

Spinosad for Plant Protection from Thrips in Controlled Environment AgroEcosystem(s)

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Abstract: Although synthetic chemical controls have reigned in popularity for agricultural pest control (and subsequent plant protection) since their advent near the end of WWII (late 1940's A.D.) many people are (re)realizing the potential and efficacy that microbe and botanically derived products offer, coupled with their typically increased benefits to human and environment health over the more traditional synthetic conventional alternatives. Greenhouses and other controlled environments where crops are produced tend to have a majority of plants at the high end of value continuum (vegetables, ornamentals, etc.) that are of value not (only) for their quantity (from such efficient production in modern systems) but their quality (the ornamentals, vegetables, fruits, and other direct market sale fresh produce much more so as compared to many agronomic crops). Integrated pest management broadly and entomopathogenic control (applied in same manner (and with much the same equipment) as chemical control) specifically (from natural sources, more specifically, and Spinosad even more specifically from soil bacterium) is needed in order to maintain this (high) level of pest (and vector) control, so both direct and indirect damages from the pest won't hurt the value of the marketable commodity. This report will focus however on the control of thrips (*Thysanoptera*) which (typically) are thought of as r-selected pests that cause direct damage to plants by feeding (in large numbers) but can also vector viruses (such as TSWV) that cause a high amount of damage, at (relatively) low(er) level of pest population.

Keywords: Integrated Pest Management (IPM), Entomopathogenic Control, Microbials, Controlled Environment Agriculture (CEA), Spinosad, Greenhouse, Vector

Introduction:

Pest Problem: One of the pests that are of greatest importance in the greenhouse setting would be the order *Thysanoptera*, commonly referred to as 'Thrips'. It is thus essential that such pests / vectors are controlled in order to avoid horizontal and vertical transmission of such carried pathogens that cause disease to (other) crops in the agroecosystem. Entomopathogenic and / or botanically derived alternatives to conventional chemical control offer the rapid response and efficacy needed for immediate action if certain disease vectoring pests are monitored. Microbially derived insecticides offer a further plethora of benefits over their (overly) depended on synthetic counterparts. Spinosad will be discussed in greater detail as it relates to the control of plant damaging vectors and pests in controlled environment agriculture.

Thrips will be the main pests of focus as due to their common abundance across many CEA agroecosystems; greenhouses will be the main setting of focus but the spectrum of artificial(y modified) environments ranging from growth chambers (whole room or cabinet-style) to (raised) row cover (style) ‘hot-houses’ will be explored Thrips are devastating to plants in an artificial environment because conditions are (usually near) perfect all year round in order for the crops to be produced, hence the point of the controlled environment. While this is beneficial for the producer versus traditional field agriculture certain issues are presented with temporal shorting of the growing season due to climatic conditions at certain parts of the year (typically cold or dry weather). This creation of the controlled environment (and the maintenance of such) allows for a lack of diapause that is typically found in Nature (Bethke 2014). This diapause is Mother Nature’s way of (quasi-culturally) curtailing pest populations in a cyclic repeating fashion each year dependent on the seasonal changes created as the Earth revolves around the Sun. Controlled environments lacks this (natural) diapause, thus allowing for many r-selected species like thrips and mites to explode in population (and maintain such high level of pest status), due to lack of (natural (or artificially induced)) ‘checks’ lowering the pest population. While some physical (fire, flame, etc.) and cultural (tillage, plowing, etc.) control practices may be more abundant in field-based agriculture versus CEA, there are often many that are not able to be practiced outright in the same manner in CEA as the setting is vastly different.

Pest Biology: The main *Thysanoptera* of interest as pests in the controlled environment setting are the ‘Greenhouse thrips’ (GHT) (*Heliothrips haemorrhoidalis*) and the ‘Western flower Thrips’ (WFT) (*Frankliniella occidentalis*); the latter tends to be brown(er) in color and the former black(er) in color, but such varies from white to yellows, browns, red, etc. to black depending on growths age and environment (UC-IPM 2010). Both species of main interest are rather small in

size, having a ‘slender’ shape; WFT can develop best (most rapidly) at round 80-85 F (typical of the settings of most olericulture production in CEA) hatching in about 3 days and then completing two larval instars that are “veracious eaters”, thus causing much of the ‘stippling’ and ‘streaking’ damage that is traditional of the direct damage seen on ornamentals and other high value produce agricultural commodities (Swier 2014 & Bethke 2014). Before pupation occurs the pest travels from the plant where it originated from being deposited as an egg and lived as a larva, to the soil where two stages of pupa then occur, wings are developed, etc. (Swier 2014). It is important to remember how small these insects are and that they can survive in many cracks, crevices, etc. of the CEA that are typically not monitored or controlled (in the same fashion or extent) as the main area where crops are produced; lack of adequate cultural control (sanitation, temperature, etc.) leads to conditions on benches, floors, and other operational sites that are more susceptible (/ favorable) to the establishment of thrips as food, shelter, and other necessary requisites for survival are provided to them in such. The needed requisites for their biological development would simply not be present if cultural control were practiced effectively and efficiently. There is often a hindrance created by capital, labor, or time constraints that don’t allow the aforementioned (simple) solution to come into (full) effect.

Pest History: Plant pests have been a reoccurring problem throughout much of (written – the ‘victors write history’; / recorded – not much in the grand scheme of things) history, as evident by the numerous bible verses, such as “Do not lie up your treasures in barns where moths will rot, rust will destroy, and thieves will steal” (*John 19:21*), among many other historical and religious writings that showcase the high level of importance such have had in human civilization’s (/ culture’s) development. Controlled environments are much more recent in the physical sense of the term, but humans have been doing essentially that (modifying the environment to reduce pest

status and related direct and indirect damage from such on humans, livestock, and crops) for millennium now in order to better control pests and produce (more) abundant high(er) quality food, feed, fiber, fuel, medicine, etc. The Romans (and probably thus the Etruscans and Greeks among others before them) are recorded as having glass(style)houses for vegetable production in the BC era (before their (re)'invention' in the Netherlands in the 1600's AD); the emperor Tiberius dabbling in the first recorded acts of controlled environment in order to produce (more favorably) cucumbers (by brining them inside and out multiple times a day to achieve best growing conditions) (Mattson 2022). Humankind (and agriculture) has come a long way since then and CEA is now even one (/many) steps beyond greenhouse style production developed by generations of *avant-garde* agriculturalists; advances in modern technology have allowed for control of temperature, humidity, ventilation, atmospheric composition, irrigation, fertigation, chemical application, etc. The advent of lighting and the addition of this to greenhouses (originally termed 'electro-culture' is really what created the modern CEA concept (/ era), as this (artificial lighting) was the last real input (/ environmental modification) that humans had yet to be able to induce in their CE (Mattson 2022). Lighting allows for the growing 'season' not just to be warmer and longer but the 'days' to be extended as well (not just the 'years').

One of CEA's best assets is the physical (preventative) control it provides (barrier, screening, etc. from pests in the outside environment and therefore the better conditions that are created to practice cultural control (the foundation / base of the IPM pyramid) and the lesser need to practice chemical and biological control (as pests from the outside should be kept out by the physical construction of the CEA). Biological control tends to work well in the inoculative approach in a CEA, as opposed to the (more costly and time / capital consuming) augmentative approach that is more typical in outdoor agroecosystems. It's these (more) recent advances in the

history of CEA that essentially allow producers to practice production on a scale of quality and quantity (year-round with less labor, as a result of the CE) that was for countless generations simply unfathomable. It is then chemical, biological, or entomopathogenic control that has to be implemented however when the populations of thrips explode, due to the aforementioned lack of diapause inherently created by the (same) CE (that is designed to benefit plants by keeping pests out).

WFT are found naturally in what is today termed Southeastern part of the United States of America, however it is the rapid commercial trade of plant material that has created them to be an introduced pests to (multiple) other areas (Clarke 2000). Once the pest is introduced to an CE there is often a lack of natural enemies, predators, parasites, or parasitoids to control such, and one can be falsely alluded into a sense of (pest control and plant protection) security due to the high level of physical and cultural control (supposedly) created by the CE. It is very important to keep in mind that all these physical and cultural controls of CEA that keep pests out, work in much the same fashion and effect in keeping pests in when they are introduced (internally) to the CEA agroecosystem. Thus, is then chemical or entomopathogenic control, often in the form of Spinosad that is needed to control these devilish pests and protect all to important plants (of which they damage).

Pest Monitoring: Weekly relative sampling should be conducted in order to get a sense of what the pest population is like in order to therefore guide microbial / entomopathogenic application(s) of Spinosad (or other pest controlling substances) for the curtailing of such pests. While it is not necessary to have an absolute count in most production settings (and often wasteful in time, capital, and labor if pursued), a relative count allows for location of pest to be determined as well. Sticky cards work great when placed singly above or on growing benches or rooms to give a qualitative

(and somewhat quantitative) sense of the pest population levels. Comparing these counts (geographically) can allow for more judicious use of microbials or chemicals and give the applicator a greater sense of where specifically control should be conducted (and to what level).

As thrips are r-selected species it (typically) takes a somewhat vast amount of them to cause (visible) damage to the crop. Greater monitoring and control will be needed if the value of the crop dictates such; ornamental flowers can often not develop from thrips feeding on the buds and vegetables are often quickly damaged due to a drop in values caused the direct (aesthetic) damages (Bethke 2014). This alone highlights the much lower threshold for many of the crops in CEA as compared to typical temperate or tropical outdoor agronomic crop production. Other methods of monitoring can be as simple as direct observation (often under leaves), as well as shaking a plant over a white piece of paper and observing / counting the thrips that fall there with on. Monitoring should be done throughout the facility (internal and external), and not just in areas where crops are produced, it's often these overlooked areas that can serve as refuge points for population to always be ready for population resurgence (after control is attempted in the rest of the agroecosystem).

Pest Impact: Damage to plants from arthropods can be direct from pests feeding but also, and sometimes much more importantly, indirect from vectors and the diseases caused by the pathogens they transmit. While thrips often cause the former and this is what dictates the need for control in most ornamental and vegetable CEA settings, it's the latter that can also be of greater concern when dealing with vegetatively propagated crops that can then vertically transmit these viruses when used or traded elsewhere and used for propagation. The viruses themselves also cause direct damage to the crop, and thus hinder the ability to take such to market. The viruses that of main interest when dealing with thrips as vectors are *Tomato Spotted Wilt Virus* (TSWV) and *Impatiens Necrotic Spot Virus* (INSV). The latter is devastating to vegetables like lettuce and tomato and the

former causes harm to its namesake among other *Solanum* species of economic importance (i.e.: Potato (*Solanum tuberosum*) & Eggplant (*Solanum melongena*), as well as other crops like floral ornamentals (Bethke 2014). Control of these pests is necessary to avoid such damages and the substance Spinosad derived from soil bacterium allows for such control in an environmentally friendly fashion, and thus is a viable alternative to many synthetic conventional chemicals that would be used in the same manner for the same (intended) effect.

Option / Implication 1: Spinosad Background

Spinosad has many benefits over traditional conventional chemical insecticides. One of the largest of such being that it is (relatively) environmentally friendly and has a high(er relative) specificity for what is controlled; there is no (known) toxicity to mammals, vertebrates, and some beneficial insects. Spinosad is sourced from the soil bacterium *Saccharopolyspora spinosa*, and is a combination of the A & D forms typically in a ~ 17:3 ratio, however many other synthetic and natural forms exist; the original isolation of the product happening near a sugar cane mill (Mertz 1990). Spinosad first became commercially available and registered in the USA in the year 1997 and since then has seen much use for control of the *Thysanoptera*, *Diptera*, *Lepidoptera*, *Coleoptera*, etc. pests both in the traditional field setting(s) and in indoor CEA agroecosystems (Sparks 2012). Since then, resistance has occurred due to its overuse in some dense spatial areas over a (relatively) short time period.

Other uses beyond agricultural production are to be noted however such as in the use in stored grain setting to prevent *Coleoptera* and *Lepidoptera* among other pests (Hertlien 2011). Medical and veterinary uses of Spinosad have documented as well, such as with control of head lice (*Pediculus humanus capitis*) in humans (*Homo sapiens sapiens*) and with the control of cat fleas (*Ctenocephalides felis*) in domesticated house cats (*Felis catus*) (Villegas 2012 & Paarlberg

2013). Deeper much though is their use in agriculture, especially in the production setting, as opposed to the few medical and veterinary uses just mentioned. This substance is favored by greenhouse and controlled environment producers because of its specificity but also because of its ability to be naturally sourced and its relatively novel mode of action (MOA). All of these advantages are seemingly advantageous but cause problems in their own right (as like anything else) when a (single) substance is overused (without substitution, alteration, or in combination with an integrative multi-tactic IPM approach). This can occur even more rapidly among 'organic' growers or those under even stricter protocols as to what chemical to apply. The safety of the pesticide however can be evidently seen from the applicator and consumer standpoint as well as the REI is only 4 hours (as typical of most low-toxicity chemicals) and the PPE required for applicators is only required at a long sleeve shirt, pants, boots, and socks (typical of most non-applicators often), as when used as Conserve SC (one of the more popular versions of this substance for use on ornamentals and turf) (Conserve SC Label).

Spinosad is rather effective because its MOA is novel in the grand scheme of pesticides, only being isolated and used commercially towards the end of the last century (/ millennium). It poisons the insect by contact and ingestion. In simple terms, Spinosad A is the more effective form, however the D form is better at penetrating into the insect, thus a combination is used (typically 17:3 (A:D) as aforementioned). The MOA is essentially the Spinosad acting as a GABA antagonist, causing the Chloride (Cl^-) current to be altered; there is then this created 'rundown' style effect, somewhat equivalent or likened to that of Ivermectin's effect (Walston 2001).

Option / Implication 2: Thrips as Pests in CEA & the use of Spinosad to Correct

Thrips feeding cause damage to plants directly. Plants at the high end of the value continuum (typically horticultural crops) found in CEA have a lower threshold for damage and thus a lower threshold for triggering applications of substances to help control such and reduce pest status. Numerous cases have been reported across CEA where thrips are controlled with the use of Spinosad, including but definitely not limited to the references included within this report.

When thrips feed, they cause direct damage to the plant that results in a silver(y) streaking appearance on the foliage; this coloration is due to the action of their feeding (which is a result of their ‘piercing-sucking’ mouthparts), as the plant(‘s (mesophyll) cell(s) (internals) are drained of their contents (which is now the thrip’s meal) while air (comes in to) replace(s) the contents of the cells creating the ‘shriveled’ silver appearance this is the typical symptom of thrip damage on foliar plant parts (Childers 1997 & Reitz et al. 2020). Saliva is also secreted by the thrips as they feed which can cause direct plant damage, easily to sensitive crops such as vegetables and ornamentals (visual observation from personal agronomic experience(s)). It is this saliva that helps with degrading plant internal cellular components (biological building blocks) such as proteins and sugars, and then makes such (more) available to the thrips in a ‘soupy mess of a meal (Stafford-Banks et al. 2014). While thrips are polyphagous in their diet and tend to not be picky about what (plants) they choose to eat, they are much like humans in that they will go for whatever is the ‘best’ food source first. Some studies have shown that Strawberry (*Fragaria x ananassa*) is the most preferred plant by thrips among other common agricultural crops and weeds in agroecosystems; much like humans the thrips will go for the ‘good tasting’ strawberries much before they feed on ‘weeds’ (or crops in the case of *Nicotiana tabacum*) such as *Nicotiana* and other plants which are simply not as ‘tasty’, and have greater expression of natural endogenous chemical resistance to

deter pests) (Reitz et al. 2020 & Rahman et al. 2010). Host location / selection and the related determination / choice of where to land is guided by a multitude of factors.

Thrips locate the plants they choose to feed on through locomotive movement that is guided by cues in the agroecosystem. These would include but are certainly not limited to color / light, shape of the host (plant), volatiles which are received by chemoreceptors of / on the thrips; also, not to be overlooked are the physical condition (health status) and physiological condition (age) of both the thrips and the plants they are (intending) to feed on (Reitz et al. 2020, Cao et al. 2018, Davidson et al. 2006, Mainali et al. 2011, & Roth et al. 2016). Thrips in the adult stage even have the ability to distinguish between the stage of plant growth of a particular species and choose what species or growth stage is best for different life practices such as oviposition or feeding (Ripa et al. 2009). All these factors work cumulatively to help the thrips find the host; however, movement can be thought of as less ‘directed’ than most other insect species (due to the broadly phytophagous feeding nature of the thrips), which can be a good or bad thing depend on the context of the production situation or where the agroecosystems is (located), among (a multitude of) other factors.

Feeding causes direct damage that results in yield loss from the plant being ‘drained’ of their contents, creating a wound where a secondary infection can than amount from the entry of foreign pathogens (fungi, bacteria, viruses, etc.), as well as the possible transmission of pathogens (viruses) that causes disease directly from the thrips themselves (Reitz et al. 2020 & Farrar et al. 1991). It is thrips thus then as a vector, not as a pest, that will be explored next.

Option / Implication 3: Thrips as Vectors in CEA - (Focus on Viruses)

Thrips can be vectors (not solely pests) that transmit the viral pathogens or *Tospoviruses* in the family *Bunyaviridae*; these include both Tomato spotted wilt virus (TSWV) & Impatiens necrotic spot virus (INSV). It is not the adults but the larvae that are (the) acquirers (from plants) of the virus(es), however the latter can evolve into the former and both such can then be carriers, the former being the transmitter (to plants) (Ullman 2002). Controlling thrips to a level where vectors are absent and transmission of the pathogens is then so too, is practically and economically difficult, even with the advances in physical control introduced in CEA. Indirect damage caused by the transmission of virus to plants by thrips is financially estimated at \$100 – 200 million per year alone in the USA (Culbreath et al. 2003). The control of thrips is necessary to avoid these economic losses, which will only increase without such control. The difficulty in controlling thrips as vectors is extrapolated by their short (re)generation time, ability to develop resistance to chemicals rather quickly, and their rather minute size (ability to shelter in hidden places and thus inability (or increased difficulty) for adequate control); other contributing factors to thrips as being excellent vectors of plant viruses include their polyphagous diet (not picky about what plants they feed on), as well as their high level of fecundity (essentially females are very fertile and thus fruitful in their ability to have a large capacity of young (offspring), helping to increase pest density to levels that dictate (need for) control rather quickly) (Rotenberg et al. 2015). Their (thrips) rather transient nature and high level of movement is (/are) also (a) contributing factor(s) to the ability of thrips to be plant pest and vectors of pathogens (viruses) which cause plant disease.

Thrips transmit tospoviruses not in a non-persistent manner but rather in a persistent manner, where the virus is retained in the insect's hemolymph for an extended period of time, before transmission occurs (Rotenberg et al. 2015). As earlier mentioned it is the pupae that acquire

the virus and can develop such in a somewhat ‘propagative manner’ inside them until transmission is able to occur as adults; the adults may acquire virus from feeding on infected plants but will not be able to transmit such to healthy plants, as the virus has not undergone the full developmental period within the insect that is necessary for transmission (to plants) to occur, it is these ‘adults’ however who are the ‘main transmitters’ of the viruses much due to their high locomotive activity (stemming from having usable wings, as compared to earlier life stages (who don’t)) (Rotenberg et al. 2009 & Montero-Astua et al. 2014). Thrips with a higher level (titer) of the virus will be more effective transmitters of such; the virus(es) replicate within the thrips midgut and salivary glands and move from the former to the latter (and vice-versa) via a conduit-like tubular salivary gland which ‘provides the [needed internal physiological /anatomical) pathway [to allow for] viral dissemination’ (Rotenberg et al. 2015).

The Tospoviruses are the main genus of concern, when dealing with thrips (*Thysanoptera*) as vectors that can transmit viruses to plants; these would include but are not limited to *Alstroemeria necrotic streak virus* (AINSV), *Bean necrotic mosaic virus* (BeNMV), *Calla lily chlorotic spot virus* (CCSV), *Capsicum chlorosis virus* (CaCV), *Chrysanthemum stem necrosis virus* (CSNV), *Groundnut bud necrosis virus* (GBNV), *Groundnut chlorotic fan-spot virus* (GFSV), *Groundnut ringspot virus* (GRSV), *Groundnut yellow spot virus* (GYSV), *Hippeastrum chlorotic ringspot virus* (HCRV), *Impatiens necrotic spot virus* (INSV), *Iris yellow spot virus* (IYSV), *Melon severe mosaic virus* (MSMV), *Melon yellow spot virus* (MYSV), *Pepper necrotic spot virus* (PCSV), *Polygonum ring spot virus* (PoIRSV), *Soybean vein necrosis virus* (SVMV), *Tomato chlorotic spot virus* (TCSV), *Tomato necrotic ringspot virus* (TNRV), *Tomato necrosis virus* (TNeV), *Tomato spotted wilt virus* (TSWV), *Tomato yellow (fruit) ring virus* (TYRV), *Tomato zonate spot virus* (TZSV), *Watermelon bud necrosis virus* (WBNV), *Watermelon silver*

mottle virus, (WSMoV), and *Zucchini lethal chlorosis virus* (ZLCV) (Reitz et al. 2020 & Rotenberg et al. 2015). As with all matters of biological discoveries and botanical-entomological-pathological scientific confirmations, this is a list that is ever changing and will be added to as more (re)(searching) scientific pursuits are undertaken.

The species of thrips that are documented as to be vectors able to transmit plant viruses include, but are probably not limited to the following: *Ceratothripoides claratris*, *Dictyothrips betae*, *Frankliniella bispinosa*, *Frankliniella cephalica*, *Frankliniella fuscica*, *Frankliniella gemina*, *Frankliniella intonosa*, *Frankliniella occidentali*, *Frankliniella schultze*, *Frankliniella zucchini*, *Neohydatothrips variabilis*, *Scirtothrips dorsalis*, *Thrips tabaci*, *Thrips palmi* and *Thrips setosus* (Reitz et al. 2020, Rotenberg et al. 2018, & Rotenberg et al. 2015). As with all matters of ‘novel’ biological ‘discovery’, this is a list that is not static and will be added to as human knowledge increases in space through time.

Another virus known to be transmitted to plants by the vector thrips (*Thrips tabaci*) is *Tobacco Streak Virus* (TSV); it is important to note however that such results were experimental and resulted from thrips being exposed to pollen and used to mechanically inoculate (transmit) *Chenopodium amaranticolor* (wild relative to the edible grain Quinoa (*Chenopodium quinoa*) plants (Sdoodee et al. 1987). This (just mentioned) reference highlights the issue that pollen borne virus can present, especially with an r-selected species which can grow abundantly in population and mechanically transmit such.

At the end of the day, it is often these diseases that develop within plants as caused by the pathogens transmitted by the thrips as vectors, that can be more indirectly damaging than the direct damage caused by these same species (on the same plants) from (direct) feeding. Therefore, control of thrips may need to be at a level that is below what is thought typical of normal economic

threshold when crops are at the higher end of value continuum and / or more susceptible to being damaged by the viruses in which (the) thrips (in the same agroecosystem) transmit. As in most cases of pest control and plant protection, a combinational IPM approach is needed; Spinosad alone will not be an effective tool against thrips as vectors (or pests) and will soon not be a tool, but rather an enemy when used too much. Like with all IPM plans, especially in controlled environment agricultural, cultural control should be the pyramid base / cornerstone that all other practices then build off of. As one moves up this pyramid (towards the use of biorationals and botanical and other biologically derived insecticides) the toxicity will tend to increase, and the selectivity will decrease; the ability to prevent becomes the need to intervene.

Conclusion: *Spinosad as a Single Prong of the Greater 'PitchFork of IPM'*

When first arriving on the market (and on the pest control scene) Spinosad was thought of as a 'miracle' compound that was biologically derived and environmentally safe. After years of (mis)use it has been shown both in the field ('real-World') and in the laboratory ('academia') that this may (and is probably not) the case in some situations. Resistance can develop in the pest intending to be controlled, as well as the harmful (environmental) effects, more specifically being the damage caused to natural enemies and biological control agents, as documented previously. While thrips cause much damage to crop in controlled environments, their high status as pests will not decrease with use of Spinosad alone. In order to avoid the damage that thrips cause to crops in controlled environments Spinosad will, have to be used in a Swiss-Army Knife approach and be just one more 'tool in the toolbox' (of plant protection).

Thrips can be best controlled in controlled environment agroecosystem, as in any other, through a combination of tactics and these would include sanitation, residue removal, using new

materials (instead of reusing old ones), blackout currents (to obscure lighted areas at nights and thus positive phototaxis of thrips), physical control to prevent entry (into the growing facility), clothing that is not attractive ((to the pests) (no yellow, green, or blue)), air currents (from HAF fans) to discourage locomotion and disrupt physical ability to transverse foliage, among other preventive tactics (Williamson 2004 & Personal Experience). Chemicals (beyond Spinosad) that can control thrips and thus that can be used when intervention is needed include, but are not limited to, *acephate*, *carbamate*, *imidacloprid*, *neonicotinoids*, *organophosphate*, *thiamethoxam* and *thiodicarb* (ALWAYS READ LABEL; geography (helps) determines legality of chemical use in many situations) (Greene et al. 2020). Botanicals or microbially derived insecticides that are often used in combination with or as alternatives to Spinosad include but are not limited to: *azadirachtin* (from the Neem tree), pyrethrin (from *Chrysanthemum spp.*), nicotine (from *Tabacum spp.*), etc. (Vassiliou 2011). In controlled environments temperature can often be modified (although albeit expenses) to temperatures (>140 F) well above what most biological life can survive (for extended periods of time) (this is even easier in the semi-controlled environments of greenhouses (from their namesake effect)), in order to create an artificial fallow-esque period / environment where *Thysanoptera*, among other pests, find it hard to survive. Tactics like this (for treatment), botanicals like Spinosad, and good foundational preventive physical and cultural control practices will ensure that thrips won't be pests or vectors that cause harm to plants in economical ways that hurt production in CEAs.

All in all, Spinosad is effective against *Thysanoptera* when used correctly and should continue to be used for plant protection in controlled environments, as more naturally derive insecticides are commercialized as substitutions / alternatives for synthetic conventional chemical controls.

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