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Full Length Research Paper

Role of infochemicals in the relationships between two-spotted spider mite *Tetranychus urticae* and predatory mite *Neoseiulus californicus*

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Two-spotted spider mite *Tetranychus urticae is* a known serious pest of several crops. Due to its rapid outbreak and short life cycle, it is difficult to control *T. Urticae*. However, nowadays biological control using predatory mites and chemical control using miticides are available. Predatory mite *Neoseiulus californicus,* which feeds on a variety of prey, can effectively control *T. Urticae*. Thus to employ this method a better understanding of the role of infochemicals is required. Therefore, the aim of this paper is to review role of infochemicals in the relationships between two-spotted mite *Tetranychus urticae* and *N. Californicus.* To achieve this objective peer-reviewed articles were used and reviewed. The source of infochemicals can be *T. Urticae* itself, its host plants, the combination of the two and organisms related with *T. Urticae*. Thus, infochemicals originated from those listed sources have great role for the tritrophic interaction between *N. Californicus,* plants and *T. Urticae*. The infochemicals help *T. Urticae* to recognize the presence of their enemy such as *N. Californicus.* Infochemicals are used by *N. Californicus* to locate the prey, trace prey density and accessibility.

Keywords: info chemicals, two-spotted spider, *Tetranychus urticae,* and predatory mite *Neoseiulus californicus*

INTRODUCTION

Two-spotted spider mite *Tetranychus urticae*

Since many years ago, different crops have been attacked by *Tetranychus urticae* known by its common name two-spotted spider mite. Using different literature review, the presence of two-spotted spider mite *Tetranychus urticae* was investigated in different parts of the world and has been known to feed on more than 300 different plant species. It belongs to the phylum Arthropoda, order Prostigmata and is a member of the family Tetranychidae. It has two distinct separate body parts:'gnathosoma' and 'idiosoma'. The gnathosoma comprises only the mouthparts whereas the idiosoma, which consists of the head, thorax and the abdomen, is the remainder of the body.

*Tetranychus cinnabarinus (*carmine mite) and *Tetranychus urticae* (two-spotted spider mite) are very similar; however, they are different in terms of their female colour, reproduction and distribution pattern. For instance, the female of the *T. Urticae* is green, relatively rare in tropical and subtropical areas, whereas *T. Cinnabarinus* is red in colour, reproduces throughout the year and is more common in subtropical and tropical regions. Gerson and Weintraub (2007) indicate that they could not interbreed and differ in some morphological characters.

Two-spotted spider mite *Tetranychus urticae* life cycle

T. urticae has a short life cycle. It comprises: egg, larva, two nymphal stages and the adult stage. All stages start and end on the crops. The life span of each stage may vary depending on different factors such as temperature, humidity, host plant, leaf age, etc. For example, the time span from egg to adult may vary from 1 to 3 weeks depending on temperature, which is the most important factor. In general, under optimal conditions, the complete life cycle takes less than twenty days.

Control of the two-spotted spider mite *Tetranychus urticae* by *Neoseiulus californicus*

However, it is difficult to control *T. Urticae* owing to the fact that their outbreaks occur rapidly. Nowadays, biological control using predatory mites and chemical control employing miticides are available as control methods. Biological control are relatively better than miticides because they reduces the effects of resistance to pesticide, no exposure of producer and applier to toxic pesticides, there is no risk of toxic residues on the end product, and less or no risk of environmental pollution. There are more than 15 predator species commercially available that are used as biological control for *T. Urticae* and other pests. For example, predatory mite *Neoseiulus californicus* can effectively control *T. Urticae* (Biddinger *et al*., 2009).

Neoseiulus californicus

N. californicus, which feeds on a variety of prey, is a tiny, mobile predatory mite. It is commonly occurring in many warm humid areas. Depending on the food source, its generation period varies usually from 5- 10 days. Female *N. Californicus* able to live up to 60 days and are able to produce about 30 eggs. As shown by Gerson and Weintraub (2007), due to its tolerance for a wide range of temperatures and humidity levels, *N. californicus* is mass-produced to control *T. urticae* currently.

Chemical communication is very important in mite life to exchange information through different volatile chemicals which helps them to check the presence of their enemies, availability of food and competitors (Dicke and Grostal, 2001). *T. urticae*, the host plants and *N. californicus* interact with each other through chemical communication. Volatile chemicals, which are produced by plants, *T. urticae*, and the interaction between the two, transmit information among themselves (Dicke and Grostal, 2001, Hatano *et al.,* 2008). The chemicals from *T. urticae* and their host plants are used by *N. californicus* in the process of prey searching. To understand the function of this chemical communication and how it influences the behavior of predator mites, it is vital to distinguish how infochemicals work among mites, their host plants and natural enemies. Therefore, the aim of this paper is to review the roles of infochemicals in the relationships between *T. urticae* and *N. californicus* using peer-reviewed articles.

Research questions

✓ What are the key volatile infochemicals involved in predator attraction?
✓ What are the major roles of volatile infochemicals in the tritrophic interaction?
✓ What are the sources of volatile infochemicals?

Infochemical terminology

Vet and Dicke (1992) define infochemical as a chemical that transmits information in an interaction between two individuals, inducing in the receiver a behavioural or physiological response. Semiochemicals are defined as chemical substances used to convey information between two organisms which are often believed to evoke a behavioural response that is adaptive to one of the organisms or both.

Pheromone has been defined differently by different authors. For the purpose of this review, few of the definitions are presented as follows. Pheromone originally defined by Karlson and Luschers (1959) cited in Dicke and Sabelis (1988) as it is a chemical secreted by an individual to the outside and to attract the same

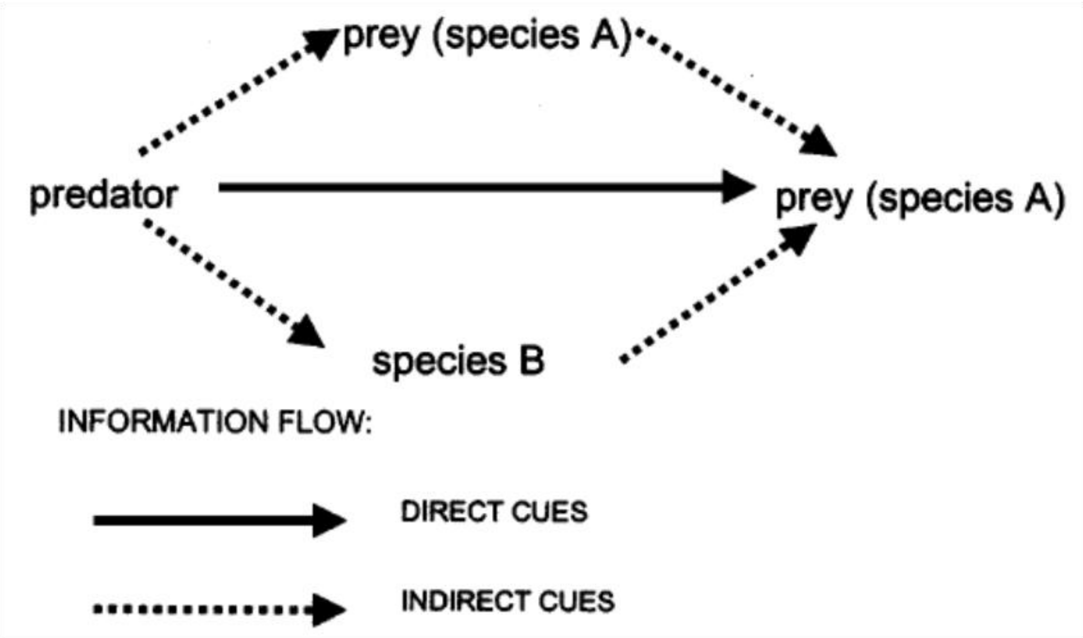

Figure 1: Information flow between predator (*N. californicus*) and prey (two-spotted spider mite *Tetranychus urticae*)[source: Dicke and Grostal (2001)]

species. Recently, Hatano et al. (2008) defined as semiochemicals released by one individual and perceived by another of the same species, however allelochemicals are semiochemicals perceived by individuals of a different species. If the only beneficiary is the receiver, the allelochemical is termed a kairomone; while the fitness of the producer is increased, it is termed an allomone. If both benefit from the information exchange, it is termed a synomone.

Source of infochemicals and information transfer

A brief review of the sources of infochemical were detailed and summarized by Vet and Dicke (1992) and shortly presented as follows: the source of infochemicals can be *T. urticae*, host plant, interaction between the two and from organisms related with *T. urticae* presence. *T. urticae* by itself supply information directly to its enemy through its fecal excretions of mandibular, cuticular, and accessory glands, pheromones, honeydew, body scales, exuviae or hemolymph. In addition, the volatiles produced from the interaction between plants and *T. urticae* can generate chemical information. Furthermore, *T. urticae* related organisms, such as microbes, may be an essential source of chemical information.

The information generated from the above sources can be transferred and acquired by *N. californicus.* The generated information tell *N. californicus* about the presence of *T. urticae*, their density and whether they are accessible or hidden. Consecutively, infochemicals helps *T. urticae* to recognize the presence of their enemies such as *N. californicus*. Therefore, the information flow from *T. urticae* to *N. californicus* and vice versa is presented in Figure 1.

Plant and two-spotted spider mite *Tetranychus urticae* interaction

The interaction between plant and *T. urticae* helps the plants to attract and employ natural enemies upon *T. urticae*. This employment would be through production of different volatile or non-volatile chemicals which act directly or indirectly upon *T. urticae*. Direct defence is through the production of chemicals which acts in the form of toxins or repellents upon the *T. urticae*, whereas indirect defence is the strategy used by plant through employing carnivorous enemies upon herbivore infestation. Thus, the tritrophic interaction between plants, *T. urticae* and *N. californicus* belongs to indirect defence in which plant call *N. californicus* up on *T. urticae* infestation. This call or attraction of *N. californicus* can be through the release of different volatiles as presented below under section - 3 of this paper.

Volatile chemicals produced in two-spotted spider mite *Tetranychus urticae* - plant interaction

For the purpose of prey searching, *N. californicus* uses different chemicals originated from *T. urticae*, plant and interaction between the two. Plant produces different chemicals up on *T. urticae* infestation. These chemicals can be volatile or non volatile. However, this paper focuses on volatile chemicals. Different authors investigated that herbivore-induced or physically damaged plant volatiles attract predators (Shiojiri et al. 2002; Takabayashi and Dicke 1996). Ishiwari *et al* (2007) and De Boer et al. (2004) checked whether these predator attractants are present in herbivore induced plant volatiles (HIPV) or green leaf volatile (GLV). These volatiles chemicals can be methyl salicylate, linalool, (*Z*)-3-hexen-1-ol, (*Z*)-3-hexenyl acetate and (*E*)-2-hexenal. The first two are categorised under herbivore-induced plant volatile whereas the later three are green leaf volatiles. Shimoda et al. (2005, 2010) compared synthetic volatile chemicals listed above with the natural blend released by a leaf infested with *T. urticae*. In their recent article, they indicated that both synthetic and non synthetic act similarly, in other words both attract *N. californicus* equally as opposed to the old article which reported that the synthetic mixture attracted more. Again in the recent article, it is indicated that methyl salicylate is the strongest attractant of *N. californicus* than any of the above listed volatile chemicals.

Factors affecting the behavioural responses of predatory mite

Different factors such as plant cultivar, herbivore species and plant developmental stage may affect the behavioural responses of predator mite to volatile infochemicals.

N. californicus' response to different infochemicals is influenced by plant developmental stage as reported by Takabayashi et al. (1994). According to Takabayashi et al. (1994), predatory mites responded to young *T. urticae* infested cucumber leaves, but not to old. They also explained the possible reasons for the variation to be the differences in blend composition of HIPV from young and old leaves and the fact that plants defend more growing parts than older ones.

Variation in herbivore-induced plant volatile between cultivars affects the response or attractiveness of the plant to predatory mites. For example, Dicke et al. (1990) reported that there is a difference in attractiveness to *Phytoseiulus persimilis* of the plant volatiles released by two different bean cultivars with the same level of infestation with *T. urticae.*

Several literatures indicate that different herbivore species elicit different volatile blends. For example, females of *P. persimilis* responded to volatiles emitted from apple leaves (Cox Orange Pippin) infested by *T. urticae,* but not to volatiles emitted from apple leaves infested by *P. ulmi.*

CONCLUSIONS

Infochemical conveyance has great importance in *T. urticae* - plants - *N. californicus* interaction. The source of these chemicals might be either from *T. urticae*, plant, interaction between the two and organisms associated with *T. urticae* presence such as microbes. *T. urticae* by itself give information directly for its predator through its fecal excretions of mandibular, cuticular, and accessory glands, pheromones, honeydew, body scales, exuviae or hemolymph.

A key volatile chemicals produced from plant, the interaction between *T. urticae* and plant are HIPVs (methyl salicylate and linalool) and GLVs ((*Z*)-3-hexen-1-ol, (*E*)-2-hexenal and (*Z*)-3-hexenyl acetate). Among these chemicals, methyl salicylate is the strongest *N. californicus* attractant.

The information produced from the above source can be transferred and acquired by *N. californicus* to locate prey, trace prey density and their accessibility. In turn, the information can also be used by *T. urticae* to recognize the presence of there enemy such as *N. californicus.* Thus this tritrophic interaction has great role for *N. californicus*, plants and *T. urticae*. The *N. californicus* is benefited by gaining information which will help them in searching their prey for the purpose of their food whereas the plants use it to defend themselves against *T. urticae*.

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