pure, at least 99% pure, or 100% pure) relative to the one or more contaminants or undesired components from the source plant as measured by weight (w/w), spectral imaging (% transmittance), or conductivity (S/m).

PMPs may optionally include additional agents, such as heterologous functional agents, e.g., pesticidal agents, fertilizing agents, plant-modifying agents, therapeutic agents, polynucleotides, polypeptides, or small molecules. The PMPs can carry or associate with additional agents (e.g., heterologous functional agents) in a variety of ways to enable delivery of the agent to a target plant, e.g., by encapsulating the agent, incorporation of the agent in the lipid bilayer structure, or association of the agent (e.g., by conjugation) with the surface of the lipid bilayer structure. Heterologous functional agents can be incorporated into the PMPs either in vivo (e.g., in planta) or in vitro (e.g., in tissue culture, in cell culture, or synthetically incorporated).

As used herein, the term “stable PMP composition” (e.g., a composition including loaded or non-loaded PMPs) refers to a PMP composition that over a period of time (e.g., at least 24 hours, at least 48 hours, at least 1 week, at least 2 weeks, at least 3 weeks, at least 4 weeks, at least 30 days, at least 60 days, or at least 90 days) retains at least 5% (e.g., at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or 100%) of the inital number of PMPs (e.g., PMPs per mL of solution) relative to the number of PMPs in the PMP composition (e.g., at the time of production or formulation) optionally at a defined temperature range (e.g., a temperature of at least 24°C (e.g., at least 24°C, 25°C, 26°C, 27°C, 28°C, 29°C, or 30°C), at least 20°C (e.g., at least 20°C, 21°C, 22°C, or 23°C), at least 4°C (e.g., at least 5°C, 10°C, or 15°C), at least -20°C (e.g., at least -20°C, -15°C, -10°C, -5°C, or 0°C), or -80°C (e.g., at least -80°C, -70°C, -60°C, -50°C, -40°C, or -30°C)); or retains at least 5% (e.g., at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or 100%) of its activity (e.g., pesticidal and/or repellent activity) relative to the initial activity of the PMP (e.g., at the time of production or formulation) optionally at a defined temperature range (e.g., a temperature of at least 24°C (e.g., at least 24°C, 25°C, 26°C, 27°C, 28°C, 29°C, or 30°C), at least 20°C (e.g., at least 20°C, 21°C, 22°C, or 23°C), at least 4°C (e.g., at least 5°C, 10°C, or 15°C), at least -20°C (e.g., at least -20°C, -15°C, -10°C, -5°C, or 0°C), or -80°C (e.g., at least -80°C, -70°C, -60°C, -50°C, -40°C, or -30°C)).

As used herein, the term “untreated” refers to a plant or plant pest that has not been contacted with or delivered a pest control (e.g., biopesticide or biorepellent) composition, including a separate plant that has not been delivered the pest control (e.g., biopesticide or biorepellent) composition, the same plant undergoing treatment assessed at a time point prior to delivery of the pest control (e.g., biopesticide or biorepellent) compositions, or the same plant undergoing treatment assessed at an untreated part of the plant.

As used herein, the term “juice sac” or “juice vesicle” refers to a juice-containing membrane-bound component of the endocarp (carpel) of a hesperidium, e.g., a citrus fruit. In some ~~aspect~~example~~s~~, the juice sacs are separated from other portions of the fruit, e.g., the rind (exocarp or flavedo), the inner rind (mesocarp, albedo, or pith), the central column (placenta), the segment walls, or the seeds. In some ~~aspect~~example~~s~~, the juice sacs are juice sacs of a grapefruit, a lemon, a lime, or an orange.

BRIEF DESCRIPTION OF THE DRAWINGS

What is claimed is:

Claims

1. A pest control composition comprising a plurality of PMPs, wherein each of the plurality of PMPs comprises a heterologous pesticidal agent and wherein the composition is formulated for delivery to a plant or a plant pest.

2. The pest control composition of claim 1, wherein the heterologous pesticidal agent is an herbicidal agent, an antibacterial agent, an antifungal agent, an insecticidal agent, a molluscicidal agent, or a nematicidal agent.

3. The pest control composition of claim 2, wherein the herbicidal agent is doxorubicin.

4. The pest control composition of claim 2, wherein the herbicidal agent is glufosinate, glyphosate, propaquizafop, metamitron, metazachlor, pendimethalin, flufenacet, diflufenican, clomazone, nicosulfuron, mesotrione, pinoxaden, sulcotrione, prosulfocarb, sulfentrazone, bifenox, quinmerac, triallate, terbuthylazine, atrazine, oxyfluorfen, diuron, trifluralin, or chlorotoluron.

5. The pest control composition of claim 2, wherein the antibacterial agent is doxorubicin.

6. The pest control composition of claim 2, wherein the antibacterial agent is an antibiotic.

7. The pest control composition of claim 6, wherein the antibiotic is vancomycin.

8. The pest control composition of claim 6, wherein the antibiotic is a penicillin, a cephalosporin, a tetracycline, a macrolide, a sulfonamide, vancomycin, polymixin, gramicidin, chloramphenicol, clindamycin, spectinomycin, ciprofloxacin, isoniazid, rifampicin, pyrazinamide, ethambutol, myambutol, or streptomycin.

9. The pest control composition of claim 2, wherein the antifungal agent is azoxystrobin, mancozeb, prothioconazole, folpet, tebuconazole, difenoconazole, captan, bupirimate, or fosetyl-Al.

10. The pest control composition of claim 2, wherein the insecticidal agent is a chloronicotinyl, a neonicotinoid, a carbamate, an organophosphate, a pyrethroid, an oxadiazine, a spinosyn, a cyclodiene, an organochlorine, a fiprole, a mectin, a diacylhydrazine, a benzoylurea, an organotin, a pyrrole, a dinitroterpenol, a METI, a tetronic acid, a tetramic acid, or a pthalamide.

11. The pest control composition of claim 1, wherein the heterologous pesticidal agent is a small molecule, a nucleic acid, or a polypeptide.

12. The pest control composition of claim 11, wherein the small molecule is an antibiotic or a secondary metabolite.

13. The pest control composition of claim 11, wherein the nucleic acid is an inhibitory RNA.

14. The pest control composition of claim 1, wherein the heterologous pesticidal agent is encapsulated by each of the plurality of PMPs.

15. The pest control composition of claim 1, wherein the heterologous pesticidal agent is embedded on the surface of each of the plurality of PMPs.

16. The pest control composition of claim 1, wherein the heterologous pesticidal agent is conjugated to the surface of each of the plurality of PMPs.

17. The pest control composition of claim 1, wherein each of the plurality of PMPs further comprises a pest repellent.

18. The pest control composition of claim 1, wherein each of the plurality of PMPs further comprises an additional heterologous pesticidal agent.

19. The pest control composition of claim 1, wherein the plant pest is a bacterium or a fungus.

20. The pest control composition of claim 19, wherein the bacterium is a *Pseudomonas* species.

21. The pest control composition of claim 20, wherein the *Pseudomonas* species is *Pseudomonas aeruginosa* or *Pseudomonas syringae.*

22. The pest control composition~~method~~ of claim 19, wherein the fungus is a *Sclerotinia* species, a *Botrytis* species, an *Aspergillus* species, a *Fusarium* species, or a *Penicillium* species.

23. The pest control composition of claim 1, wherein the plant pest is an insect, a mollusk, or a nematode.

24. The pest control composition of claim 23, wherein the insect is an aphid or a lepidopteran.

25. The pest control composition of claim 23, wherein the nematode is a corn root-knot nematode.

26. The pest control composition of claim 1, wherein the composition is stable for at least one day at room temperature, and/or stable for at least one week at 4°C.

27. The pest control composition of claim 1, wherein the PMPs are stable for at least 24 hours, 48 hours, seven days, or 30 days at 4°C.

28. The pest control composition of claim 27, wherein the PMPs are stable at a temperature of at least 20°C, 24°C, or 37°C.

29. The pest control composition of claim 1, wherein the plurality of PMPs in the composition is at a concentration effective to decrease the fitness of a plant pest.

30. The pest control composition of claim 1, wherein the plurality of PMPs in the composition is at a concentration of at least 1, 10, 50, 100, or 250 µg PMP protein/mL.

31. The pest control composition of claim 1, wherein the composition comprises an agriculturally acceptable carrier.

32. The pest control composition of claim 1 wherein the composition is formulated to stabilize the PMPs.

33. The pest control composition of claim 1, wherein the composition is formulated as a liquid, a solid, an aerosol, a paste, a gel, or a gas composition.

34. The pest control composition of claim 1, wherein the composition comprises at least 5% PMPs.

35. A pest control composition comprising a plurality of PMPs, wherein the PMPs are isolated from a plant by a process which comprises the steps of:

(a) providing an initial sample from a plant, or a part thereof, wherein the plant or part thereof comprises EVs;

(b) isolating a crude PMP fraction from the initial sample, wherein the crude PMP fraction has a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the initial sample;

(c) purifying the crude PMP fraction, thereby producing a plurality of pure PMPs, wherein the plurality of pure PMPs have a decreased level of at least one contaminant or undesired component from the plant or part thereof relative to the level in the crude EV fraction;

(d) loading the plurality of pure PMPs with a pest control agent; and

(e) formulating the PMPs of step (d) for delivery to a plant or a plant pest.

36. A plant comprising the pest control composition of claim 1.

37. A plant pest comprising the pest control composition of claim 1.

38. A method of delivering a pest control composition to a plant comprising contacting the plant with the composition of claim 1.

39. A method of increasing the fitness of a plant, the method comprising delivering to the plant the composition of claim 1, wherein the method increases the fitness of the plant relative to an untreated plant.

40. The method of claim 38, wherein the plant has an infestation by a plant pest.

41. The method of claim 40, wherein the method decreases the infestation relative to the infestation in an untreated plant.

42. The method of claim 40, wherein the method substantially eliminates the infestation relative to the infestation in an untreated plant.

43. The method of claim 38, wherein the plant is susceptible to infestation by a plant pest.

44. The method of claim 43, wherein the method decreases the likelihood of infestation in the plant relative to the likelihood of infestation in an untreated plant.

45. The method of claim 40, wherein the plant pest is a bacterium or a fungus.

46. The method of claim 45, wherein the bacterium is a *Pseudomonas* species.

47. The method of claim 45, wherein the fungus is a *Sclerotinia* species, a *Botrytis* species, an *Aspergillus* species, a *Fusarium* species, or a *Penicillium* species.

48. The method of claim 40, wherein the plant pest is an insect, a mollusk, or a nematode.

49. The method of claim 48, wherein the insect is an aphid or a lepidopteran.

50. The method of claim 48, wherein the nematode is a corn root-knot nematode.

51. The method of claim 38, wherein the pest control composition is delivered as a liquid, a solid, an aerosol, a paste, a gel, or a gas.

52. A method of delivering a pest control composition to a plant pest comprising contacting the plant pest with the composition of claim 1.

53. A method of decreasing the fitness of a plant pest, the method comprising delivering to the plant pest the composition of claim 1, wherein the method decreases the fitness of the plant pest relative to an untreated plant pest.

54. The method of claim 52, wherein the method comprises delivering the composition to at least one habitat where the plant pest grows, lives, reproduces, feeds, or infests.

55. The method of claim 52, wherein the composition is delivered as a plant pest comestible composition for ingestion by the plant pest.

56. The method of claim 52, wherein the plant pest is a bacterium or a fungus.

57. The method of claim 52, wherein the plant pest is an insect, a mollusk, or a nematode.

58. The method of claim 57, wherein the insect is an aphid or a lepidopteran.

59. The method of claim 57, wherein the nematode is a corn root-knot nematode.

60. The method of claim 52, wherein the composition is delivered as a liquid, a solid, an aerosol, a paste, a gel, or a gas.

61. A method of treating a plant having a fungal infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs.

62. A method of treating a plant having a fungal infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an antifungal agent.

63. The method of claim 62, wherein the antifungal agent is a nucleic acid that inhibits expression of a gene in a fungus that causes the fungal infection.

64. The method of claim 63, wherein the gene is *dcl1* and/or *dcl2*.

65. The method of claim 61, wherein the fungal infection is caused by a fungus belonging to a *Sclerotinia* species, a *Botrytis* species, an *Aspergillus* species, a *Fusarium* species, or a *Penicillium* species.

66. The method of claim 65, wherein the *Sclerotinia* species is *Sclerotinia sclerotiorum*.

67. The method of claim 65, wherein the *Botrytis* species is *Botrytis cinerea*.

68. The method of claim 61, wherein the composition comprises a PMP derived from Arabidopsis.

69. The method of claim 61, wherein the method decreases or substantially eliminates the fungal infection.

70. A method of treating a plant having a bacterial infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs.

71. A method of treating a plant having a bacterial infection, wherein the method comprises delivering to the plant a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an antibacterial agent.

72. The method of claim 71, wherein the antibacterial agent is doxorubicin.

73. The method of claim 70, wherein the bacterial infection is caused by a bacterium belonging to a *Pseudomonas* spp.

74. The method of claim 73, wherein the *Pseudomonas* spp. is *Pseudomonas syringae*.

75. The method of claim 70, wherein the composition comprises a PMP derived from Arabidopsis.

76. The method of claim 70, wherein the method decreases or substantially eliminates the bacterial infection.

77. A method of decreasing the fitness of an insect plant pest, wherein the method comprises delivering to the insect plant pest a pest control composition comprising a plurality of PMPs.

78. A method of decreasing the fitness of an insect plant pest, wherein the method comprises delivering to the insect plant pest a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an insecticidal agent.

79. The method of claim 78, where in the insecticidal agent is a peptide nucleic acid.

80. The method of claim 77, wherein the insect plant pest is an aphid.

81. The method of claim 77, wherein the insect plant pest is a lepidopteran.

82. The method of claim 81, wherein the lepidopteran is *Spodoptera frugiperda*.

83. The method of claim 77, wherein the method decreases the fitness of the insect plant pest relative to an untreated insect plant pest.

84. A method of decreasing the fitness of a nematode plant pest, wherein the method comprises delivering to the nematode plant pest a pest control composition comprising a plurality of PMPs.

85. A method of decreasing the fitness of a nematode plant pest, wherein the method comprises delivering to the nematode plant pest a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises a nematicidal agent.

86. The method of claim 85, wherein the nematicidal agent is a peptide.

87. The method of claim 86, wherein the peptide is Mi-NLP-15b.

88. The method of claim 84, wherein the nematode plant pest is a corn root-knot nematode.

89. The method of claim 84, wherein the method decreases the fitness of the nematode plant pest relative to an untreated nematode plant pest.

90. A method of decreasing the fitness of a weed, wherein the method comprises delivering to the weed a pest control composition comprising a plurality of PMPs.

91. A method of decreasing the fitness of a weed, wherein the method comprises delivering to the weed a pest control composition comprising a plurality of PMPs, and wherein each of the plurality of PMPs comprises an herbicidal agent.

92. The method of claim 90 or 91, wherein the method decreases the fitness of the weed relative to an untreated weed.