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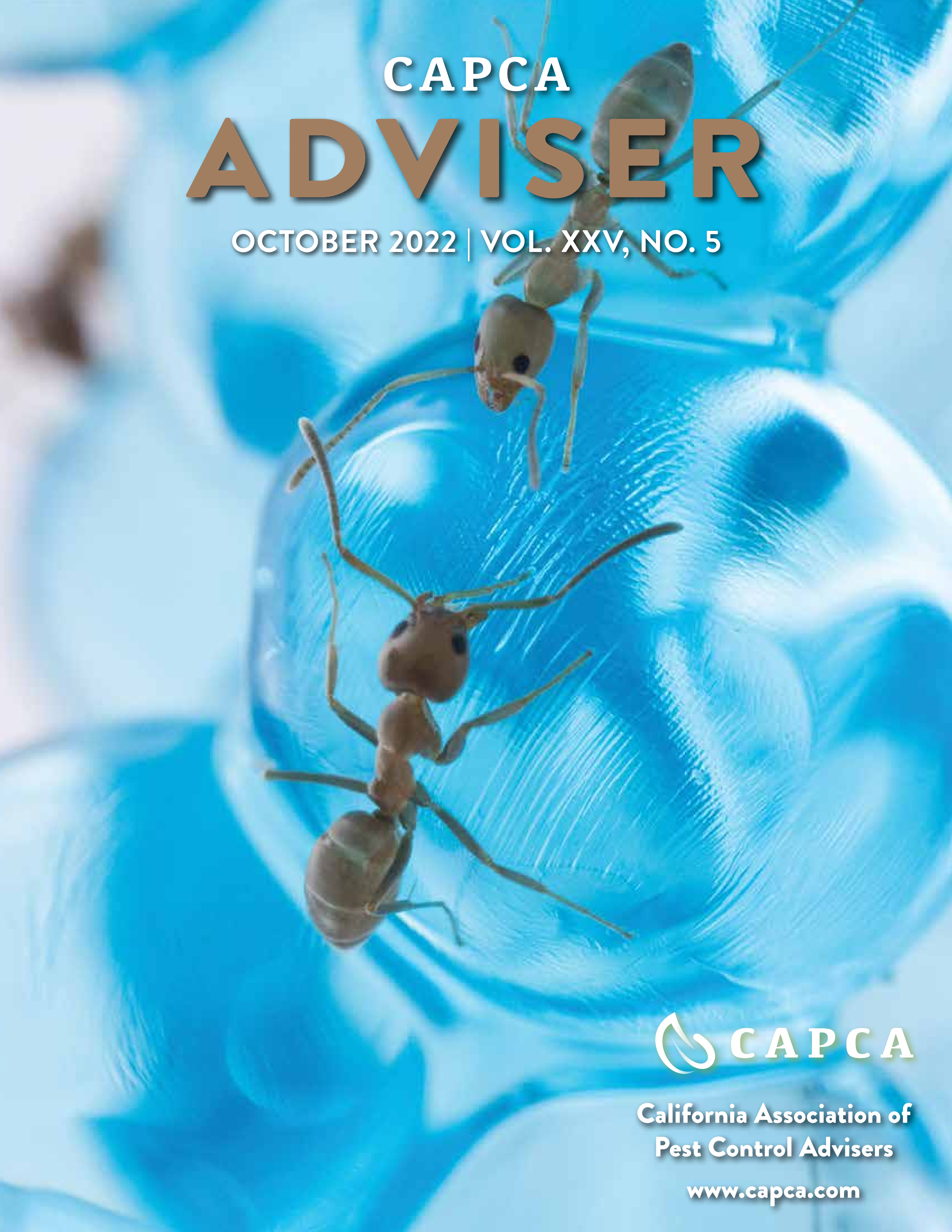

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INDUSTRY UPDATE

Using infra-red sensors and the Internet of Things to automate Argentine ant counts

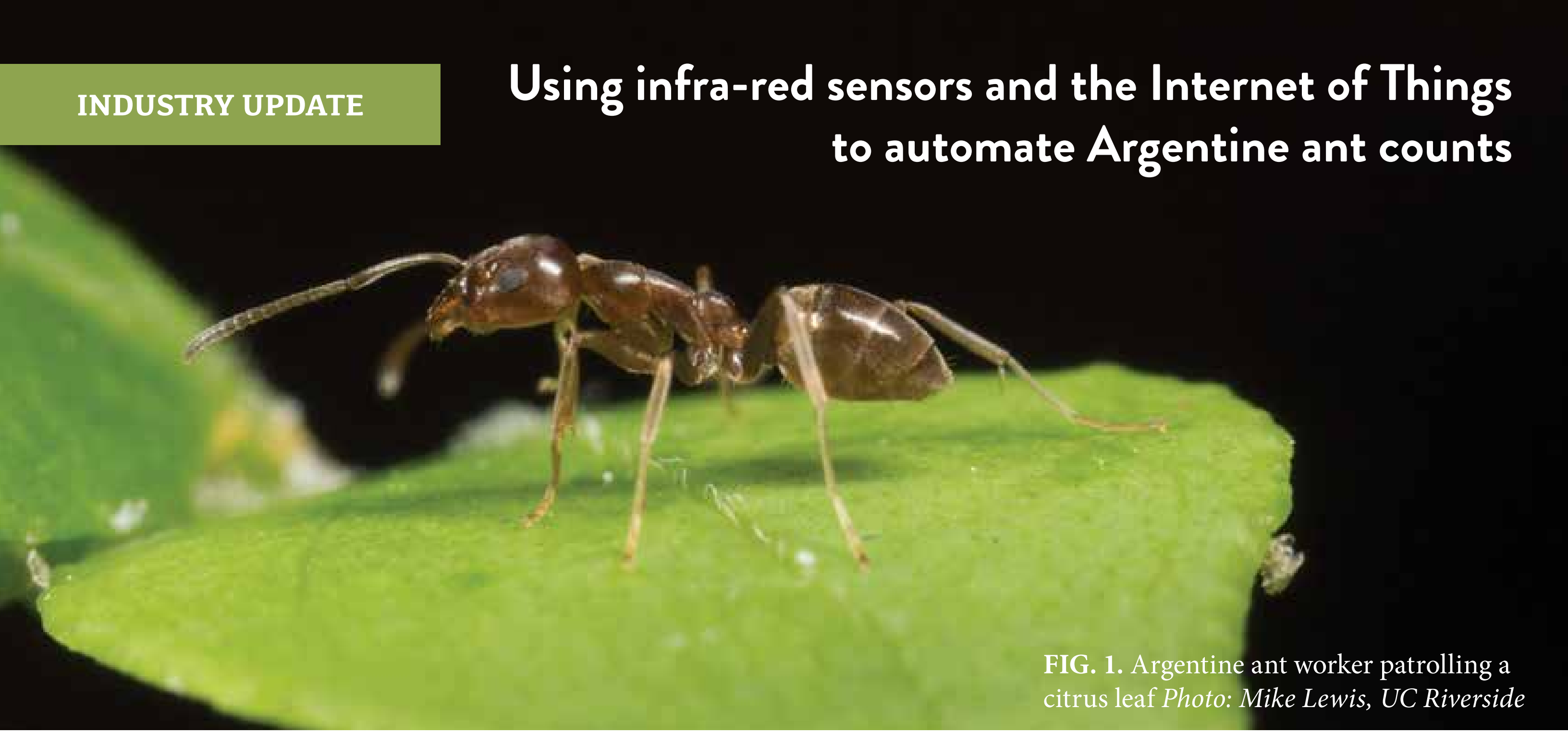

FIG. 1. Argentine ant worker patrolling a citrus leaf *Photo: Mike Lewis, UC Riverside*

Mark S. Hoddle[1], Shailendra Singh[2,3], Eamonn Keogh[2,3], Lin Cong[4], Yehua Li[4], Weixin Yao[4], Francesc Gomez-Marco[1], Christina D. Hoddle[1], Nic Irvin[1], Michael Lewis[1], and Ivan Milosavljević[1]

[1]Department of Entomology, University of California, Riverside; [2]Dept of Computer Science and Engineering, UC Riverside; [3]FarmSense, Riverside, CA; [4]Department of Statistics, UC Riverside

Argentine ant, *Linepithema humile* (Fig. 1), native to parts of South America, is an invasive pest that has been present in Southern California since 1905. This pest ant has established widely around the world due to accidental movement into new areas by humans. In invaded regions massive ant populations cause problems in natural (e.g., ants interfere with native nectar feeders), urban (e.g., infestations of trailing ants in kitchens), and agricultural areas. In agricultural crops, like citrus and grapes, Argentine ants form relationships with sap sucking pests that excrete honeydew (Fig. 2). Honeydew is a sugar-rich waste product that ants harvest and return to underground nests to feed nest mates. An undesirable outcome of this mutualism is that ants protect honeydew producers from the predators and parasitoids that attack these pests. Because ants get food for these protective services and biocontrol agents are harassed or killed by patrolling ants both pest and ant populations increase in size which can result in pest densities that are damaging and may need treating with insecticides.

FIG. 2. Argentine ants harvesting honeydew from Asian citrus psyllid nymphs. *Photo: Mark Hoddle, UC Riverside*

Even though Argentine ant is a well-recognized pest in citrus there are no standardized approaches to monitoring ant densities to assist control decision-making. Two methods for monitoring Argentine ants include timed visual counts of ants on tree trunks (Fig. 3A) or use of sugar water filled monitoring vials (Fig. 3B) to measure number of ant visits to a sucrose resource over a 24 hour period. The amount of liquid imbibed from a monitoring vial provides an estimate of the number of ants that visited the vial. Both of these methods have shortcomings. Visual counts are labor intensive and quickly become inaccurate when ant densities are high and counting fatigue sets in. Monitoring vials may over estimate ant activity as ants are attracted to the sugar water inside vials. In addition to an absence of efficient

FIG. 3. Estimates of Argentine ant densities in citrus orchards can be made by (A) timed visual counts of ants on tree trunks *(Photo: Mark Hoddle)*, or (B) the use of monitoring vials filled with 25% sucrose solution *(Photo: Mike Lewis).*

monitoring tools there is also no scientifically-determined action threshold that once crossed could result in initiation of treatment applications (e.g., liquid baits) for Argentine ant control (see. Milosavljević et al. in this issue of CAPCA Adviser provides more details on liquid baits for ant control.)

There is a clear need to develop an accurate, time, and labor efficient method for monitoring Argentine ant in agricultural crops. Any new tools developed for ant monitoring would ideally be accurate, cheap, automated, unaffected by heat, rain, and irrigation water, have low maintenance and power requirements, have no effect on ant behavior, and provide user-friendly data summaries that are accessible on the cloud via an App on a smart device. One approach our team has been exploring is the development and field evaluation of infra-red (IR) sensors to count ants in citrus. An IR sensor is composed of an IR emitter that projects an infra-red beam to an IR receiver and this beam is blocked when an object passes through it. This process is similar to a door chime in a shop that rings when a customer enters and breaks a beam spanning the doorway thereby audibly notifying the shop attendant. For the IR sensors, this break in connectivity due to a transient blockage (i.e., an ant moving through the IR beam) can be detected by programmable hardware and the number of IR beam breaks can be recorded which provides an estimate of the number of ants that have passed between the IR emitter and receiver.

A critical question with respect to use of IR sensors in orchards to count ants is where do you place them? Fortunately, the solution to this question is easy. Argentine ants exhibit a rigid highly stereotypical behavior in orchards with respect to irrigation lines (e.g., polyethylene tubing) that sit on top of soil under trees. Ants use these long straight runs of smooth pipes as "super-highways" (Fig. 4) to move from subterranean nests to off-ramps near tree trunks which they ascend before making the return trip back to the nest with collected honeydew. The reason these pipes are used is because they are straight and smooth which maximizes foraging efficiency by reducing transit times between nests and food sources.

With assistance from students and faculty in the Computing and Engineering Department at UC Riverside and computer engineers with FarmSense, we developed waterproof IR

FIG. 4. Argentine ants use polyethylene irrigation pipes that sit on the soils surface as "super-highways" to move from underground nests to tree canopies where they collect honeydew. *Photo: Mark Hoddle*

sensors that could be mounted onto irrigation pipes using 3D printed clamps (Fig. 5). These sensors are an Internet of Things (IoT) tool that can automatically collect and transmit data through a communications network. Sensors are programmed to wake from hibernation once an hour every hour to count ants for a set time period (e.g., 1 minute) and record the number of ants on the pipe that pass through the IR beam that spans the width of the pipe. The sensor then relays data to a Gateway which moves data over the LTE cellular network to a cloud-based server where data are stored and updated every hour. In commercial citrus orchards, we have connected 200 sensors at a time to a Gateway to automatically move ant count data to the cloud. Cloud-stored data is accessed using a Farmsense App and can be viewed in near real time. The interface provides the user fine resolution data summaries such as heat maps showing varying levels of intensity of ant activity in different areas of the orchard over time and the numbers of ants moving along pipes each hour of the day and night (Fig. 6). Sensors also have the capacity to provide information on battery power and they can be outfitted with temperature and humidity readers and GPS tags to provide details on environmental and locality factors that could be affecting ant activity at different locations and times in the orchard.

An obvious shortcoming with counting ants on pipes is that these ants are not in the canopy tending sap sucking pests

FIG. 5. IR sensor clamped onto an irrigation line in a commercial citrus orchard. *Photo: Mike Lewis*

and harassing natural enemies. A reasonable question to ask would be: "Since ants use pipes to move from subterranean nests to collect honeydew in the canopy is there a relationship between the numbers of ants on pipes and the numbers of ants on tree trunks?" If there is a relationship could we use this to estimate the number of ants moving into the citrus canopy by using counts of ants moving on

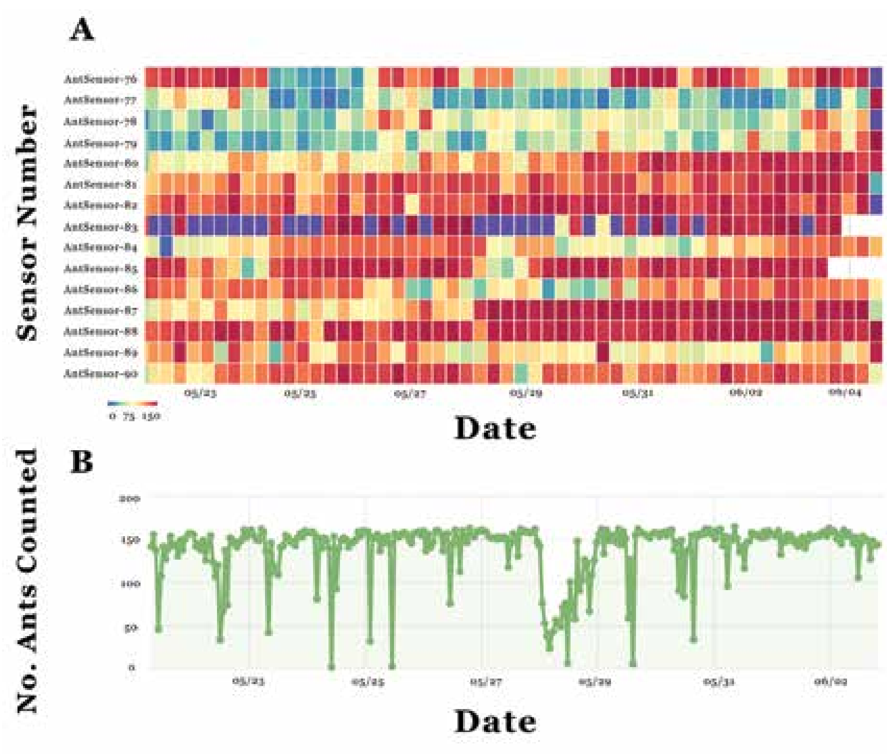

FIG. 6. The FarmSense Ant Count App can generate (A) heat maps of ant activity, and (B) provide individual sensor counts for ants.
Plate prepared by Mike Lewis

pipes? To answer these questions we generated a very large data set by counting ants on pipes and counting ants on citrus trunks immediately adjacent the pipe where the pipe counts were taken. With help from a Ph.D. student and faculty in the Statistics Department at UC Riverside, we were able to determine through complex statistical analyses that there is a very strong relationship (>85%) between the numbers of ants counted on pipes and trunks. Determining the strength of this relationship and being able to describe it mathematically now enables us to build this equation into the FarmSense App enabling it to convert IR counts of ants on pipes to estimates of ants on trunks that are tending sap sucking pests in the canopy. Now that we can use IR sensors to automate ant counts to provide an estimate of the number of ants moving into canopies we need to compare these estimates to the "Action Threshold." The "Action Threshold" is the density of ants, which once exceeded, warrants control to minimize negative impacts by ants on the free pest control services provided by natural enemies. At this time, we don't have a good estimate for the Action Threshold for Argentine ants in citrus. This is an important problem we are currently working on.

This automated approach to monitoring Argentine ant is using a cheap new tool (i.e., an IR sensor) and exploiting the IoT (i.e., an App to access ant count data stored in the cloud) to improve the accuracy of pest management while simultaneously reducing labor costs associated with pest monitoring. We see this type of advance in pest monitoring as part of an accelerating and exciting trend that is paving the way for the innovative high-tech future of agricultural pest management. ■

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