

## CONTROLLED RELEASE TRUNK IMPLANT FORMULATION AND TRUNK IMPLANT COMPRISING THE SAME

### FIELD OF INVENTION

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The present invention relates to a controlled release trunk formulation and a trunk implant comprising the same. The invention further relates to a method of producing the trunk implant and a method of applying the trunk implant to tree trunk.

### 10 BACKGROUND

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Bagworms and nettle caterpillars are a common problem in the cultivation of oil palm, coconut and other palm trees. Other (or similar) pests also cause problems for other monocot plants and trees, which also includes screwpines (Pandaceae), bananas (Musaceae), *Yucca*, *Aloe*, *Dracaena*, and *Cordyline*.

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In order to deal with such pests, the conventional method is to prepare a formulation for injection at the site of the monocot tree and then inject this into the vascular system of the monocot tree using an injector gun. However, this approach is laborious and comes with risks for the people preparing and injecting the pesticide. For example, the pesticide is generally supplied in a powdered form that needs to be dissolved in a suitable solvent (potentially with further excipients) on-site to prepare the injectable solution for application to the monocot trees. As will be appreciated, such on-site preparation may lead to the preparation of a sub-optimal dose of the pesticide due to incomplete dissolution of the pesticide (or the addition of too much pesticide may lead to a potential over-dosing of the tree). In addition, the injection gun is subject to frequent clogging, which requires time and manual manipulation to clear. As will be appreciated, the need to prepare the pesticide formulation, add it to an injector gun and clear blocks from the gun substantially increases the exposure of the person conducting the treatment of the monocot trees, potentially risking adverse health effects. Finally, the injections need to be repeated frequently because the active substance is released immediately into the vascular system of the plant. Therefore, the labour costs and risk of exposure is substantially increased.

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Thus, there is a need for improved formulations for the delivery of plant treatment agents, including pesticides, to plants, particularly trees including, but not limited to monocot trees. Monocot trees present unique challenges due to their distributed vascular system, which means that the vascular system does not generally include substantial quantities of water.

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**SUMMARY OF INVENTION**

This invention is directed at the control of leaf eating pests (e.g. bagworms, caterpillars and Rhinoceros beetles) as well as trunk-pests (e.g. beetles such as Red Palm Weevil), in trees including palm trees, but not limited to, monocot trees. The invention provides a controlled release trunk implant comprising an active ingredient such as a plant treatment agent, in a solid form, to be applied into holes created within the trunk of a tree, palm tree or a monocot tree, for eradicating and/or controlling pest in a tree and/or treating the tree. The controlled release trunk implant is formed by homogeneously mixing a trunk implant formulation comprising an active ingredient, such as a plant treatment agent into a biodegradable, water soluble, polymeric matrix with a binder, engineered to respond to environmental stimulus (e.g. presence of moisture) present within the trunk hole, to dose the optimal amount of plant treatment agent into the trunk. Conventional means use a trunk injection method that requires using a driller and an injector gun to deliver an instantaneous release form of a suitable active ingredient such as acephate or methamidophos, in an aqueous solution form.

In a first aspect of the invention, a controlled release trunk implant formulation for eradicating and/or controlling pest in a tree and/or treating the tree is provided. The trunk implant formulation comprises at least one water soluble polymer present in an amount of from 5 to 60 wt%; at least one plant treatment agent present in an amount of from 1 to 90 wt%; at least one binder present in an amount of from 4 to 60 wt%; and one or more excipients.

In one embodiment, the at least one water soluble polymer is present in an amount of from 7.5 to 40 wt%; the at least one plant treatment agent is present in an amount of from 30 to 85 wt%; the at least one binder is present in an amount of from 10 to 40 wt%; and the one or more excipients is present in the remaining amount.

In a second aspect of the invention, a controlled release trunk implant comprising the trunk implant formation of the present invention is provided. In various embodiments, the trunk implant is provided in the form of a tablet, pellet, block, rod, or granulated particles.

In one embodiment, the controlled release trunk implant comprises at least one water soluble polymer present in an amount of from 5 to 60 wt%; at least one plant treatment agent present in an amount of from 1 to 90 wt%; at least one binder present in an amount of from 0.01 to 10 wt%; and one or more excipients; and wherein the trunk implant is provided in the form of a tablet, pellet, block, rod, or granulated particles.

In one embodiment, the at least one water soluble polymer comprises a first polymer and a second polymer, wherein the first polymer is present in an amount of from 50 to 99 wt% and the

second polymer is present in an amount of from 1 to 50 wt% based on the total amount of water soluble polymer present in the trunk implant formulation.

In various embodiments, the controlled release trunk implant is prepared to release the at least one plant treatment agent over a period from 5 to 90 days, preferably 10 to 70 days.

In a third aspect of the invention, a method of producing a controlled release trunk implant for eradicating and/or controlling pest in a tree and/or treating the tree is provided. The method comprising:

- 10 (a) providing a trunk implant formulation comprising:
  - at least one water soluble polymer;
  - at least one plant treatment agent;
  - at least one binder; and
  - one or more excipients; and
- 15 (b) extruding the mixture at room temperature; and
- (c) shaping and/or cutting the extrudate to form a controlled release trunk implant.

In various embodiments, the at least one water soluble polymer is selected from the group consisting of alginic acid, carrageenan, cellulose ether, chitosan, dextran, gelatin, hyaluronic acid, pectins, polyacrylamide, polyacrylic acid, polyvinyl alcohol, polyvinylpyrrolidone, polysaccharide, pullulan, starch, salts thereof, derivatives thereof, copolymers thereof and blends thereof.

In various embodiments, the at least one plant treatment agent is selected from the group consisting of pesticides, insecticides, biocides, fungicides, bacteria, enzymes and nutrients.

In various embodiments, the at least one binder is selected from the group consisting of substances with OH moiety, polar solvents or mixtures thereof.

In one embodiment, the method further comprises drying the controlled release trunk implant to remove the binder from the controlled release trunk implant.

In a fourth aspect of the invention, a method of eradicating and/or controlling pest in a tree and/or treating the tree is provided. The method comprises inserting a controlled release trunk implant of the present invention into a hole drilled into a trunk of a tree to provide a continuous release of the plant treatment agent to the tree; and optionally sealing the hole; wherein the hole is moist on the inner region of the hole.

In one embodiment, the controlled release trunk implant is configured to provide a continuous release of the plant treatment agent for 30 to 90 days.

## DRAWINGS

The above and other features and advantages of the present invention will be apparent from a reading of the following detailed description and from the accompanying drawings.

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Figure 1 is a chart showing the release profile of the controlled release trunk implant formulation of the present invention.

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Figure 2 is a chart showing the acephate trunk implant release profile obtained from the tests described herein below in Example 1.

Figure 3 is a chart showing the acephate trunk implant release profile and acephate residual content in oil palm leaves correlation studies.

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Figure 4 is a chart showing the acephate trunk implant bagworm live larvae count and acephate residual content in oil palm leaves correlation studies.

## DESCRIPTION

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It has been surprisingly found that a controlled release trunk implant formulation can be formed that can release a plant treatment agent, for example pesticide over a sustained period of time when placed into the moist, but not wet, environment of the vascular system of a tree including palm trees, but not limited to, monocot tree.

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The term “tree” as used herein is defined as a woody perennial plant, typically having a single stem or trunk growing to a considerable height and bearing lateral branches, fronds or leaves at some distance from the ground. A tree produces leaves and flowers, provide habitat and shade, stabilizing soil, maintaining biodiversity and helping with climate control.

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When used herein, the term “monocot tree” refers to large monocot plants that undergo anomalous secondary growth due to their lack of vascular cambium. Examples of monocot trees include, but are not limited to palms (*Arecaceae*), screwpines (*Pandanaceae*), bananas (*Musaceae*), *Yucca*, *Aloe*, *Dracaena*, and *Cordyline*.

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In a first aspect of the present invention, a controlled release trunk implant formulation for eradicating and/or controlling pest in a tree and/or treating the tree is provided. The controlled release trunk implant formulation comprises:

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- at least one water soluble polymer;
- at least one plant treatment agent;
- at least one binder; and
- one or more excipients.

In embodiments herein, the word “comprising” may be interpreted as requiring the features mentioned, but not limiting the presence of other features. Alternatively, the word “comprising” may also relate to the situation where only the components/features listed are intended to be present (e.g. the word “comprising” may be replaced by the phrases “consists of” or “consists essentially of”). It is explicitly contemplated that both the broader and narrower interpretations can be applied to all aspects and embodiments of the present invention. In other words, the word “comprising” and synonyms thereof may be replaced by the phrase “consisting of” or the phrase “consists essentially of” or synonyms thereof and *vice versa*.

- 10 The term “pest” as used herein is intended to relate to any creature that inflicts damage on a monocot tree or palm trees. Examples of such pests include leaf eating pests, leaf sucking pests, trunk boring pests, and wood boring pests. Leaf eating pests include, but are not limited to, caterpillars (e.g. Nettle Caterpillars), bagworms, beetles (e.g. Rhinoceros beetle), cockchafters, and scale insects. Leaf sucking pests include, but are not limited to, thrips, aphids, and mites.
- 15 Trunk boring pests include, but are not limited to, weevils (e.g. red palm weevil), and beetles. Wood boring pests include, but are not limited to, weevils, beetles, termites, and wasps.

When used herein, “water soluble polymer” refers to a polymeric material that is capable to dissolve fully in water when fully immersed therein. In the context of the present invention, the water soluble polymer is one that will swell and dissolve in water. Thus, in the monolithic formulations described herein, the outermost portion/layer of the formulation will be first exposed to water and the polymer within said layer will swell, releasing the embedded active ingredients from the said portion/layer by diffusion. The swelled layer may erode or break down due to a loss in structural integrity, thereby further releasing the embedded active ingredients in the process. This process is repeated until the entire formulation has been consumed. As will be appreciated, the process halts when there is no water and will resume when water is present. Other stimuli such as volume of water will affect the dosage levels (i.e. the amount of active ingredient released at any given time). There is no residue left of the formulation at the end of the treatment period, as all materials will either be absorbed by the plant or biodegrade.

- 30 In one embodiment, the controlled release trunk implant formulation comprises:
- the at least one water soluble polymer present in an amount of from 5 to 60 wt%;
  - the at least one plant treatment agent present in an amount of from 1 to 90 wt%;
  - the at least one binder present in an amount of from 4 to 60 wt%; and
  - 35 one or more excipients present in remaining amount.

- In another embodiment, the controlled release trunk implant formulation comprises:
- the at least one water soluble polymer present in an amount of from 7.5 to 40 wt%;
  - the at least one plant treatment agent present in an amount of from 30 to 85 wt%;
  - 40 the at least one binder present in an amount of from 10 to 40 wt%; and

one or more excipients present in remaining amount.

It will be appreciated that the percentages provided herein refer to minimal and maximal bounds and in the formulation the values are intended to be selected to add up to 100%. However, it will also be appreciated that additional components and excipients or additives may also be present as discussed hereinbelow, each with their own percentage values. Further, the plant treatment agent could contain binders and this should be taken in account as part of the binder content in the formulation. As can be seen, these additional components, excipients and additives may also be incorporated into the formulation without exceeding 100%.

The trunk implant formulation of the present invention is readily formable into any suitable shape and size to form a trunk implant for complete insertion into the trunk of a tree, where release of the plant treatment agent is activated by the presence of moisture in the tree trunk. That is, the plant treatment agent can be released over an extended period of time even if the trunk implant is not subjected to immersion in a stream of liquid water within the vascular system of the tree, but is instead subjected to moist conditions caused by transpiration of water from the roots through the vascular system to the canopy.

It will be appreciated that the trunk implant formulation may be presented as a trunk implant in any suitable shape and form for insertion into a hole bored into the trunk of a tree. For example, in various embodiments, the trunk implant may be in the form of a tablet, pellet, block, cylinder/rod, or granulated particles (or combinations thereof, where it may be desired to mix forms of the trunk implant together to provide tailored release profiles, such as providing granulated particles with blocks to enable an increased initial release of active ingredient provided by the higher surface area (and hence dissolution speed) granulated particles and a longer sustained release phase provided by one or more blocks of the formulation).

Therefore, in accordance with a second aspect of the invention, a controlled release trunk implant comprising a trunk implant formulation of the present invention is provided, wherein the trunk implant is in the form of a tablet, pellet, block, rod, or granulated particles.

In one embodiment, the controlled release trunk implant comprises:

at least one water soluble polymer present in an amount of from 5 to 60 wt%;

at least one plant treatment agent present in an amount of from 1 to 90 wt%;

at least one binder present in an amount of from 0.01 to 10 wt%; and

one or more excipients; and

wherein the trunk implant is provided in the form of a tablet, pellet, block, rod, or granulated particles.

When used herein, the term "controlled release" refers to release of an active ingredient, such as a plant treatment agent(s) from the trunk implant formulation over an extended period of time, following contact with water. The extended period of time may refer to a period of from 5 days to 90 days, or from 10 days to 70 days, or from 15 days to 45 days or from 20 days to 30 days.

5 In various embodiments, the trunk implant is prepared to release the at least one plant treatment agent over a period of 5 to 90 days; 10 to 70 days; 15 to 45 days or 20 to 30 days.

The at least one plant treatment agent may be nutrients or a systemic pesticide selected from one or more of the group consisting of insecticides, biocides, fungicides, bacteria and enzymes.

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When used herein "systemic and translocative pesticide" refers to an active ingredient that can be distributed throughout the trunk and foliage of a monocot tree or palm trees. Suitable systemic and translocative pesticides include, but are not limited to, insecticides, biocides, fungicides, bacteria, and enzymes. In particular embodiments, the at least one pesticide agent  
15 may be a biocide. For example, the biocide may be selected from one or more of the group consisting of herbicides, insecticides, insect growth regulators, nematocides, termiticides, molluscicides, piscicides, avicides, rodenticides, predacides, bactericides, microbicide, spermicides, algicides, nematocides, molluscicides, schistosomacides, larvicides, adulticides, insect repellents, animal repellents, antimicrobials, and fungicides. In particular embodiments  
20 that may be mentioned herein, the biocide may be O,S-Dimethyl N-acetylphosphoramidothioate (acephate).

Any suitable amount of the at least one plant treatment agent may be used in the formulation, provided that it achieves the effect of supplying a sufficient quantity of the active ingredient to  
25 deter or kill pests. For example, the at least one plant treatment agent may be present in an amount of from 30 to 90 wt% based on the total weight of the trunk implant formulation, preferably 50 to 90 wt%. In cases where a binder is present in an amount of from 10 to 40 wt%, the at least one plant treatment agent may be present in an amount of from 55 to 81 wt%. Alternatively, in cases where the binder is present in an amount from 0.01 to less than 10 wt%,  
30 the at least one plant treatment agent may be present in an amount of from 70 to 90 wt%.

The trunk implant formulation of the invention comprises at least one binder that is added to the formulation during manufacture. The binder is selected from the group consisting of substances with OH moiety (for example alcohols, polyols), polar solvents or a mixture thereof. In various  
35 embodiments, the binder may be a mono-alkoxyalcohol, or more particularly, a dialkoxyalcohol, a trialkoxyalcohol, a poly-alkoxyalcohol, water, an aprotic solvent or mixtures thereof. Without wishing to be bound by theory, the binder may help to bind the polymer together into a solid, malleable mass that can be processed into various desired shapes according to the desired dosage form of the formulation. In addition, the binder may also function as a mediator for  
40 controlling the malleability of the polymer matrix, allowing for the room temperature, low

pressure processing of the matrix and also for making the formulation in a variety of forms. The degree of malleability of the polymer matrix may be affected by the percentage of binder within the polymer matrix. The higher the percentage of binder, the more malleable the matrix may become. It will be appreciated that the selection of the binder may depend, in part, on the plant treatment agent that is to be used. A suitable amount of binder in embodiments of the invention may be from 4 to 60 wt%, preferably 10 to 40 wt%, more preferably 10 to 37 wt%, or 10 to 30 wt%, or even more preferably 10.6 to 21 wt% based on the total weight of the trunk implant formulation. As will be appreciated, a binder is essential during the preparation of the trunk implant, but may be removed by drying thereafter. As such, during the preparation of the trunk implant, the binder may be provided in an amount from 4 to 60%, preferably 10 to 40 wt%, more preferably 10 to 25 wt%, and more preferably 10 to 37 wt%, 10 to 30 wt% or even more preferably 10.6 to 21 wt% based on the total weight of the mixture for use in producing the trunk implant. After the binder is removed by drying the trunk implant, a small amount of binder remains and may be in an amount ranging from 0.01 to 10 wt% based on the total weight of the trunk implant formulation in the trunk implant.

When used herein the term "at least one water soluble polymer" is intended to mean that there is one polymer, or two or more (e.g. 2, 3, 4, or 5) polymers used as a blend to form the water soluble polymer component. Any suitable water soluble polymer may be used herein. Examples of suitable water soluble polymers include, but are not limited to, alginic acid, carrageenan, cellulose ether (for example, carboxymethylcellulose, hydroxypropylmethylcellulose), chitosan, dextran, gelatin, hyaluronic acid, pectins, polyacrylamide, polyacrylic acid, polyvinyl alcohol, polysaccharide (for example, maltodextrin, xanthum gum, guar gum), pullulan, starch, salts thereof, derivatives thereof, copolymers thereof and blends thereof.

In cases where there is a blend, the first polymer may be present in an amount of from 50 to 99 wt% and the second polymer is present in an amount of from 1 to 50 wt% based on the total weight of the water soluble polymer present in the trunk implant formulation, more particularly the first polymer may be present in an amount of from 70 to 95 wt% and the second polymer is present in an amount of from 5 to 30 wt%, yet more particularly the first polymer may be present in an amount of from 80 to 85 wt% and the second polymer is present in an amount of from 15 to 20 wt%, still more particularly the first polymer is present in an amount of 82.1 wt% and the second polymer is present in an amount of 17.9 wt%.

In certain embodiments of the invention, the trunk implant formulation may further comprise a crosslinking agent that crosslinks the water soluble polymers. Without wishing to be bound by theory, the crosslinking agent may enhance the controlled release performance of the formulation by attenuating the dissolution rate of the water soluble polymer, thereby affecting the dissolution profile of the polymer, which may in turn affect the release profile of the active ingredient(s). The crosslinking agent selected depends on the polymer(s) in the formulation

that it is desired to crosslink. Examples of crosslinking agents include, but are not limited to, ammonium zirconium carbonate, sodium borate dialdehyde, melamine-formaldehyde, urea-formaldehyde, polyamide-epichlorohydrin, dimethylolurea, a polyfunctional aziridine, methoxymethylmelamine, a melamine-formaldehyde resin prepolymer, a urea-formaldehyde resin prepolymer, calcium salts, barium salts, and combinations thereof (e.g. ammonium zirconium carbonate, sodium borate dialdehyde, and combinations thereof).

It will be appreciated that particular crosslinking agents may be more suitable for certain polymers than others. For example, in some embodiments, a crosslinking agent for methylcellulose may be selected from, but not limited to, organic acids, dimethylolurea, polyfunctional aziridines, stearatochromyl chloride complex, methoxymethylmelamine, melamine-formaldehyde resin prepolymers and urea-formaldehyde resin prepolymers. A crosslinking agent for salts of alginic acid may be selected from, but not limited to, calcium salts and barium salts.

In embodiments of the invention where there are at least two water soluble polymers in the formulation, when a crosslinking agent is present, it may selectively crosslink with one of the two polymers. Of course, in embodiments of the invention when there are more than two polymers (e.g. 3, 4, 5, 6, 7, 8, 9, 10, etc.), it will be appreciated that the crosslinking agent may crosslink with more than one polymer, or that there may be more than one crosslinking agent present that may selectively crosslink some of the polymers present, while leaving at least one polymer uncross-linked. In particular embodiments of the invention that may be mentioned herein, the polymer to be crosslinked (i.e. from the list of first polymers mentioned hereinbefore) may be hydroxypropyl methyl cellulose and the crosslinking agent may be citric acid.

In various embodiments of the invention, the crosslinking agent may be present in an amount of from 0.5 to 20.0 wt% based on the total weight of the trunk implant formulation. For example, in some embodiments, the crosslinking agent may be present in an amount of from 0.75 to 2.0 wt%, preferably around 7.3 wt%.

As noted hereinbefore, the trunk implant formulation may further include one or more additives or excipients. Such additives and excipients include materials such as a crosslinking agents, preservatives, lubricant, defoamers, surfactants, fillers, and colorants.

As the trunk implant formulation and the trunk implant may be stored for a period of time before use, it is important to ensure that the trunk implant formulation and trunk implant remains stable before use. This is particularly important where the active ingredient may otherwise be subject to degradation over time. As such, a preservative may be used to stabilise the trunk implant formulation and the trunk implant for storage in certain embodiments. Preservatives that may be used in the trunk implant formulation include, but are not limited to, sorbic acid and salts

thereof (e.g. sodium, potassium and calcium sorbate), benzoic acid and salts thereof (e.g. sodium, potassium and calcium benzoate), hydroxybenzoate and derivatives thereof, sulphur dioxide, sulphites, nitrites, nitrates, lactic acid, propionic acid, propionates (e.g. sodium, potassium and calcium propionate), ascorbic acid, ascorbates (e.g. sodium, potassium and calcium ascorbate), butylated hydroxytoluene, butylated hydroxyanisole, gallic acid, gallates (e.g. sodium, potassium and calcium gallate), sulfur dioxide, sulphites, o-cophenols, and, more particularly, citric acid. When present, the preservative may be present in an amount of from 0.4 to 2 wt% based on the total weight of the trunk implant formulation. For example, when a binder is present in an amount of from 10 to 40 wt%, the preservative is present in an amount of from 0.4 to 1.5 wt%, or when a binder is present in an amount of from 0.01 to less than 10 wt%, the preservative may be present in an amount of from 0.5 to 1.9 wt% (e.g. from 0.8 to 1.9 wt%).

Lubricants that may be used in the trunk implant formulation disclosed herein include, but are not limited to, mineral oil, synthetic oil (e.g. one or more of the group selected from polyalpha-olefins, synthetic esters, polyalkylene glycols, phosphate esters, alkylated naphthalenes, silicate esters, ionic fluids, and multiply-alkylated cyclopentanes), and biolubricant (e.g. selected from one or more of the group consisting of canola oil, castor oil, palm oil, sunflower seed oil, rapeseed oil, soybean oil and tall oils). In particular embodiments that may be mentioned herein, the lubricant may be soybean oil. When present, the lubricant is present in an amount of from 0.4 to 1 wt% based on the total weight of the trunk implant formulation. For example, when a binder is present in an amount of from 10 to 40 wt%, the lubricant is present in an amount of from 0.4 to 0.75 wt%, or when the binder is present in an amount 0.01 to less than 10 wt%, the lubricant may be present in an amount of from 0.5 to 1.0 wt% (from 0.8 to 1.0 wt%).

A defoamer is a chemical additive that reduces and hinders the formation of foam a liquid. Defoaming agents that may be mentioned herein include, but are not limited to insoluble oils, polydimethylsiloxanes and other silicones, stearates and glycols. The additive may be used to prevent formation of foam or may be added to break a foam that has already formed. When present, the defoamer is present in an amount of from 0.5 to 10 wt% based on the total weight of the trunk implant formulation. For example, when a binder is present in an amount of from 10 to 40 wt%, the defoamer may be present in an amount of from 0.5 to 4 wt% (e.g. around 2.7 wt%), or when the binder is present in an amount from 0.01 to less than 10 wt%, the defoamer is present in an amount of from 2 to 10 wt% (e.g. around 2.7 wt%).

A surfactant may be added to the trunk implant formulation and may be selected from one or more of amphoteric, non-ionic and ionic surfactants. Surfactants that may be mentioned herein include, but are not limited to silicon surfactants, fluorosurfactants and polymeric surfactants. Non-ionic surfactants that may be mentioned herein include, but are not limited to, ethoxylated linear alcohols, ethoxylated alkyl phenols, fatty acid esters, fatty alcohol polyglycosides,

alkylpolyglucosides ethleneoxide/propyleneoxide copolymers, polyalcohols, ethoxylated polyalcohols, thiols (mercaptans), amides, alkylpolyglucosides and combinations thereof. Particular non-ionic surfactants that may be mentioned herein include, but are not limited to, tridecanol, 2° alcohol ethoxylate, ter-octyl-phenol, nonylphenol ethoxylate, abietic acid, 1,4-  
5 sorbitan, 2,5-sorbitan, 1,5-sorbitan, 1,4,3,6-isosorbitan, di-acyl ethoxy urea, ethoxylated imide, and ter-dodecyl mercaptan. In particular embodiments of the invention that may be mentioned herein, when a non-ionic surfactant is present in the composition it may be selected from one or more of the group consisting of ethoxylated alkyl phenols and fatty alcohol polyglycosides. Ionic surfactants include amphoteric, anionic (e.g., but not limited to, ammonium lauryl  
10 sulfate, sodium lauryl sulfate, and/or carboxylates such as sodium stearate and sodium lauroyl sarcosinate) and cationic surfactants. In particular embodiments of the invention, cationic surfactants may be preferred. Suitable cationic surfactants include, but are not limited to benzalkonium chloride, benzethonium chloride, 5-bromo-5-nitro-1,3-dioxane, cetrimonium bromide, cetrimonium chloride, distearyldimethylammonium chloride, lauryl methyl gluceth-10  
15 hydroxypropyl dimonium chloride, octenidine dihydrochloride, olaflur, tetramethylammonium hydroxide, and combinations thereof. Amphoteric surfactants that may be mentioned herein include, but are not limited to sultaines (e.g. CHAPS (3-[(3-cholamidopropyl)dimethylammonio]-1-propanesulfonate), cocamidopropyl hydroxysultaine), betaines (e.g. cocamidopropyl betaine), phosphatidylserine, phosphatidylethanolamine, phosphatidylcholine, sphingomyelins  
20 and lecithins.

Fillers that may be used in the trunk implant formulation disclosed herein include, but are not limited to, maltodextrin and/or sodium sulphite. Fillers are intended to add bulk to the formulation. When present, the filler is present in an amount of from 0.5 to 15 wt% based on the total weight  
25 of the trunk implant formulation. For example, when a binder is present in an amount of from 10 to 40 wt%, the filler may be present in an amount of from 0.5 to 8 wt% (e.g. around 7.3 wt%), or when the binder is present in an amount of from 0.01 to less than 10 wt%, the filler may be present in an amount of from 5 to 15 wt% (e.g. around 7.3 wt%).

30 A colorant may provide a defined colour to the trunk implant formulation to make it easier to spot in the water body and make it easier to work out when a new dose of the trunk implant formulation may be needed. Such colourants may be any suitable colour. When present, the colorant is present in an amount of from 0.01 to 2 wt% based on the total weight of the trunk implant formulation. For example, when a binder is present in an amount of from 10 to 40 wt%,  
35 the colorant may be present in an amount of from 0.01 to 1 wt%, preferably from 0.04 to 1 wt%, or when the binder is present in an amount of from 0.01 to less than 10 wt%, the colorant may be present in an amount of from 0.04 to 2 wt%, such as from 0.04 to 1 wt%.

In one embodiment, the controlled release trunk implant formulation of the present invention  
40 comprises:

- at least one water soluble polymer in an amount of from 7.7 to 21 wt%;
- at least one plant treatment agent in an amount of from 56 to 80.3 wt%;
- a binder in an amount of from 10 to 21 wt%;
- a preservative in an amount of from 0.45 to 1.5 wt%; and
- 5 a lubricant in an amount of 0.5 to 0.75 wt%.

In another embodiment, the controlled release trunk implant formulation of the present invention comprises:

- at least one water soluble polymer in an amount of from 11.6 to 20.7 wt%;
- 10 at least one plant treatment agent in an amount of from 56 to 70.5 wt%;
- a binder in an amount of from 15.5 to 20.6 wt%;
- a preservative in an amount of from 0.7 to 1.5 wt%; and
- a lubricant in an amount of 0.7 to 0.75 wt%.

- 15 In yet another embodiment, the controlled release trunk implant formulation of the present invention comprises:

- at least one water soluble polymer in an amount of from 8.5 to 27 wt%;
- at least one plant treatment agent in an amount of from 70 to 90 wt%;
- a preservative in an amount of from 0.5 to 2 wt%; and
- 20 a lubricant in an amount of 0.5 to 1 wt%, wherein the formulation is substantially free of a binder.

In a further embodiment, the controlled release trunk implant formulation of the present invention comprises:

- 25 at least one water soluble polymer in an amount of from 13.5 to 26.5 wt%;
- at least one plant treatment agent in an amount of from 70 to 84 wt%;
- a preservative in an amount of from 0.8 to 1.9 wt%; and
- a lubricant in an amount of 0.85 to 0.95 wt%, wherein the formulation is substantially free of a binder.

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When used herein, the phrase “substantially free of a binder” refers to 0.01 to 0.1 wt% of binder present in the trunk implant formulation.

- 35 To prepare the trunk implant of the present invention, the essential trunk implant formulation may be mixed together and blended at room temperature to form a homogenous mixture that may initially be a soft, malleable mass. The use of room-temperature blending not only ensures that any heat-sensitive ingredients are not degraded, but also ensures the integrity of the active ingredient whose properties may be damaged or changed at elevated temperatures required in other processes. Due to the malleability of the initial formulation, it may be extruded at a low
- 40 pressure that allows a significant amount of liquid ingredients, for instance the desirable liquid

active ingredient, to be incorporated in the formulation. For example, the initial formulation may be extruded at a low pressure of about 5 psi to about 50 psi. If the matrix is subject to a high pressure, the liquid ingredients may be squeezed out from the matrix during the extrusion phase. Therefore, the low pressure processing in the extruder according to the invention ensures that  
5 the active ingredient is not removed during processing of the formulation.

Therefore, in accordance with a third aspect of the invention, a method of producing a controlled release trunk implant is provided. The method comprises:

- (a) providing a formulation comprising:  
10           at least one water soluble polymer;  
            at least one plant treatment agent;  
            at least one binder; and  
            one or more excipients; and
- (b) extruding the mixture at room temperature; and
- 15       (c) shaping and/or cutting the extrudate to form a controlled release trunk implant.

After the soft and malleable mass is extruded, the extrudate is cut into segments which are then machined into different shapes and sizes, depending on the intended use and release profile. In various embodiments, the controlled release trunk implant is in the form of tablets, pellets,  
20 blocks, cylinders, rods, granulated particles, or the like.

In particular embodiments of the method, the binder is provided in an amount of from 4 to 60 wt%, preferably 10 to 40 wt%, more preferably from 10 to 25 wt%; the least one water soluble polymer is provided in an amount of from 5 to 60 wt%; preferably 7.5 to 55 wt%, more preferably  
25 7.5 to 40 wt%, even more preferably from 7.7 to 21 wt%; the least one plant treatment agent agent is provided in an amount of from 1 to 90 wt%, preferably 30 to 85 wt%, more preferably from 56 to 80.3 wt%; and the balance comprising one or more excipients.

As described hereinabove, while the method of preparing the formulation requires a binder to  
30 be present, the method may further include drying the controlled release trunk implant to remove the binder from the controlled release trunk implant. In this embodiment, the final trunk implant may be substantially free of a binder (e.g. less than 10 wt%, such as less than 5wt%, less than 2 wt%, less than 0.5 wt%, or less than 0.01 wt% of the total weight of the formulation).

35 In one embodiment, the controlled release trunk implant, after subjecting to removal of binder, comprises:  
          at least one water soluble polymer in an amount of from 5 to 60 wt%;  
          at least one plant treatment agent in an amount of from 1 to 90 wt%;  
          at least one binder in an amount of from 0.01 to 10 wt%; and  
40       one or more excipients.

Unless otherwise stated, the components and amounts of said components are identical to those described hereinabove for the trunk implant formulation. For example, in the trunk implant formulation, the at least one plant treatment agent may be present in an amount of from 56 to 80.3 wt% based on the total weight of the trunk implant formulation or from 55 to 81 wt% in the method, but may be present in a higher or lower amount in the final formulation.

When present in the method of producing the trunk implant, the preservative is present in an amount of from 0.4 to 1.5 wt%; the lubricant is present in an amount of from 0.4 to 0.75 wt%; the crosslinking agent is present in an amount of from 0.5 to 20 wt%; the defoamer is present in an amount of from 0.5 to 10 wt%; the filler is present in an amount of from 0.5 to 15 wt%; and the colorant is present in an amount of from 0.01 to 2 wt%, based on the total weight of the trunk implant formulation.

When a crosslinker is present in the formulation, after the formulation is machined in its final shape, it is left in an ambient space for about a few hours to enable the *in-situ* crosslinking of the water-soluble polymer to be completed before use and/or further processing (e.g. packaging, etc.). Without wishing to be bound by theory, the crosslinking may increase the molecular weight of the polymer and therefore reduce the dissolution rate of the polymer, leading to a more controlled release of the active ingredient.

The invention thus provides a controlled release formulation for continuous eradication or control of pests which are characterized by: full water solubility; being made using low pressures, so that high levels of liquid active ingredients are contained in the formulation; and being made at room temperature hence the active ingredient is not subject to deterioration at elevated temperature.

The room temperature and low pressure processing simplifies the manufacture of the formulation at low cost. It is believed that controlling the amount of crosslinking or through the inclusion polymers having different molecular weights, it is possible to obtain formulations that are capable of providing a sustained, controlled release of an active ingredient into a monocot tree over an extended period of time, even in situations where the formulation is not subjected to full immersion in water (whether in whole or in part).

As will be appreciated, the trunk implant formulation disclosed herein is intended for use in systemic treatment of trees including, but not limited to, monocot trees. As such, there is also disclosed a method for eradicating and/or controlling pests in a tree and/or treating a tree, the method comprising applying a control release trunk implant comprising the trunk implant formulation as described herein to a tree, in an amount sufficient to eradicate and/or control a pest and/or to treat a tree. The method of application may be by insertion of the control release

trunk implant comprising the trunk implant formulation into a hole drilled into a trunk of the tree. After insertion, the hole may be sealed, thereby preventing ingress of pests or water from the environment into the hole. As will be expected, the hole will self-heal over time.

5 Therefore, in accordance with a fourth aspect of the invention, a method of eradicating and/or controlling pest in a tree and/or treating the tree is provided. The method comprises inserting a controlled release trunk implant of the present invention into a hole drilled into a trunk of a tree to provide a continuous release of the plant treatment agent to the tree; and optionally sealing the hole; and wherein the hole is moist on the inner region of the hole.

10

In various embodiments, the controlled release trunk implant is configured to provide a continuous release of the plant treatment agent for 30 to 90 days.

Thus, there is disclosed a trunk implant formulation that is a water-triggered controlled release  
15 platform using a monolithic, hydrophilic, water soluble polymeric matrix, homogenously embedded with one or more active ingredients. The mode of release is a combination of diffusion and dissolution of active ingredients from the matrix, which undergoes swelling, erosion and dissolution upon contact with water (even if no full immersion takes place). The trunk implant formulation can be designed to respond to different environmental stimuli to  
20 achieve an optimal dosage profile for the active ingredients. The trunk implant formulation can also accommodate a high active loading, which should reduce the need for constant costly reapplication of the active ingredients. There is no residue left of the trunk implant formulation of the trunk implant at the end of the treatment period, as all materials will either be absorbed by the plant or biodegrade.

25

The trunk implant formulation, the trunk implant and the methods of the present invention have several advantages. The advantages associated with the trunk implant formulation, the trunk implant and the methods of the present invention include the following:

30 The present invention eliminates the need of handling active ingredients in aqueous solution form both during mixing and application, which can be dangerous and cumbersome. It eliminates discrepancies in dosage, arising from errors in mixing and application. It reduces the frequency of active ingredient application. It also reduces the amount of active ingredients which are leached into the tree or environment, and so reduces the amount of active ingredients  
35 required to provide treatment.

US 6216388 B1 discloses a method of introducing a polymer plug into a bored hole in the trunk of a tree as a mean to introduce treatment agents into the tree. However, the method disclosed in this publication involves forming a polymer plug by first melting the polymer and admixing the  
40 polymer with a treatment agent while the polymer is still in the molten state and then cooling the

mixture down in a mold to form the plug. The approach of introducing heat to melt the polymer introduces several disadvantages and limitations. Firstly, the active ingredient is exposed to elevated temperature which may compromise the active ingredient's integrity and properties. Biological active ingredient would not be able to withstand such manufacturing process.

5 Secondly, the casting process used means that the finished product cannot have a regular cross-section area. The cross-section area of one end is smaller than the other end. This introduces some inefficiencies in the application as the trunk hole will have a regular cross-section area, so the diameter of the trunk hole should be big enough to accommodate the bigger cross-section end of the plug. Thirdly, temperatures during shipment or transportation can reach

10 as high as 60°C. Considering this, the storage stability of plugs made with PEG of molecular weight below 8000 may not be able to meet specifications. Lastly, it is mentioned that the plug can offer a treatment period of 3 - 5 days, with the longest period being 7 - 10 days.

In the present invention, active ingredient such as plant treatment agent is admixed with one or

15 more water soluble polymers and plasticized by a binder with OH moiety into a malleable mass. The malleable mass is shaped by extrusion at room temperature into the required shape. A hole in the trunk of the tree is created by a driller and the controlled release trunk implant is inserted into the hole to provide an instantaneous and continuous release of plant treatment agent to the tree. The release period can last from 1 month up to 3 months.

20 In comparison to US 6216388, the present invention does not require heat for manufacturing. The controlled release trunk implant is produced from an extrusion process, which is more efficient and has higher throughput, compared to a casting process. Lastly, the treatment duration offered is longer.

25 WO18048357A1 discloses a water soluble controlled release formulation that floats on water surface for eradication or control of insects and/or vegetation in a water body.

In the present invention, the environment within a trunk hole is not filled with water but rather is

30 only moist on the inner region of the trunk hole. There are occasions where the trunk hole become filled with water but this is not the dominant circumstance. The formulation disclosed in WO18048357A1 is required to be submerged in a water body for active ingredient release to occur and it may not work effectively in a moist condition as in the present invention. It may not activate at all or take too long to release the active ingredient. The other issue is that the

35 formulation disclosed in WO18048357A1 is a buoyant one. Buoyancy is not required in the present invention. Actually, a non-buoyant controlled release formula is preferred to ensure that it is in constant contact with the bottom surface of the trunk hole even when the trunk hole is filled with water.

40 The method of the present invention does not require heat and hence the method maintains the

integrity of the active ingredient. The controlled released trunk implant formulation offers a longer treatment period. It has better storage stability, due to better temperature stability of polymers at elevated temperatures. The controlled release trunk implant formulation can release active ingredient even when the trunk hole has very low water content and it does not have to be submerged in a water body to activate the release of the active ingredient. The controlled release trunk implant formulation is compatible with both water soluble and poorly water soluble actives, in solid, liquid or gel forms. It has a burst release profile followed by zero order release.

10 In some embodiments of the present invention, the shape of the controlled release trunk implant could be other than a rod, it could be granular, film, tablet, as long as it fits into the bored trunk hole. The treatment period could be shorter than 1 month or longer than 2 months. Adjuvants such as dye, mold release agents, preservatives are optional. The plant treatment agent could be plant nutrients and substances other than pesticides. In some embodiments, more than one  
15 plant treatment agent could be incorporated into the controlled release trunk implant.

The controlled release trunk implant formulation of the present invention is compatible with both water soluble and poorly water soluble active ingredients, in solid, liquid or gel forms. The controlled release trunk implant is fully biodegradable. The trunk implant formulation can be used to customise the dosage and release profile of the active ingredient(s). For example, by  
20 changing the polymer chemistry, water solubility of the active ingredient, the polymer and active ingredient concentration and controlled release tablet shape and geometry. The trunk implant formulation can be adapted to respond to different environmental stimuli to achieve optimal active ingredient dosage profile. The trunk implant formulation can be processed at room  
25 temperature and pressures, making it easy to form the desired products. The trunk implant formulation can contain a significant amount of active ingredient (e.g. up to 90 wt%), thereby reducing the need for frequent re-dosing. The formulation allows more efficient application of insecticides – able to control multiple life larvae stages of pests such as bagworm from small-larvae to large-larvae (i.e. Bagworm and Nettle Caterpillar infestations and the re-occurrence of  
30 bagworm and nettle caterpillar's problems due to shorter residual effect of the current method of trunk injection). A further advantage includes improving the safety and health of workers having to apply the pesticide (e.g. acephate), while also improving the productivity of the workers, given the reduced time needed to apply the insecticides / no manual mixing (i.e. problems of mixing powder form acephate insecticide) and injecting the insecticides into the  
35 tree trunk / ease of use. The reduction in application time is accomplished by a simplified method of application, which only requires a driller, trunk implant and a seal (e.g. with clay). This eliminates the use of an injector gun and the problems associated with it.

The method and formulation of the present invention are able to prolong the efficacy of each  
40 round of treatment, through the longer residual release of active ingredients into the

leaves/system of a tree. The treatment may be more effective than, be more environmentally friendly (by reducing pollution) than, and cost less than conventional treatment options. The present invention overcomes the problem of treating bagworms in young mature palm with trunk height below 1.5 m. The extrusion based process allows product shapes with regular cross section area, is low cost and has a high throughput. Burst release following with consistent release profile is obtained.

It has been surprisingly found that even though the active ingredient, such as plant treatment agent is homogeneously distributed throughout the polymer matrix, a burst release of active ingredient is observed, followed by an almost zero order active ingredient release kinetics (refer to Figure 1). This characteristic could be attributed by the high surface of a rod shape block, which leads to a high dissolution rate of the matrix at the surface of the block. However, shortly after the initial dissolution, swelling of the polymer kicks, putting a halt to dissolution. The release mechanism shifts into a combination of diffusion through the swelled front and dissolution of the swelled front. The latter release mechanism is responsible for the almost zero order active ingredient release kinetics achieved.

While the embodiments described herein are intended as an exemplary controlled release formulation for eradicating or controlling pests and/or vegetation, it will be appreciated by those skilled in the art will understand that the present invention is not limited to the embodiments illustrated. Those skilled in the art will envision many other possible variations and modifications by means of the skilled person's common knowledge without departing from the scope of the invention, however, such variations and modifications should fall into the scope of this invention.

## **EXAMPLES**

### Example 1

#### Development and Characterization of Acephate Slow Release Insecticide

The objective of this experiment is to determine suitable formulation to incorporate acephate into the slow release tablet matrices.

Methodology: Identify a suitable controlled release mechanism and the corresponding formulation direction. Development of controlled release trunk implant formulation with acephate as active ingredient. Fine tuning of formulation to achieve desired release parameters and physical characteristics.

The following studies were conducted:-

- Physical and chemical characterization of tablet suitability for insertion in palm trunks, characterization, dissolution in water, and active ingredient release rate.

- Assessment of manufacturability of tablets on production equipment
- Storage stability and shelf life analysis
- Identification of suitable packaging method and materials
- Preparation of Safety Data Sheet (SDS)

5

Deliverables:

- Tablets for laboratory and field trials
- Characterization data (dissolution & release profile, physical and chemical properties, storage stability and shelf life)
- 10 • Preliminary bioassay results
- Testing protocols
- SDS (Safety Data Sheet)

15 The criteria for qualifying as a successful formula is possession of all 3 characteristics as follows:

- (i) Extrudability on production scale equipment with extrudate diameter of 15mm and below;
- (ii) Suitable dissolution profile for application in palm trunks where water volumes are very low. The internal surface of the tree hole is just moist; and
- 20 (iii) Active ingredient loading of 50% and above for economic reasons (relative lowering of product cost and reduces frequency of refill). The upper limit is 80%, beyond which the formula loses controlled release behaviour.

Table 1

| Formulation (F1)              | Weight % |
|-------------------------------|----------|
| Water                         | 20.7     |
| Acephate (in solid form)      | 56.3     |
| Citric acid                   | 1.5      |
| Hydroxypropylmethyl cellulose | 20.8     |
| Soybean oil                   | 0.7      |

- 25 All ingredients were mixed together until homogeneous. The mixture was placed in an extruder and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was sliced into the required length of 15 cm.

Table 2

| Formulation (F2)         | Weight % |
|--------------------------|----------|
| Water                    | 16.1     |
| Acephate (in solid form) | 70.8     |
| Citric acid              | 0.7      |

|                               |      |
|-------------------------------|------|
| Hydroxypropylmethyl cellulose | 11.7 |
| Mineral oil                   | 0.7  |

All ingredients were mixed together until homogeneous. The mixture was placed in an extruder and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was first sliced into the required length of 15 cm.

5

Table 3

| <b>Formulation (F3)</b>       | <b>Weight %</b> |
|-------------------------------|-----------------|
| Water                         | 18.8            |
| Acephate (in solid form)      | 51.3            |
| Citric Acid                   | 2.1             |
| Polysaccharide                | 18.8            |
| Hydroxypropylmethyl cellulose | 5.6             |
| Mineral oil                   | 3.4             |

All ingredients were mixed together until homogeneous. The mixture was placed in an extruder and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was sliced into the required length of 15 cm.

10

Table 4

| <b>Formulation (F4)</b>        | <b>Weight %</b> |
|--------------------------------|-----------------|
| Water                          | 4.2             |
| Methamidophos (in liquid form) | 72.1            |
| Citric Acid                    | 1.5             |
| Hydroxypropylmethyl cellulose  | 17.2            |
| Mineral oil                    | 5               |

All ingredients were mixed together until homogeneous. The mixture was placed in an extruder and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was sliced into the required length of 15 cm.

15

Table 5

| <b>Formulation (F5)</b>       | <b>Weight %</b> |
|-------------------------------|-----------------|
| Water                         | 20.7            |
| Acephate (in solid form)      | 56.3            |
| Sodium benzoate               | 1.5             |
| Maltodextrin                  | 10              |
| Hydroxypropylmethyl cellulose | 10.8            |

|             |     |
|-------------|-----|
| Mineral oil | 0.7 |
|-------------|-----|

Formulation F5 is T1-Acephate trunk implant fast release (Fast) - 7.5 G A.I. Tablet. All ingredients were mixed together until homogeneous. The mixture was placed in an extruder and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was  
5 sliced into the required length of 6.3 cm.

Table 6

| Formulation (F6)              | Weight % |
|-------------------------------|----------|
| Water                         | 20.7     |
| Acephate (in solid form)      | 56.3     |
| Sodium benzoate               | 1.5      |
| Hydroxypropylmethyl cellulose | 20.8     |
| Mineral oil                   | 0.7      |

Formulation F6 is T2-Acephate trunk implant slow release (Slow) - 7.5 G A.I. Tablet. All ingredients were mixed together until homogeneous. The mixture was placed in an extruder  
10 and was extruded into 1.5 cm diameter blocks at room temperature. The extruded material was sliced into the required length of 6.3 cm.

### Example 2

Acephate Trunk Implant Control Release Insecticide Profile Determination via Simulated Trunk  
15 Hole Laboratory Set Up.

The objective of this experiment is to determine the release profile and mechanism of action of acephate trunk implant in water.

20 In this experiment, studies on the release profile of the acephate trunk implant were conducted via a simulated trunk-hole laboratory set up. Sample of acephate solution released from the tablet was collected at specified sampling intervals and a clean and dry sampling container (100 ml) was used to collect the liquid in the plastic vial. The sampling container with the liquid was submitted to the laboratory for analysis of acephate content using HPLC methods. Sampling  
25 interval is every 80 hours and/or the last sampling would be whenever the tablet had fully dissolved in water. The content of acephate released over a period of time from the acephate trunk implant was determined via High Performance Liquid Chromatography (HPLC) analytical method and the results are presented below in Table 5.

30 Table 7: Acephate content upon after released in water from acephate trunk implant formulation (80-560 HAT)

| Treatment                                            | Acephate content upon released in water from acephate trunk implant formulation (PPM) |          |          |          |         |         |         |
|------------------------------------------------------|---------------------------------------------------------------------------------------|----------|----------|----------|---------|---------|---------|
|                                                      | 80 HAT                                                                                | 160 HAT  | 240 HAT  | 320 HAT  | 400 HAT | 480 HAT | 560 HAT |
| T1-Acephate trunk implant (Fast) - 7.5 G A.I. Tablet | 16.46 b <sup>z</sup>                                                                  | 241.06 a | 170.91 a | 163.87 a | 40.23 a | NA* c   | NA b    |
| T2-Acephate trunk implant (Slow) - 7.5 G A.I. Tablet | 21.46 b                                                                               | 150.95 b | 45.49 c  | 23.37 c  | 39.61 a | 35.05 a | 32.28 a |
| T3-Acephate 75% SP (Acephate Solution)               | 237.93 a                                                                              | 138.39 b | 106.14 b | 75.24 b  | 47.70 a | 31.44 b | NA b    |

Table 8: Acephate content upon after released in water from acephate trunk implant formulation (640-1120 HAT)

| Treatment                                            | Acephate content upon released in water from acephate trunk implant formulation (PPM) |         |         |         |         |          |          |
|------------------------------------------------------|---------------------------------------------------------------------------------------|---------|---------|---------|---------|----------|----------|
|                                                      | 640 HAT                                                                               | 720 HAT | 800 HAT | 880 HAT | 960 HAT | 1040 HAT | 1120 HAT |
| T1-Acephate trunk implant (Fast) - 7.5 G A.I. Tablet | NA b                                                                                  | NA b    | NA b    | NA b    | NA b    | NA b     | NA b     |
| T2-Acephate trunk implant (Slow) - 7.5 G A.I. Tablet | 29.79 a                                                                               | 28.72 a | 16.97 a | 22.48 a | 29.06 a | 23.37 a  | 22.28 a  |
| T3-Acephate 75% SP (Acephate Solution)               | NA b                                                                                  | NA b    | NA b    | NA b    | NA b    | NA b     | NA b     |

5 Table 9: Acephate content upon after released in water from acephate trunk implant formulation (1200-1680 HAT)

| Treatment                                            | Acephate content upon released in water from acephate trunk implant formulation (PPM) |          |          |          |          |          |          |
|------------------------------------------------------|---------------------------------------------------------------------------------------|----------|----------|----------|----------|----------|----------|
|                                                      | 1200 HAT                                                                              | 1280 HAT | 1360 HAT | 1440 HAT | 1520 HAT | 1600 HAT | 1680 HAT |
| T1-Acephate trunk implant (Fast) - 7.5 G A.I. Tablet | NA b                                                                                  | NA b     | NA b     | NA b     | NA b     | NA b     | NA b     |
| T2-Acephate trunk implant (Slow) - 7.5 G A.I. Tablet | 20.47 a                                                                               | 32.99 a  | 17.51 a  | 18.83 a  | 15.51 a  | 22.55 a  | 12.51 a  |
| T3-Acephate 75% SP (Acephate Solution)               | NA b                                                                                  | NA b     | NA b     | NA b     | NA b     | NA b     | NA b     |

This example shows that acephate trunk implant slow release (Slow) formulation is capable to continue releasing acephate up to 1680 hours after treatment (HAT) which is equivalent to 70 days before the slow release formulation completely dissolved. The acephate trunk implant slow release profile proved to be the novelty of the formulation. Whereas the acephate trunk implant fast release formulation dissolved much earlier at 400 HAT (16.67 days) which confirmed its fast release formulation profile. Figure 2 shows the release profiles of the three samples, namely the acephate trunk implant fast release, acephate trunk implant slow release and acephate 75% SP (acephate solution) over a period of 80 to 1680 HAT.

### Example 3

Determination of Acephate Content in Oil Palm Leaves Upon Application of Acephate Trunk Implant Controlled Release Insecticide in the Oil Palm Trunk.

20

The objective of this experiment is to determine residual content of acephate in oil palm leaves upon after application of the trunk implant-controlled release insecticide in the oil palm trunk.

The residual content of acephate in the trunk-injected oil palm leaves were determined using the Gas Chromatography-Flame Photometric Detector (GC-FPD) analytical method.

In this experiment, treatment of the palm trunk using acephate trunk implant at 3.75, 7.5, 15, 22.5 and 30 g a.i per palm for both fast release (Fast) and slow release (Slow) formulation showed the presence of acephate residue in the leaves at 42 days after treatment (DAT). This is significantly better than the standard Acephate 75%SP treatment at 7.5 g a.i. per palm. These results indicated that acephate trunk implant formulation has been able to act in a controlled mechanism to prolong the release of active ingredients into the palm trunk and translocated up into the palm leaves up to 42 DAT. The more interesting findings were the detection of acephate in the oil palm leaves at 84 DAT for acephate trunk implant slow release formulation at 7.5 g a.i. per palm, even though it was not detected at 56 DAT. At 84 DAT, acephate trunk implant slow release formulation at 7.5, 15, 22.5 and 30g a.i. per palm were significantly higher than Acephate 75% SP at 84 DAT. No significant difference was observed between acephate trunk implant slow and fast release formulation at 28 and 42 DAT.

The release profile results obtained in this experiment provide a good explanation on the presence of the acephate in the leaves at 84 DAT in that acephate was released up to 70 days in the water which explains the mechanism of acephate translocation into the palm leaves at 84 DAT. The results further confirmed that in oil palm trunk, the systemic insecticide such as acephate is translocated into the leaf canopy via the transpiration pull (Chung, G.F., "Review on major pest management in oil palm", The Planter Vol 93, No. 1090 (January 2017), pages 29-47).

Table 10: Acephate residual content upon after released in water from acephate trunk implant (1-28 DAT)

| TREATMENT                                       | ACEPHATE RESIDUAL CONTENT IN PALM LEAVES (PPB)<br>AFTER TREATMENTS |        |        |        |       |     |
|-------------------------------------------------|--------------------------------------------------------------------|--------|--------|--------|-------|-----|
|                                                 | 1 DAT                                                              | 7 DAT  | 14 DAT | 28 DAT |       |     |
| T1-Acephate trunk implant 3.75g -Fast-W/Water   | 12.25                                                              | cdef   | 44.62  | abc    | 23.15 | bc  |
| T2-Acephate trunk implant 3.75g -Slow-W/Water   | 7.39                                                               | def    | 51.94  | abc    | 41.71 | ab  |
| T3-Acephate trunk implant 3.75g -Fast-No Water  | 6.49                                                               | def    | 26.69  | abc    | 32.64 | bc  |
| T4-Acephate trunk implant 3.75g -Slow-No Water  | 6.62                                                               | def    | 30.04  | bcd    | 30.29 | bc  |
| T5-Acephate trunk implant 7.5g -Fast-W/Water    | 6.21                                                               | def    | 40.81  | abcd   | 37.92 | abc |
| T6-Acephate trunk implant 7.5g -Slow-W/Water    | 6.60                                                               | def    | 73.10  | ab     | 42.80 | ab  |
| T7-Acephate trunk implant 7.5g -Fast-No Water   | 9.13                                                               | def    | 50.73  | abc    | 43.27 | ab  |
| T8-Acephate trunk implant 7.5g -Slow-No Water   | 8.14                                                               | def    | 78.27  | a      | 40.57 | ab  |
| T9-Acephate trunk implant 15g -Fast-W/Water     | 9.93                                                               | def    | 47.77  | abc    | 55.43 | ab  |
| T10-Acephate trunk implant 15g -Slow-W/Water    | 8.86                                                               | def    | 38.46  | abcd   | 46.12 | ab  |
| T11-Acephate trunk implant 15g -Fast-No Water   | 65.64                                                              | ab     | 44.52  | abc    | 46.48 | ab  |
| T12-Acephate trunk implant 15g -Slow-No Water   | 51.21                                                              | abcd   | 48.85  | abc    | 47.90 | ab  |
| T13-Acephate trunk implant 22.5g -Fast-W/Water  | 60.18                                                              | ab     | 46.87  | abc    | 55.59 | ab  |
| T14-Acephate trunk implant 22.5g -Slow-W/Water  | 39.60                                                              | abcdef | 44.92  | abc    | 40.09 | abc |
| T15-Acephate trunk implant 22.5g -Fast-No Water | 37.13                                                              | bcd    | 60.74  | abc    | 54.76 | ab  |
| T16-Acephate trunk implant 22.5g -Slow-No Water | 55.06                                                              | abc    | 31.94  | bcd    | 43.49 | ab  |
| T17-Acephate trunk implant 30g -Fast-W/Water    | 71.36                                                              | ab     | 31.07  | bcd    | 51.67 | ab  |
| T18-Acephate trunk implant 30g -Slow-W/Water    | 44.77                                                              | abcde  | 47.69  | abc    | 57.01 | ab  |
| T19-Acephate trunk implant 30g -Fast-No Water   | 49.22                                                              | abcde  | 27.27  | cd     | 40.89 | ab  |
| T20-Acephate trunk implant 30g -Slow-No Water   | 61.39                                                              | ab     | 22.97  | cd     | 48.64 | ab  |
| T21-BlankTrunkImplant -Fast-W/Water             | 0.00                                                               | f      | 0.00   | d      | 0.00  | c   |
| T22-BlankTrunkImplant -Slow-W/Water             | 0.00                                                               | f      | 0.00   | d      | 0.00  | c   |

|                                                               |       |        |       |      |       |     |       |   |
|---------------------------------------------------------------|-------|--------|-------|------|-------|-----|-------|---|
| T24-Acephate trunk implant - 3.75g Fast + 3.75g Slow-No/Water | 49.19 | abcde  | 25.04 | cd   | 42.38 | ab  | 15.66 | b |
| T25-Acephate trunk implant - 7.5g Fast + 7.5g Slow-W/Water    | 49.74 | abcde  | 37.34 | abcd | 36.31 | abc | 22.02 | b |
| T26-Acephate trunk implant - 7.5g Fast + 7.5g Slow-No/Water   | 60.45 | ab     | 28.16 | cd   | 33.94 | bc  | 28.11 | b |
| T27-Acephate trunk implant - 15g Fast + 15g Slow-W/Water      | 43.91 | abcdef | 41.88 | abcd | 35.91 | abc | 18.68 | b |
| T28-Acephate trunk implant - 15g Fast + 15g Slow-No/Water     | 48.38 | abcde  | 49.53 | abc  | 37.06 | abc | 36.69 | b |
| T29-Acephate trunk implant - 22.5 Fast + 22.5g Slow-W/Water   | 30.26 | bcdef  | 39.38 | abcd | 79.64 | a   | 16.51 | b |
| T30-Acephate trunk implant - 22.5g Fast + 22.5g Slow-No/Water | 45.51 | abcde  | 25.10 | cd   | 28.76 | bc  | 0.00  | b |
| T31-Acephate trunk implant - 30g Fast + 30g Slow-W/Water      | 57.02 | abc    | 47.97 | abc  | 41.92 | bc  | 41.22 | b |
| T32-Acephate trunk implant - 30g Fast + 30g Slow-No/Water     | 62.03 | ab     | 52.13 | abc  | 37.48 | abc | 45.93 | b |
| T33-Acephate 75%SP-3.75g                                      | 39.66 | abcdef | 41.54 | abcd | 34.93 | bc  | 25.67 | b |
| T34-Acephate 75%SP-7.5g                                       | 37.26 | bcdef  | 39.28 | abcd | 44.21 | ab  | 9.14  | b |
| T35-Acephate 75%SP-15g                                        | 43.63 | abcdef | 36.71 | abcd | 40.20 | abc | 25.59 | b |
| T36-Acephate 75%SP-22.5g                                      | 83.81 | a      | 38.67 | abcd | 36.09 | abc | 14.73 | b |
| T37-Acephate 75%SP-30g                                        | 46.32 | abcde  | 42.42 | abcd | 40.13 | abc | 18.63 | b |
| T38-Untreated Control - With Water                            | 0.00  | f      | 0.00  | d    | 0.00  | c   | 0.00  | b |
| T39-Untreated Control - No Water                              | 0.00  | f      | 0.00  | d    | 0.00  | c   | 0.00  | b |

Table 11: Acephate residual content upon after released in water from acephate trunk implant (45-84 DAT)

| TREATMENT                                                     | ACEPHATE RESIDUAL CONTENT IN PALM LEAVES (PPB) AFTER TREATMENTS |        |        |      |
|---------------------------------------------------------------|-----------------------------------------------------------------|--------|--------|------|
|                                                               | 42 DAT                                                          | 56 DAT | 84 DAT |      |
| T1-Acephate trunk implant 3.75g -Fast-W/Water                 | 8.40                                                            | bc     | 0.00   | d    |
| T2-Acephate trunk implant 3.75g -Slow-W/Water                 | 19.78                                                           | abc    | 0.00   | d    |
| T3-Acephate trunk implant 3.75g -Fast-No Water                | 14.68                                                           | abc    | 0.00   | d    |
| T4-Acephate trunk implant 3.75g -Slow-No Water                | 22.20                                                           | abc    | 0.00   | d    |
| T5-Acephate trunk implant 7.5g -Fast-W/Water                  | 32.70                                                           | abc    | 0.00   | d    |
| T6-Acephate trunk implant 7.5g -Slow-W/Water                  | 33.82                                                           | abc    | 0.00   | d    |
| T7-Acephate trunk implant 7.5g -Fast-No Water                 | 20.51                                                           | abc    | 0.00   | d    |
| T8-Acephate trunk implant 7.5g -Slow-No Water                 | 16.86                                                           | abc    | 0.00   | d    |
| T9-Acephate trunk implant 15g -Fast-W/Water                   | 41.27                                                           | abc    | 0.00   | d    |
| T10-Acephate trunk implant 15g -Slow-W/Water                  | 87.94                                                           | abc    | 14.39  | abcd |
| T11-Acephate trunk implant 15g -Fast-No Water                 | 50.52                                                           | abc    | 13.69  | bcd  |
| T12-Acephate trunk implant 15g -Slow-No Water                 | 144.48                                                          | abc    | 0.00   | d    |
| T13-Acephate trunk implant 22.5g -Fast-W/Water                | 136.02                                                          | abc    | 13.69  | bcd  |
| T14-Acephate trunk implant 22.5g -Slow-W/Water                | 94.80                                                           | abc    | 0.00   | d    |
| T15-Acephate trunk implant 22.5g -Fast-No Water               | 187.48                                                          | abc    | 42.69  | abc  |
| T16-Acephate trunk implant 22.5g -Slow-No Water               | 46.61                                                           | abc    | 37.53  | abcd |
| T17-Acephate trunk implant 30g -Fast-W/Water                  | 99.40                                                           | abc    | 49.31  | abc  |
| T18-Acephate trunk implant 30g -Slow-W/Water                  | 70.84                                                           | abc    | 56.03  | ab   |
| T19-Acephate trunk implant 30g -Fast-No Water                 | 91.81                                                           | abc    | 56.04  | ab   |
| T20-Acephate trunk implant 30g -Slow-No Water                 | 192.40                                                          | ab     | 56.13  | ab   |
| T21-BlankTrunkImplant -Fast-W/Water                           | 0.00                                                            | d      | 0.00   | d    |
| T22-BlankTrunkImplant -Slow-W/Water                           | 0.00                                                            | d      | 0.00   | d    |
| T24-Acephate trunk implant - 3.75g Fast + 3.75g Slow-No/Water | 42.42                                                           | abc    | 0.00   | d    |
| T25-Acephate trunk implant - 7.5g Fast + 7.5g Slow-W/Water    | 41.99                                                           | abc    | 0.00   | d    |
| T26-Acephate trunk implant - 7.5g Fast + 7.5g Slow-No/Water   | 45.73                                                           | abc    | 8.41   | cd   |
| T27-Acephate trunk implant - 15g Fast + 15g Slow-W/Water      | 57.54                                                           | abc    | 18.87  | abcd |
| T28-Acephate trunk implant - 15g Fast + 15g Slow-No/Water     | 46.22                                                           | abc    | 0.00   | d    |
| T29-Acephate trunk implant - 22.5 Fast + 22.5g Slow-W/Water   | 46.96                                                           | abc    | 36.82  | abcd |
| T30-Acephate trunk implant - 22.5g Fast + 22.5g Slow-No/Water | 34.97                                                           | abc    | 43.07  | abcd |
| T31-Acephate trunk implant - 30g Fast + 30g Slow-W/Water      | 46.90                                                           | abc    | 34.13  | abcd |
| T32-Acephate trunk implant - 30g Fast + 30g Slow-No/Water     | 58.96                                                           | abc    | 57.01  | a    |
| T33-Acephate 75%SP-3.75g                                      | 0.00                                                            | d      | 0.00   | d    |
| T34-Acephate 75%SP-7.5g                                       | 0.00                                                            | d      | 0.00   | d    |
| T35-Acephate 75%SP-15g                                        | 8.90                                                            | bc     | 0.00   | d    |
| T36-Acephate 75%SP-22.5g                                      | 0.00                                                            | d      | 0.00   | d    |
| T37-Acephate 75%SP-30g                                        | 18.77                                                           | abc    | 0.00   | d    |
| T38-Untreated Control - With Water                            | 0.00                                                            | d      | 0.00   | d    |
| T39-Untreated Control - No Water                              | 0.00                                                            | d      | 0.00   | d    |

- 5 \* Means within each column followed by the same letter are not significantly different at  $\alpha = 0.05$  by Turkey's Studentized Range (HSD). Test Data was transformed into log transformation for statistical analysis and actual data was used for this purpose. \*DAT = Days After Treatment

Example 4

Bioefficacy Evaluation of Acephate Trunk Implant Control Release Insecticide (acephate trunk implant) for Bagworm Control in Oil Palm

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The objective of this experiment is to evaluate the field bioefficacy of the trunk implant-controlled release insecticide in controlling bagworm.

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Field bioefficacy studies were conducted whereby treatment was conducted by inserting the trunk implant insecticide into a drilled hole in the palm trunk and the hole was then sealed with a clay plug. The treatment also consisted of the addition of water and without the addition of water in the drilled hole to study the effect of water on the release of acephate from the acephate trunk implant. Treatments were compared against the standard acephate soluble powder formulation. Census for the number of live bagworm larvae per frond (LPF) was conducted at pre-treatment, 7, 14, 21, 28, 42, 56, 70 and 84 days after treatment. The experimental design was Randomised Complete Block Design (RCBD) with 5 single-palm replicates of 8 years old oil palm.

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The results obtained are shown in Table 4. This experiment showed that all the acephate trunk implant formulations at the rate of 7.5, 15, 22.5 and 30 g a.i. per palm was effective in controlling bagworm via the trunk implantation method either with the presence or without the addition of water into the drilled hole until 28 DAT. At 42 DAT, both fast and slow release acephate trunk implant treatments at 7.5 g a.i. per palm showed significantly better control of bagworm (zero live larvae) than Acephate 75%SP soluble powder formulation at 7.5 g a.i. per palm with the presence of water in the hole. There are no significant differences on the effect of bagworm mortality between treatment with water or without water in the hole for acephate trunk implant at 7, 21, 28 and 42 DAT. There were also no significant differences observed at 7, 14, 21 and 28 DAT between the fast release and slow release acephate trunk implant formulation. The optimum-effective treatment of bagworm by acephate trunk implant that was significantly better than Acephate 75% SP was acephate trunk implant at 7.5, 15, 22.5 and 30 g a.i. with both the fast and slow release profile. These results supported the earlier studies done by Chung (1989) (Chung, G.F., "Spraying and trunk injection of oil palm for pest control", The Planter, Vol. 65, No. 764, Nov 1989, pages 500-524) and Lai & Tey (2009) (Lai, C.H., et al., "Evaluation of systemic insecticides for trunk injection against bagworm", Proceedings of the MPOB International Palm Oil Congress (PIPOC) 2009 (Agriculture, Biotechnology and Sustainability), MPOB, pages 450-462) that acephate at 7.5 g a.i. per palm was capable to cause 100% mortality of bagworm at 14 DAT.

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Table 12: Field Bioefficacy Trial Result (7-28 DAT)

| TREATMENT | NUMBER OF LIVE BAGWORM LARVAE AFTER TREATMENTS |       |        |        |        |
|-----------|------------------------------------------------|-------|--------|--------|--------|
|           | PreTrt                                         | 7 DAT | 14 DAT | 21 DAT | 28 DAT |

|                                                              |       |                |       |    |      |       |      |   |      |    |
|--------------------------------------------------------------|-------|----------------|-------|----|------|-------|------|---|------|----|
| T1-Acephate trunk implant 3.75g -Fast-W/Water                | 139.8 | a <sup>z</sup> | 117.2 | ab | 0.2  | e     | 0.2  | b | 0.0  | c  |
| T2-Acephate trunk implant 3.75g -Slow-W/Water                | 141.2 | a              | 57.8  | ab | 0.0  | cde   | 0.0  | b | 0.0  | c  |
| T3-Acephate trunk implant 3.75g -Fast-No Water               | 176.6 | a              | 32.8  | ab | 0.2  | e     | 0.2  | b | 0.0  | c  |
| T4-Acephate trunk implant 3.75g -Slow-No Water               | 164.0 | a              | 107.2 | ab | 0.6  | abcde | 0.6  | b | 0.0  | c  |
| T5-Acephate trunk implant 7.5g -Fast-W/Water                 | 209.8 | a              | 97.6  | ab | 2.2  | e     | 0.0  | b | 0.0  | c  |
| T6-Acephate trunk implant 7.5g -Slow-W/Water                 | 186.6 | a              | 49.0  | ab | 2.2  | e     | 0.2  | b | 0.0  | c  |
| T7-Acephate trunk implant 7.5g -Fast-No Water                | 125.8 | a              | 49.2  | ab | 3.2  | bcde  | 0.0  | b | 0.0  | c  |
| T8-Acephate trunk implant 7.5g -Slow-No Water                | 181.0 | a              | 45.4  | ab | 4.2  | cde   | 0.0  | b | 0.0  | c  |
| T9-Acephate trunk implant 15g -Fast-W/Water                  | 153.4 | a              | 76.2  | ab | 4.8  | abcde | 0.0  | b | 0.0  | c  |
| T10-Acephate trunk implant 15g -Slow-W/Water                 | 153.4 | a              | 56.2  | ab | 2.0  | e     | 0.0  | b | 0.0  | c  |
| T11-Acephate trunk implant 15g -Fast-No Water                | 125.2 | a              | 31.6  | ab | 2.6  | cde   | 0.0  | b | 0.0  | c  |
| T12-Acephate trunk implant 15g -Slow-No Water                | 165.6 | a              | 57.6  | ab | 5.0  | abcde | 0.0  | b | 0.0  | c  |
| T13-Acephate trunk implant 22.5g -Fast-W/Water               | 85.2  | a              | 106.2 | ab | 3.8  | abcde | 0.6  | b | 0.0  | c  |
| T14-Acephate trunk implant 22.5g -Slow-W/Water               | 148.2 | a              | 40.2  | ab | 1.6  | e     | 0.0  | b | 0.0  | c  |
| T15-Acephate trunk implant 22.5g -Fast-No Water              | 155.2 | a              | 74.4  | ab | 1.4  | e     | 0.0  | b | 0.0  | c  |
| T16-Acephate trunk implant 22.5g -Slow-No Water              | 151.0 | a              | 57.4  | ab | 0.8  | e     | 0.6  | b | 0.0  | c  |
| T17-Acephate trunk implant 30g -Fast-W/Water                 | 122.2 | a              | 46.2  | ab | 1.8  | e     | 0.0  | b | 0.0  | c  |
| T18-Acephate trunk implant 30g -Slow-W/Water                 | 181.2 | a              | 57.4  | ab | 2.2  | cde   | 0.4  | b | 0.0  | c  |
| T19-Acephate trunk implant 30g -Fast-No Water                | 144.4 | a              | 55.6  | ab | 1.0  | e     | 0.0  | b | 0.0  | c  |
| T20-Acephate trunk implant 30g -Slow-No Water                | 102.8 | a              | 49.4  | ab | 0.0  | e     | 0.6  | b | 0.0  | c  |
| T21-BlankTrunkImplant -Fast-W/Water                          | 138.0 | a              | 61.8  | ab | 15.6 | abcd  | 5.8  | a | 8.4  | ab |
| T22-BlankTrunkImplant -Slow-W/Water                          | 122.2 | a              | 43.4  | ab | 16.4 | abc   | 6.8  | a | 8.8  | b  |
| T23-Acephate trunk implant -3.75g Fast+3.75g Slow-W/Water    | 160.4 | a              | 61.6  | ab | 5.2  | abcde | 1.0  | b | 0.0  | c  |
| T24-Acephate trunk implant -3.75g Fast+3.75g Slow-No/Water   | 166.4 | a              | 58.4  | ab | 1.4  | e     | 0.0  | b | 0.0  | c  |
| T25-Acephate trunk implant -7.5g Fast + 7.5g Slow-W/Water    | 139.0 | a              | 60.2  | ab | 0.0  | e     | 0.2  | b | 0.0  | c  |
| T26-Acephate trunk implant -7.5g Fast + 7.5g Slow-No/Water   | 152.4 | a              | 23.0  | b  | 1.8  | e     | 0.0  | b | 0.0  | c  |
| T27-Acephate trunk implant -15g Fast + 15g Slow-W/Water      | 137.2 | a              | 65.0  | ab | 0.4  | e     | 0.0  | b | 0.0  | c  |
| T28-Acephate trunk implant -15g Fast + 15g Slow-No/Water     | 143.6 | a              | 49.0  | ab | 8.8  | abcde | 0.0  | b | 0.0  | c  |
| T29-Acephate trunk implant -22.5 Fast + 22.5g Slow-W/Water   | 138.4 | a              | 31.8  | ab | 1.2  | e     | 0.8  | b | 0.0  | c  |
| T30-Acephate trunk implant -22.5g Fast + 22.5g Slow-No/Water | 125.0 | a              | 46.8  | ab | 9.6  | abcde | 1.8  | b | 0.0  | c  |
| T31-Acephate trunk implant -30g Fast + 30g Slow-W/Water      | 126.4 | a              | 39.8  | ab | 0.0  | e     | 0.0  | b | 0.0  | c  |
| T32-Acephate trunk implant -30g Fast + 30g Slow-No/Water     | 137.2 | a              | 60.6  | ab | 3.6  | cde   | 1.6  | b | 0.0  | c  |
| T33-Acephate 75%SP-3.75g                                     | 240.0 | a              | 49.2  | ab | 2.2  | cde   | 0.4  | b | 0.0  | c  |
| T34-Acephate 75%SP-7.5g                                      | 186.4 | a              | 77.2  | ab | 0.2  | e     | 0.0  | b | 0.0  | c  |
| T35-Acephate 75%SP-15g                                       | 155.2 | a              | 67.6  | ab | 0.0  | e     | 0.0  | b | 0.0  | c  |
| T36-Acephate 75%SP-22.5g                                     | 207.0 | a              | 21.4  | ab | 0.0  | e     | 0.0  | b | 0.0  | c  |
| T37-Acephate 75%SP-30g                                       | 181.6 | a              | 36.0  | ab | 0.0  | e     | 0.0  | b | 0.0  | c  |
| T38-Untreated Control - With Water                           | 202.2 | a              | 37.8  | ab | 20.6 | ab    | 14.2 | a | 11.6 | ab |
| T39-Untreated Control - No Water                             | 144.0 | a              | 146.4 | ab | 24.4 | a     | 13.6 | a | 11.8 | a  |

Table 13: Field Bioefficacy Trial Result (42-84 DAT)

| TREATMENT                                                  | NUMBER OF LIVE BAGWORM LARVAE AFTER TREATMENTS |             |              |           |
|------------------------------------------------------------|------------------------------------------------|-------------|--------------|-----------|
|                                                            | 42 DAT                                         | 56 DAT      | 70 DAT       | 84 DAT    |
| T1-Acephate trunk implant 3.75g -Fast-W/Water              | 0.8 de                                         | 6.6 abcdefg | 5.2 abcdefg  | 2.2 bcdef |
| T2-Acephate trunk implant 3.75g -Slow-W/Water              | 1.0 de                                         | 5.6 efgh    | 1.2 efgh     | 0.8 ef    |
| T3-Acephate trunk implant 3.75g -Fast-No Water             | 1.4 cde                                        | 3.4 efgh    | 1.0 efgh     | 0.0 f     |
| T4-Acephate trunk implant 3.75g -Slow-No Water             | 0.0 e                                          | 8.0 fgh     | 0.4 fgh      | 1.4 cdef  |
| T5-Acephate trunk implant 7.5g -Fast-W/Water               | 0.0 e                                          | 1.0 fgh     | 0.4 fgh      | 0.0 f     |
| T6-Acephate trunk implant 7.5g -Slow-W/Water               | 0.0 e                                          | 0.2 efgh    | 1.0 efgh     | 1.0 ef    |
| T7-Acephate trunk implant 7.5g -Fast-No Water              | 0.0 e                                          | 1.2 efgh    | 0.8 efgh     | 0.0 f     |
| T8-Acephate trunk implant 7.5g -Slow-No Water              | 27.6 abcde                                     | 9.8 abcdefg | 5.4 abcdefgh | 3.0 cdef  |
| T9-Acephate trunk implant 15g -Fast-W/Water                | 0.0 e                                          | 1.2 h       | 0.0 h        | 0.0 f     |
| T10-Acephate trunk implant 15g -Slow-W/Water               | 0.0 e                                          | 0.0 cdefgh  | 1.6 cdefgh   | 0.6 ef    |
| T11-Acephate trunk implant 15g -Fast-No Water              | 0.0 e                                          | 0.4 fgh     | 0.6 fgh      | 1.4 ef    |
| T12-Acephate trunk implant 15g -Slow-No Water              | 0.0 e                                          | 0.4 h       | 0.0 h        | 0.0 f     |
| T13-Acephate trunk implant 22.5g -Fast-W/Water             | 0.0 e                                          | 0.0 h       | 0.0 h        | 0.0 f     |
| T14-Acephate trunk implant 22.5g -Slow-W/Water             | 0.0 e                                          | 0.0 h       | 0.0 h        | 0.0 f     |
| T15-Acephate trunk implant 22.5g -Fast-No Water            | 0.0 e                                          | 0.0 fgh     | 0.6 fgh      | 0.8 ef    |
| T16-Acephate trunk implant 22.5g -Slow-No Water            | 0.0 e                                          | 0.0 hh      | 0.0 h        | 0.0 ef    |
| T17-Acephate trunk implant 30g -Fast-W/Water               | 0.0 e                                          | 0.0 defgh   | 2.6 defgh    | 2.4 def   |
| T18-Acephate trunk implant 30g -Slow-W/Water               | 0.0 e                                          | 0.2 bcdefgh | 1.8 bcdefgh  | 1.2 cdef  |
| T19-Acephate trunk implant 30g -Fast-No Water              | 0.0 e                                          | 0.0 fgh     | 0.8 efgh     | 0.4 ef    |
| T20-Acephate trunk implant 30g -Slow-No Water              | 0.0 e                                          | 0.0 fgh     | 0.4 fgh      | 0.6 ef    |
| T21-BlankTrunkImplant -Fast-W/Water                        | 23.4 ab                                        | 17.6 abcd   | 7.0 abcd     | 6.2 ab    |
| T22-BlankTrunkImplant -Slow-W/Water                        | 11.6 abc                                       | 12.4 a      | 10.8 a       | 5.4 abc   |
| T23-Acephate trunk implant -3.75g Fast+3.75g Slow-W/Water  | 7.0 bcde                                       | 0.0 h       | 0.0 h        | 0.0 f     |
| T24-Acephate trunk implant -3.75g Fast+3.75g Slow-No/Water | 0.0 e                                          | 0.0 h       | 0.0 h        | 0.0 f     |
| T25-Acephate trunk implant -7.5g Fast + 7.5g Slow-W/Water  | 0.0 e                                          | 3.0 defgh   | 1.6 defgh    | 0.0 f     |

|                                                              |      |       |      |         |      |         |      |      |
|--------------------------------------------------------------|------|-------|------|---------|------|---------|------|------|
| T26-Acephate trunk implant -7.5g Fast + 7.5g Slow-No/Water   | 0.0  | e     | 5.2  | h       | 0.0  | h       | 1.6  | def  |
| T27-Acephate trunk implant -15g Fast + 15g Slow-W/Water      | 0.0  | e     | 0.0  | h       | 0.0  | h       | 0.0  | f    |
| T28-Acephate trunk implant -15g Fast + 15g Slow-No/Water     | 0.0  | e     | 0.0  | h       | 0.0  | h       | 0.0  | f    |
| T29-Acephate trunk implant -22.5 Fast + 22.5g Slow-W/Water   | 0.0  | e     | 0.4  | h       | 0.0  | h       | 0.0  | f    |
| T30-Acephate trunk implant -22.5g Fast + 22.5g Slow-No/Water | 0.0  | e     | 1.2  | gh      | 0.0  | h       | 0.0  | f    |
| T31-Acephate trunk implant -30g Fast + 30g Slow-W/Water      | 0.0  | e     | 0.0  | h       | 0.2  | gh      | 0.4  | ef   |
| T32-Acephate trunk implant -30g Fast + 30g Slow-No/Water     | 0.0  | e     | 0.0  | h       | 0.0  | h       | 0.0  | f    |
| T33-Acephate 75%SP-3.75g                                     | 6.8  | abcd  | 8.0  | abcd    | 6.6  | abcd    | 3.2  | bcde |
| T34-Acephate 75%SP-7.5g                                      | 7.8  | abcd  | 12.4 | abcd    | 5.2  | abcde   | 6.2  | ab   |
| T35-Acephate 75%SP-15g                                       | 6.4  | abcd  | 8.8  | abcdef  | 4.4  | abcdef  | 5.4  | abc  |
| T36-Acephate 75%SP-22.5g                                     | 4.0  | abcde | 7.6  | abc     | 7.4  | ab      | 4.8  | abcd |
| T37-Acephate 75%SP-30g                                       | 2.6  | bcde  | 10.0 | abcdefg | 6.0  | abcdefg | 7.4  | ab   |
| T38-Untreated Control - With Water                           | 14.4 | abc   | 14.2 | ab      | 8.2  | ab      | 6.6  | ab   |
| T39-Untreated Control - No Water                             | 31.2 | a     | 27.0 | a       | 10.2 | a       | 16.8 | a    |

*\*Means within each column followed by the same letter are not significantly different at  $\alpha = 0.05$  by Turkey's Studentized Range (HSD). Test Data was transformed into log transformation for statistical analysis and actual data was used for this purpose. \*DAT = Days After Treatment*

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### Example 5

Phytotoxicity Effect of Acephate Trunk Implant Control Release Acephate Insecticide (acephate trunk implant) on Oil Palm

- 10 The objective of this experiment is to determine any phytotoxicity effect on the oil palms after the application of the trunk implant into the palm trunk.

Phytotoxicity effect on the palm was conducted and assessed in this Example. Studies was conducted whereby treatment was conducted by inserting the trunk implant insecticide into the drilled hole in the palm trunk and the drilled hole was then sealed with a clay plug. Post treatment census on phytotoxicity were compared against the standard acephate soluble powder formulation. Phytotoxicity effect on oil palm were assessed based on the Phytotoxicity Score Rating Scale at Pretreatment, 7, 14, 21, 28, 42, 56, 70 and 84 days after treatment (DAT). The experimental design was RCBD with 5 single-palm replicates of 8 years old oil palm.

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No phytotoxicity symptoms were observed on the oil palm for all acephate trunk implant treatments based on the assessment in this example. All treatments showed 0% phytotoxicity from 7 to 84 days after treatments.

### Correlation Studies

Table 14 and Figure 3 correlate results from Example 2 and Example 3, and positive and significant correlation between the acephate trunk implant slow release profile in water and the residual content of acephate in oil palm leaves for acephate trunk implant slow release formulation at 7.5g a.i. ( $r=0.89$ ) were observed. The p-value was below the alpha level of 0.05 indicating that the correlation is significant between acephate trunk implant slow release profile data and acephate trunk implant residual content in oil palm leaves. Therefore, it was concluded that there was a significant relationship between acephate trunk implant release profile data

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and acephate trunk implant residual content in oil palm leaves. These confirmed the slow release profile and mechanism of release of the acephate trunk implant in oil palm trunk.

Table 14: Correlation of Acephate Trunk Implant Release Profile and Residual Effect in Oil Palm Leaves

| Correlation of Acephate Trunk Implant Experiments | 7 DAT   | 14 DAT  | 28 DAT  | 42 DAT  | 56 DAT  | 72 DAT  | r =  |
|---------------------------------------------------|---------|---------|---------|---------|---------|---------|------|
| Acephate trunk implant 7.5g- Slow profile study   | 214.06  | 163.87  | 29.79   | 29.06   | 17.51   | 12.51   | 0.89 |
| Acephate trunk implant 7.5g – Slow W/Water        | 0.07310 | 0.04280 | 0.02345 | 0.03382 | 0.00000 | 0.00000 |      |

In another analysis (Table 15 and Figure 4), there were moderate to strong correlation between the acephate trunk implant residual content of acephate in oil palm leaves for acephate trunk implant slow release formulation at 7.5g a.i. and acephate trunk implant bagworm control (live larvae count) ( $r=0.78$ ). The analysis showed the presence of acephate in oil palm leaves has indicated and caused the mortality to the bagworm in the palm canopy over a period or prolonged release of the actives.

Table 15: Correlation between Acephate Trunk Implant Effect on Live Larvae Count Profile and Acephate Trunk Implant & Residual Effect in Oil Palm Leaves

| Treatment                                                                       | 7 DAT   | 14 DAT  | 28 DAT  | 42 DAT  | 56 DAT  | 72 DAT  | r =      |
|---------------------------------------------------------------------------------|---------|---------|---------|---------|---------|---------|----------|
| Acephate trunk implant 7.5g- Slow- W/Water – Residue content in oil palm leaves | 0.07310 | 0.04280 | 0.03382 | 0.00000 | 0.00000 | 0.01546 | r = 0.79 |
| Acephate trunk implant 7.5g – Slow W/Water – Bagworm live larvae count          | 49.0    | 2.2     | 0.0     | 0.2     | 1.0     | 1.0     |          |

### Conclusion

It was inferred that Acephate Trunk Implant Controlled Release Insecticide (acephate Trunk Implant) was capable to cause significant satisfactory mortality of bagworm and capable to prolong the period of insecticide active release in the palm trunk and period of control of the bagworm up to 42 days after treatment. Among the novel findings of the studies were the ability and the mechanism of acephate trunk implant formulations that were capable to release the acephate active ingredients in a controlled mechanism into the palm trunks and leaves up to 42 to 84 days after treatment. Acephate trunk implant proved to be fully biodegradable, water soluble and able to release acephate in the slow and control mechanism in the presence of moisture with no phytotoxicity effect on the oil palm. The released profile, mechanism of action and bioefficacy of the acephate trunk implant were determined in these research experiments.

The above is a description of the subject matter the inventors regard as the invention. It is envisioned that those skilled in the art may and will design alternative embodiments that fall within the scope as set forth in the following claims.

## Claims:

1. A controlled release trunk implant formulation for eradicating and/or controlling pest in a tree and/or treating the tree, comprising:
  - 5 at least one water soluble polymer present in an amount of from 5 to 60 wt%, wherein the at least one water soluble polymer is selected from the group consisting of alginic acid, carrageenan, cellulose ether, chitosan, dextran, gelatin, hyaluronic acid, pectins, polyacrylamide, polyacrylic acid, polyvinyl alcohol, polyvinylpyrrolidone, polysaccharide, pullulan, starch, salts thereof, copolymers thereof and blends thereof;
  - 10 at least one plant treatment agent present in an amount of from 1 to 90 wt%, wherein the at least one plant treatment agent is selected from the group consisting of pesticides, insecticides, biocides, fungicides, bacteria, enzymes and nutrients;
  - at least one binder present in an amount of from 4 to 60 wt%, wherein the at least one binder is selected from the group consisting of substances with OH moiety, polar solvents and mixtures thereof;
  - 15 one or more excipients; and
  - a crosslinking agent that crosslinks the at least one water soluble polymer, wherein the binder allows for room temperature processing of the polymer.
2. The controlled release trunk implant formulation according to claim 1, wherein
  - 20 the at least one water soluble polymer is present in an amount of from 7.5 to 40 wt%;
  - the at least one plant treatment agent is present in an amount of from 30 to 85 wt%;
  - the at least one binder is present in an amount of from 10 to 40 wt%; and
  - the one or more excipients is present in the remaining amount.
- 25 3. The controlled release trunk implant formulation according to claim 1 or 2, wherein the at least one water soluble polymer comprises a first polymer and a second polymer, wherein the first polymer is present in an amount of from 50 to 99 wt% and the second polymer is present in an amount of from 1 to 50 wt% based on the total amount of water soluble polymer present in the trunk implant formulation.
- 30 4. The controlled release trunk implant formulation according to claim 1 or 2, wherein the trunk implant formulation further comprises one or more additives and/or excipients selected from the group consisting of preservative, lubricant, defoamer, surfactant, filler, and colorant.
5. A controlled release trunk implant comprising a formulation according to any one of the preceding claims, wherein the trunk implant is in the form of a tablet, pellet, block, rod, or granulated particles.
- 35 6. A controlled release trunk implant comprising:
  - at least one water soluble polymer present in an amount of from 5 to 60 wt%, wherein the at
  - 40 least one water soluble polymer is selected from the group consisting of alginic acid, carrageenan,

cellulose ether, chitosan, dextran, gelatin, hyaluronic acid, pectins, polyacrylamide, polyacrylic acid, polyvinyl alcohol, polyvinylpyrrolidone, polysaccharide, pullulan, starch, salts thereof, copolymers thereof and blends thereof;

at least one plant treatment agent present in an amount of from 1 to 90 wt%, wherein the at least one plant treatment agent is selected from the group consisting of pesticides, insecticides, biocides, fungicides, bacteria, enzymes and nutrients;

at least one binder present in an amount of from 0.01 to 10 wt%, wherein the at least one binder is selected from the group consisting of substances with OH moiety, polar solvents and mixtures thereof;

one or more excipients; and

a crosslinking agent that crosslinks the at least one water soluble polymer; and

wherein the trunk implant is provided in the form of a tablet, pellet, block, rod, or granulated particles and is fully water soluble.

7. The controlled release trunk implant according to claim 5 or 6, wherein the trunk implant is prepared to release the at least one plant treatment agent over a period from 5 to 90 days.

8. The controlled release trunk implant according to claim 7, wherein the trunk implant is prepared to release the at least one plant treatment agent over 10 to 70 days.

9. The controlled release trunk implant according to claim 7, wherein the trunk implant is prepared to release the at least one plant treatment agent over 15 to 45 days.

10. The controlled release trunk implant according to claim 7, wherein the trunk implant is prepared to release the at least one plant treatment agent over 20 to 30 days.

11. The controlled release trunk implant according to claim 6, wherein the water soluble polymer comprises a first polymer and a second polymer, wherein the first polymer is present in an amount of from 50 to 99 wt% and the second polymer is present in an amount of from 1 to 50 wt% based on the total amount of water soluble polymer present in the trunk implant formulation.

12. The controlled release trunk implant according to claim 6, wherein the formulation further comprises one or more additives and/or excipients selected from the group consisting of preservative, lubricant, defoamer, surfactant, filler, and colorant.

13. A method of producing a controlled release trunk implant for eradicating and/or controlling pest in a tree and/or treating the tree, the method comprising:

(a) providing a trunk implant formulation comprising:

at least one water soluble polymer selected from the group consisting of alginic acid, carrageenan, cellulose ether, chitosan, dextran, gelatin, hyaluronic acid, pectins,

polyacrylamide, polyacrylic acid, polyvinyl alcohol, polyvinylpyrrolidone, polysaccharide, pullulan, starch, salts thereof, copolymers thereof and blends thereof;

at least one plant treatment agent selected from the group consisting of pesticides, insecticides, biocides, fungicides, bacteria, enzymes and nutrients;

5 at least one binder selected from the group consisting of substances with OH moiety, polar solvents or mixtures thereof;

one or more excipients; and

a crosslinking agent that crosslinks the at least one water soluble polymer in the mixture; and

10 (b) extruding the formulation at room temperature; and

(c) shaping and/or cutting the extrudate to form a controlled release trunk implant.

14. The method according to claim 13, wherein the binder is in an amount of from 4 to 60 wt% based on the total weight of the formulation.

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15. The method according to claim 13, wherein the trunk implant formulation further comprises one or more additives and/or excipients selected from the group consisting of preservative, lubricant, defoamer, surfactant, filler, and colorant.

20 16. The method according to claim 13, wherein the trunk implant formulation comprises:  
the at least one water soluble polymer in an amount of from 5 to 60 wt%;  
the at least one plant treatment agent in an amount of from 1 to 90 wt%;  
the at least one binder in an amount of from 4 to 60 wt%; and  
one or more excipients.

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17. The method according to claim 13, wherein the trunk implant formulation comprises:  
the at least one water soluble polymer in an amount of from 7.5 to 40 wt%;  
the at least one plant treatment agent in an amount of from 30 to 85 wt%;  
the at least one binder in an amount of from 10 to 40 wt%; and  
30 the one or more excipients present in the remaining amount.

18. The method according to any one of claims 13 to 17, further comprising:  
drying the controlled release trunk implant to remove the binder from the controlled release trunk implant.

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19. The method according to claim 18, wherein the controlled release trunk implant comprises:  
at least one water soluble polymer in an amount of from 5 to 60 wt%;  
at least one plant treatment agent in an amount of from 1 to 90 wt%;  
at least one binder in an amount of from 0.01 to 10 wt%; and  
40 one or more excipients.

20. The method according to claim 13 or 19, wherein the controlled release trunk implant is in the form of a tablet, pellet, block, rod, or granulated particles.

5 21. A method of eradicating and/or controlling pest in a tree and/or treating the tree, the method comprising:

inserting a controlled release trunk implant as claimed in any one of claims 5 to 12 into a hole drilled into a trunk of a tree to provide a continuous release of the plant treatment agent to the tree; and optionally sealing the hole;

10 wherein the hole is moist on the inner region of the hole.

22. The method according to claim 21, wherein the controlled release trunk implant is configured to provide a continuous release of the plant treatment agent for 30 to 90 days.

15 23. The method according to claim 21 or 22, wherein the controlled release trunk implant completely dissolves at the end of treatment period of the tree.