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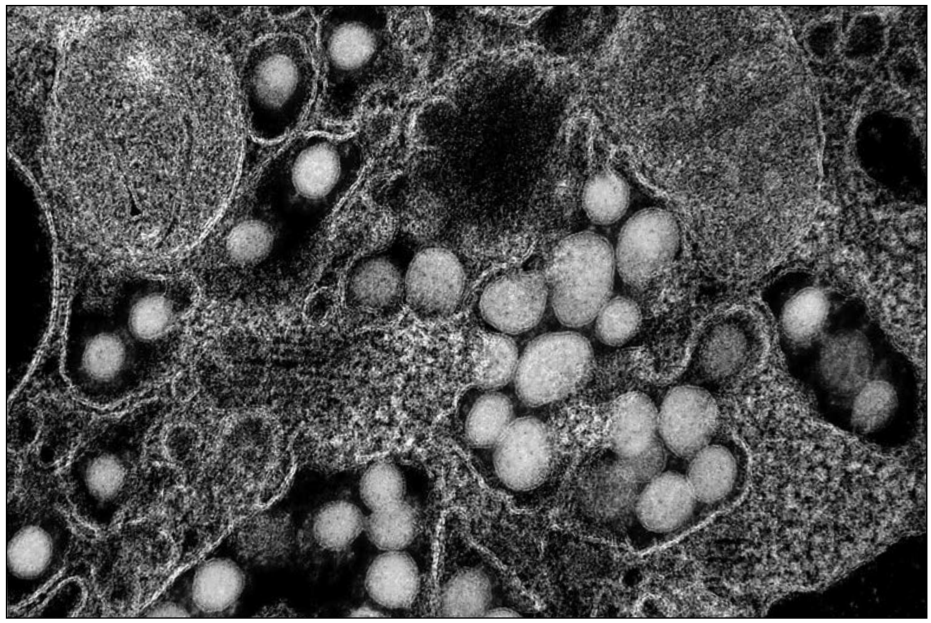
Coronavirus and Ecology

By William Quarles

The same ecological disturbances that have devastated populations of wild vertebrates, monarch butterflies, bees and other beneficial insects have contributed to the emergence of the coronavirus disease COVID-19. The near doubling of the world population in the last 40 years from 4.5 to 7.9 billion has led to reductions of 50% or more in the populations of many wildlife species (Quarles 2019). Increasing human population has led to encroachment on wildlife areas and closer contact with animals carrying viruses and other pathogens that are able to infect humans. And fewer wild vertebrate hosts mean that humans are an attractive target for zoonotic pathogens (Cui et al. 2019).

A zoonotic pathogen is one that jumps from other animals to humans. In fact, most of the major human infectious diseases originated in other animals and COVID-19 is no exception (Wolfe et al. 2007). According to a recent study, many zoonotic diseases are old and originated with agriculture. Domesticated animals such as pigs, cattle, horses, and dogs are a major source of zoonotic pathogens. Twelve domesticated animal species harbor about 50% of known zoonotic viruses. Examples are mumps, measles, and smallpox (Olival et al. 2017; Johnson et al. 2020).



National Institute of Allergy and Infectious Diseases, Rocky Mountain Lab

This electron transmission photo shows tissue infected with the coronavirus SARS-CoV-2. SARS-CoV-2 spreads mainly as an aerosol, and causes the disease COVID-19.

Why so Many New Pathogens?

But there are many new pathogens. From 1980 to 2007, 87 new human zoonotic pathogens emerged. This number does not include vectorborne diseases such as West Nile, Zika virus, and the emerging new tickborne diseases (Quarles 2018; Woolhouse and Gaunt 2007).

New pathogens have been discovered at the average rate of about three per year. Global warming may be responsible for some of the increase, especially for vectorborne diseases where ticks and other vectors are moving into new areas. But the overwhelming driver is ecological changes. Increased development is destroying wildlife habitat, pushing humans into contact with wild animals. There are also many direct interactions of humans with wild animals through hunting and the wildlife trade. Establishment of new farms generates large numbers of domestic animals near wildlife areas (Karesh et al. 2005; Woolhouse and Gaunt 2007; Quarles 2007).

According to Cui et al. (2019), "…many viruses have existed in their natural reservoirs for a very long time. The constant spillover of viruses from natural hosts to humans and other animals is largely due to human activities, including modern agricultural practices and urbanization." Much of the problem is recent, and the risk of repeated pandemics is increasing (Wilkinson et al. 2018; Woolhouse and Gaunt 2007; Quarles 2019). (see Box A)

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The IPM Practitioner
Monitoring the Field of Pest Management

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Update

SARS was a Warning

The SARS (Severe Acute Respiratory Syndrome) epidemic of 2002-2003 was a warning. It spread to 33 countries, causing more than 8000 infections and nearly 800 deaths. After the first wave, it emerged again in China in 2003-2004. The two epidemics were caused by SARS coronaviruses, but the strain that jumped to humans in 2002 was different from the one seen in the later epidemic. The SARS virus jump to humans must have been easy because it happened twice (Wang et al. 2006).

Bats are the reservoir species for the SARS virus (see Box A). The virus jumps from bats to other animals (Lau et al. 2005). Other animals then infect humans. Research has shown that 10 different mammalian species, including mice, rats, domestic cats, raccoons, pigs, and civet cats, *Paguma larvata,* are susceptible to the SARS coronavirus. Most, but not all, of the human infections likely came from civet cats. After the SARS outbreak in Guangzhou, China more than 800,000 animals were confiscated from the local markets (Karesh et al. 2005; Wang et al. 2006).

The SARS epidemic was a warning that world conditions favored a coronavirus pandemic. We received 18 years of advance notice, and yet we did very little to prepare.

SARS-CoV-2

COVID-19 has respiratory symptoms similar to SARS, and the coronavirus that causes it is called SARS-CoV-2. The virus has spread from Wuhan, China throughout the world, and there are now (May 6) about 3.8 million confirmed cases of COVID-19 and about 260,000 deaths (6.8%). The case fatality rate from confirmed cases will eventually be higher (see Case Fatality Rate below). SARS had a case fatality rate of 9.6% (Worldometers 2020; Zhou et al. 2020). On May 5, the U.S. had 1.2 million confirmed cases and 70,990 deaths (5.8%). If the case fatality rate reaches that of SARS

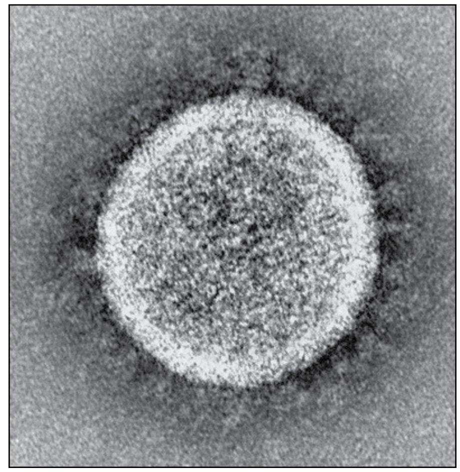


Photo courtesy NIAID-RML

Spike proteins appear as a halo or corona, and that gives the virus its name.

(9.6%), deaths will be more than 115,000 (Worldometers 2020).

SARS-CoV-2 is a betacoronavirus, and is a positive sense, single stranded RNA virus with a single linear RNA segment. It has an envelope and four structural proteins, Spike (S), Envelope (E), Membrane (M) and Nucleocapsid (N). S, E, and M proteins create the envelope. It is a small spherical virus, about 50-200 nanometers in diameter, and it is covered with spikes.

The Spike (S) protein is responsible for infectivity, as it attaches to a human cell receptor. Spike proteins engage with the human Angiotensin Converting Enzyme II (ACE2) receptor. SARS-CoV-2 shares about 80% genetic identity with the SARS virus. The big change is in the genes for the Spike protein that is responsible for transmission of infection (Cui et al. 2019; Zhou et al. 2020).

Where did it Come From?

SARS-CoV-2 has 96.2% genetic homology with betacoronavirus RaTG13, which was found in horseshoe bats, *Rhinolophus affinis*, in the Yunnan province of China in 2013. This virus is the closest relative to SARS-CoV-2 that has so far been found in nature (Zhou et al. 2020).

The horseshoe bat, *Rhinolophus affinis*, is a common species that is widely scattered throughout

China and Southeast Asia. It roosts in caves at altitudes between 670 and 1692 meters (2200 to 5550 ft). It is an insectivorus bat, mainly eating moths and beetles. The question is how a virus from the cave of a mountain bat got into the urban population of Wuhan, which lies 121 feet above sea level. There have been several theories, but a definitive answer has not been produced.

Direct Human Infection or Not?

One theory is a direct accidental infection of humans. A scientist from Wuhan doing research on bat viruses could have become infected. The Wuhan Virology Lab is active in this work, but an accident of this kind is unlikely because a professional virologist would not ignore personal protection. Or a wild animal trader could have brought some of the bats to Wuhan, as *Rhinolophus* and other bats are used in traditional Chinese medicine. This scenario is more likely, as trade in these bats is common, and the bat catchers may not have been that careful (Ge et al. 2013; Wassenaar and Zou 2020).

Or a local villager infected by the bats in Yunnan could have traveled to Wuhan. To support this idea, direct human infection has been seen with SARS related bat coronaviruses. Wang et al (2018) found that 2.7% of 218 villagers living near bat caves in Yunnan had antibodies to bat coronaviruses. None of the humans infected showed any clinical symptoms.

Bats are important reservoirs of viruses, and more than 200 viruses are associated with them. These viruses can jump from bats to other species, and pathogenic bat viruses can end up in humans. Human infection mostly occurs stepwise through adaptation to a secondary host. For instance, the SARS virus likely jumped from bats to civet cats to humans. The MERS (Middle Eastern Respiratory Syndrome) virus moved from bats to camels to humans (Zhou et al. 2020; Cui et al. 2019)

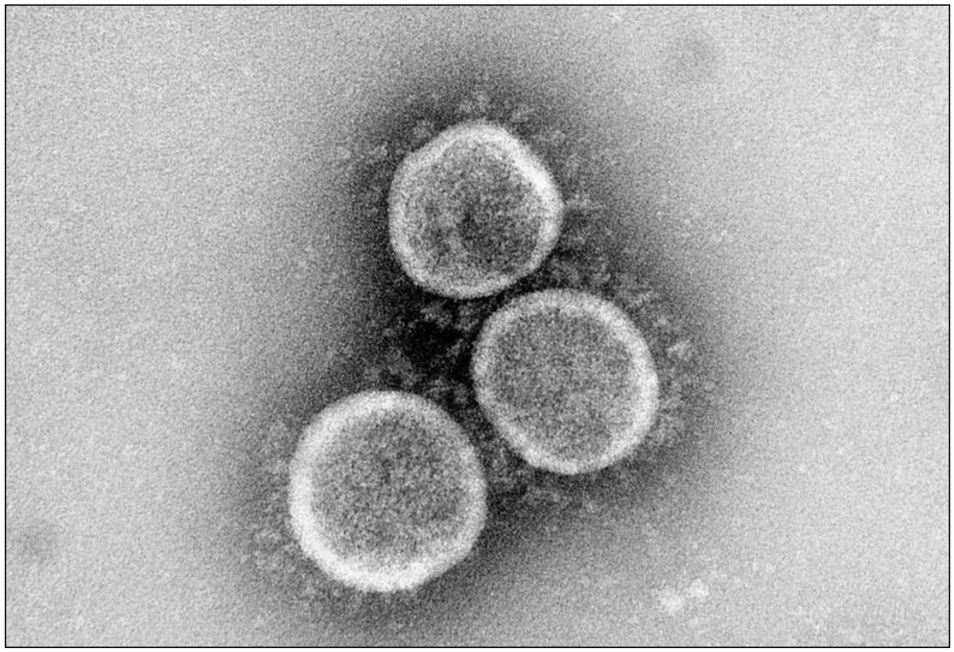


Photo courtesy NIAID-RML

In this electron transmission photo of SARS-CoV-2, Spike proteins and the outer envelope can be clearly seen. The pathogen probably emerged as a mutation-recombination event from a bat virus.

Direct Transfer can Occur

But direct transfer can occur in some cases. The first report of transmission from bats directly to humans was rabies virus in 1911. Nipah virus from bats is usually transmitted to pigs and then to humans. But direct transmission from bats to humans can occur if humans consume contaminated food such as date palm sap (CDC 2014; Allocati 2016).

Bat betacoronoviruses such as WIV1 and WIV16 are capable of transmission directly to humans, and RaTG13 Spike genes are closely related to those of SARS-CoV-2. Spike genes produce receptor binding proteins needed for attachment to the ACE2 human receptor, and RaTG13 likely has some capacity for human to human transmission. A mutation recombination event that occurred when RaTG13 jumped to humans could have made it pathogenic (Menachery et al. 2015, 2016; Zhou et al. 2020).

Secondary Transfer

Another theory is that the virus jumped from the host bat to an animal that was subsequently sold at the Wuhan food market. Virus adaptation to the animal converted RaTG13 into a pathogen. Food handlers were contaminated by the animal. Then the virus spread from food handlers to the general population. This fits the epidemiology of other bat coronaviruses such as those for SARS and MERS. Because the market was closed and disinfected on December 31, 2019, we may never know which animal species was involved (Cui et al. 2019).

Classic Epidemiology

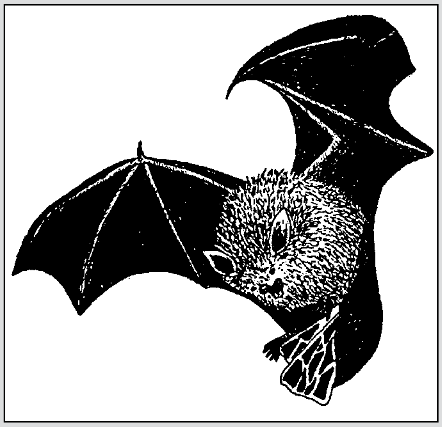
Detailed analysis of the first 41 patients who were hospitalized between December 1 and December 31, 2019, showed 27 (65.8%) had direct exposure at the Huanan wholesale food market in Wuhan, and many were workers at the market. This fact led epidemiologists to think that the virus jumped to humans from an animal species present at the market. Since most of the cases came from the market, the Chinese mistakenly thought there was little human to human transmission (Huang et al. 2020).

Box A. Pathogens of Emerging Diseases

Since 1980, the most frequent pathogens (56%) of emerging human diseases have been RNA viruses (Woolhouse and Gaunt 2007). About 80% have non-human vertebrates, mostly mammals, as a reservoir. Woolhouse and Gaunt (2007) predicted that the most likely future pathogens would be RNA viruses with a non-human reservoir, a broad host range, and some capacity for human transmission. The coronavirus for COVID-19 fits the profile (Huang et al. 2020).

Rodents, bats, and primates are hosts for about 76% of the new zoonotic viruses found to date. Bats may have a special status because they roost in high densities, have long lifespans, quickly spread by flying, and may roost in human structures, encouraging human contact. Fruit eating bats leave partially eaten fruit contaminated with viruses that may infect other wildlife. Bats host more zoonotic pathogens per species than rodents, another important source of zoonotic infections (Luis et al. 2013; Luis et al. 2015).

Another major source is wild animals threatened by human invasions into their territory. A major driver of human infections is the hunting of wild animals. HIV/AIDS and Ebola originated in this way. There is also a large world wildlife trade market. Trade in wildlife such as civet cats likely led to the SARS epidemic in 2002. Trade in bats for traditional Chinese medicine may have led to COVID-19. Threats increase with the number of different viruses a species is carrying, its population and population density, genetic closeness, and geographical proximity to humans (Karesh et al. 2005; Johnson et al. 2020).



Bats are the reservoir species for SARS-CoV and SARS-CoV-2.

Human to human transmission is a key factor. According to Geoghagen et al. (2016) viruses most likely to result in human to human transmission are those with low host mortality, that establish long-term chronic infections, that are non-segmented and non-enveloped, and are not transmitted by vectors. For example, of 69 vectorborne viruses studied, only six were capable of human-to-human transmission.

Reservoir Species

Zoonotic pathogens seldom make the jump directly to humans. There is usually a reservoir species such as bats. The pathogens are adapted to their host, and usually do not cause any signs of sickness. The pathogen is often not able to move directly from the reservoir species to humans (Wolfe et al. 2007).

Infection of humans is often a two-step process. The pathogen may not be able to infect humans, but may have genes that allow infection of a secondary species. Mutations involved in adaptation to the secondary species provide the machinery for subsequent human infection (Woolhouse and Gaunt 2007).

Why do Coronaviruses Jump Between Species?

Coronaviruses undergo frequent mutation, and when two or more related viruses occur in the same animal, recombination occurs, forming a new virus (Cui et al. 2019; Wang et al. 2018; Zhou et al. 2020). A coronavirus is programmed to reproduce itself. It is a small organism, and like most viruses it coopts the biology of the host to effect its own reproduction. Maximum spread and reproduction of a virus occurs if it can infect many different species. The optimal situation is when there are large numbers of hosts available, such as humans and their domestic animals (Woolhouse and Gaunt 2007).

But the outbreak origin is also consistent with a virus circulating in the Wuhan population before the first clinical infections were noticed. The first case, identified December 1, had not been exposed at the Huanan market. All of his family members were uninfected at the time he was hospitalized. Since the incubation period is about a week, the infection had evidently been circulating in the Wuhan community in November, perhaps as asymptomatic cases (Huang et al. 2020).

The Chinese finally realized there was human to human transmission. A report on the first 198 cases by the Chinese CDC on January 19, 2020 showed that only 43 (21.7%) of the first cases had been exposed at the Huanan Market. The rest of the original 198 cases were probably generated through human to human transmission. If the COVID-19 virus emerged from a bat or another animal at the Huanan market, 43 people have now infected the whole world (Wu et al. 2020).

Update

The Virus Comes to America

The first COVID-19 case detected in the U.S. was a travel related case in Washington State on January 20. By that time, community transmission in the U.S. was already occurring. The first death due to community transmission occurred in the Silicon Valley of CA on February 6 (SF Chronicle 2020).

America was caught by surprise, and federal leadership was poor. The Trump administration had cut budgets of the CDC and the NIH, leaving fewer resources. The first strategy was denial. Then containment efforts were slow, clumsy and ineffective. States were forced to scramble for resources on their own. Health workers were crippled by lack of personal protection. The CDC was slow to distribute a reliable test for the virus. As a result, the U.S. now has about one-third of the world cases, more than any other country in the world (Worldometers 2020).

SARS-CoV-2 circulated unchecked because asymptomatic people can transmit the virus, and the U.S. did not have the testing capacity to identify infected carriers. In Wuhan, 86% of the infections were mild and undocumented, yet individuals with undocumented infections caused 79% of the serious cases confirmed by testing (Li et al. 2020).

Are Pigs and Livestock Threatened?

Large factory farms with large numbers of animals are attractive targets, and pigs are very susceptible to coronaviruses. Examples are porcine enteric virus, porcine respiratory virus, and the novel coronavirus that caused a swine acute diarrhea syndrome (SADS) in Guangdong province in 2016-2017. About 90% of infected pigs died (Cui et al. 2019).

Fortunately, German and Chinese researchers have shown that pigs, chickens, and ducks are not susceptible to SARS-CoV-2. However, domestic cats and ferrets can be infected (Shi et al. 2020).

Photo courtesy Nancy Heaslip, NYS Dept. Environ. Conserv.

SARS-related coronaviruses have not yet been found in U.S. bats like the little brown bat, *Myotis lucifugus*.

Not in U.S. Bats

COVID-19 should not trigger a crusade against bats. Bats have many positive attributes. They are good biocontrol agents. Bat houses have often been recommended for insect pest control. But because of rabies and other diseases, close contact without personal protection should be avoided (Quarles 2013).

So far, SARS related coronaviruses have been found only in Asian, European, African, and Mexican bats. But other coronaviruses have been found in U.S. bats. For instance, *Eptesicus fuscus* and *Myotis occultus* bats from the Rocky Mountains have Group I coronaviruses that are not related to SARS (Cui et al. 2019; Dominguez et al. 2007; Anthony et al. 2013).

Pattern of Infection

SARS-CoV-2 is more contagious than the flu. The basic reproductive number, R0, is between 1.4 and 3.9. An R0 of 1 or less is needed for a virus to die out after an initial infection. Initial Chinese estimates of R0 were 2.6. This number means that 10 infected people can infect 26 others, and that the natural course of the infection is exponential increase (Huang et al. 2020).

Because of exponential increase in an unprotected population, one health care professional calculated that without mitigation 2.2 million Americans could die. Even with mitigation such as shelter in place and social distancing, a large number of infections are possible. There were 632,548 confirmed U.S. cases on April 16, 2020. On April 29, there were more than a million. In about two weeks, cases had nearly doubled (Worldmeters 2020).

Major spreading is through inhaled aerosols, although there is some transmission from surfaces to hands, then to mouth, nose or eyes. A mask can help reduce aerosol transmission, hand washing helps stop secondary spread. The virus is extremely stable in the environment and can last on undisturbed surfaces for more than four hours. It can be killed by bleach and other disinfectants (CDC 2020).

May Penetrate Masks

On April 17 San Francisco Bay Area lawmakers decided everyone must wear masks in public. Health professionals are protected by N95 masks. The filter size of the N95 is 300 nanometers. [A nanometer is one-billionth of a meter.] It is designed to exclude 95% of particles 300 nm or larger. The virus is between 50 and 200 nm in diameter, and it is smaller than the mask filter size. The virus rides on larger aerosol particles, but the masks probably allow some virus particles to get through (3M 2020).

Symptoms of COVID-19

Once inside the nasal passages, SARS-CoV-2 invades cells and multiplies quickly by using host machinery to clone itself many times. It usually concentrates in the lungs, triggering a dry cough and an increase in temperature due to an inflammation response (Huang et al. 2020).

The incubation period is 5-6 days. About 80% of the infections are mild, and may be asymptomatic. But 20% of the infections can become serious, leading to hospitalization and even the ICU.

Chances of survival are better with good nutrition. In China, those hospitalized in general clinical wards had higher hemoglobin levels than those in the ICU (Huang et al. 2020).

In a few cases, a massive inflammatory response called a “cytokine storm” is triggered, and macrophages and other white cells accumulate in the lungs, making breathing difficult. Steroids are often given to suppress autoimmune responses. Chinese doctors tried therapeutic use of steroids, but steroids did not improve the mortality outcome (Huang et al. 2020).

Fate of the Infected

According to a recent study of Kaiser Permanente members in Northern California, about 8% (1299) of those tested in March 2020 were confirmed positive. Of those positive, about 29% (377) had to be hospitalized and 8.7% (113 patients) needed the ICU. When the study was published in April, about 14.8% (56), of those admitted were still in the hospital, most on ventilators. Of those who were discharged or died (321), about 15.6% (50) had died. Of ICU patients who were discharged or died (68), about half (34) had died. Since the prognosis of those lingering on ventilators is not good, the death rate of those who are hospitalized is likely to be much more than 15% (Myers et al. 2020).

Case Fatality Rate

A rough estimate of the case fatality rate is the number of deaths reported divided by the number of confirmed cases. Spanish death rates calculated this way are now (May 5) about 11.6% (Worldometers 2020). This estimate is lower than the closed case death rate, which is calculated after the pandemic is over. As the pandemic progresses and early cases start to die, estimates become more representative of the closed case death rate. Closed case death rate for SARS was about 9.6% (Spychalski et al. 2020). The death rate in the original cohort of 41 cases of COVID-19 was 15% (Huang et al. 2020).

The COVID-19 pattern of infection leaves a deceitful timeline. Because serious cases can linger on a ventilator for two weeks to more than a month before dying, the reported death rate at any time always underestimates the gravity of the situation. Spain had 9300 cases and 330 deaths on March 17, roughly a 3.5% case fatality rate. But one week later on March 24, there were 33,000 cases and 2200 deaths, roughly a 6.6% case fatality rate. On April 16 there were 190,859 cases and 20,002 deaths. That is a 10.5% death rate. Case fatality rates increased as the lingering early cases died (Worldometers 2020).

Number Infected

Clinicians have known since the start of the pandemic that the number of people infected are much larger than the number of confirmed cases. Asymptomatic carriers in the Chinese outbreak were at least 7 times the confirmed case number (Li et al. 2020).

Antibody tests show who has been exposed to the virus. Stanford University tested 3,300 people in Santa Clara county California and estimated that about 2.49-4.16% of the county population had antibodies to virus, between 48,000 and 81,000 people. This number is 50-85 times the confirmed case rate in the county (Bendavid et al. 2020). A similar experiment in New York City found about 21% of those tested had antibodies.

There are now more than a million confirmed cases in the U.S. If the small sample antibody tests hold true for the whole U.S. population, more than 50 million people in the U.S. have been exposed. Case fatality rates calculated on probable exposures rather than confirmed cases will be significantly lower (Worldometers 2020).

Immunity and Mutation

Antibodies to SARS-CoV-2 develop in infected individuals. It is not yet known how much protection they confer and for how long. Antibodies to SARS were greatest 1-4 months after initial symptoms. Antibodies were lost over time, but likely gave some protection for at least a year (Wu et al. 2007; Zhou et al. 2020).

RNA viruses are unstable and mutate frequently. In a pandemic they may mutate to a more benign form because parasites pay a price if they kill the entire host population. Viruses new to a species adjust until they find the optimum situation for their continued reproduction. For instance, corona porcine enteric virus mutated into porcine respiratory virus. The enteric virus is extremely deadly and has killed millions of pigs. However, porcine respiratory virus kills only a small fraction of infected individuals (Boniotti et al. 2016).

As the number of infections increase, SARs-CoV-2 may mutate to a more benign form. There are already several variants in circulation, and the origin of any particular isolate can be genetically traced. The 1918 flu never went away, but has mutated into the current strains we see. The bad flus of 1958 and 1967 are descendants. Flu evolves so quickly new vaccines must be manufactured for each flu season (Morens and Fauci 2013).

Update

A Challenging Future

The bad news is that there is a cluster of SARS related coronaviruses in bats, and several of them are poised for emergence into the human population (Zhou et al. 2020; Menachery et al. 2016; Hu et al. 2017). Some of them might be able to jump directly to humans without adapting to an intermediate host (Ge et al. 2013; Menachery et al. 2015). According to Zhou et al. (2020), "broad spectrum antiviral drugs and vaccines should be prepared for emerging infectious diseases that are caused by this cluster of viruses in the future. Most importantly, strict regulations against the domestication and consumption of wildlife should be implemented."

Conclusion

The ecological disturbances we have created have devastated many species, and now they are beginning to kill us. Americans have tended to ignore emergence of disease in remote areas such as Africa and China. This strategy has worked in the past because infections have often been strictly zoonotic without sustained human to human transmission. Treating COVID-19 as a once in 100 year plague, is a mistake. COVID-19 should teach us to invest more resources in worldwide pathogen surveillance that will prepare us for future pandemics. Where pandemics are concerned, cooperation, not isolation is the way to go. We should also try to mitigate some of the ecological damage that led to the outbreak. Regulation of the worldwide trade in wild animals would be a good start.

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EPA's New Evaluation of Neonicotinoids

By William Quarles

Neonicotinoids (neonics) are the most widely used insecticides in the world. They are used in field crops, orchards, parks, landscapes, backyard gardens, on ornamentals, lawns, pets, and in structural pest control. Neonics are applied as foliar sprays, soil drenches, granules, tree injections, and as seed treatments. They are not benign. They can kill pollinators and biological controls. Because they are water soluble and extremely persistent they can pollute water, killing aquatic invertebrates. Neonics have been implicated in insect decline. Loss of insects leads to impacts on bird, frog, and bat populations. Neonics may well be the new DDT because of their persistence and effects on wildlife (Hladik et al. 2018; Hallmann et al. 2014; Sanchez-Bayo and Wyckhuys 2019; Quarles 2019).

Because of the potential risks, the EPA has re-evaluated neonicotinoids. The agency has found unacceptable risks for certain applications, and they are proposing mitigation measures. Some applications would be banned altogether. Any mitigation measures are certainly welcomed, but the proposed measures do not go far enough to mitigate the environmental damage to bees, birds, mammals, and aquatic creatures.

By far, the greatest amounts of neonics are used in seed treatments. The need for seed treatments is questionable, and neonicotinoids have been banned for application to field crops in Europe (Quarles 2019). Rather than outright bans on seed treatments, EPA is proposing half measures such as improved housekeeping to remove spilled seeds, and prohibition of planting equipment cleanup in surface water.

For soil and foliar applications, EPA would establish reduced application rates and prohibit application to flowering crops. To prevent water pollution, there are proposed restrictions on applications to bulb vegetables.

For structural pest control, residential imidacloprid applications to turf would be banned. To prevent water contamination, perimeter treatments would be reduced, and applications to impervious surfaces would not be allowed. According to the EPA, residential imidacloprid applications to ornamental plants presents the greatest risk to bees. EPA proposes limiting this use to professional applicators.

Seed Treatments

Between 2005 and 2015, about 700,000 lbs of imidacloprid each year were used for corn, cotton, soybean, potato and wheat seed treatments. Also corn, cotton, soybeans, and wheat seeds were treated with 1.4 million pounds of clothianidin each year. According to the EPA, exposure from treated seed represents the greatest acute and chronic risks to terrestrial organisms of all the routes of application. Bees are exposed to contaminated pollen and nectar and seed treatment dust. EPA risk assessments showed mammals and birds often receive doses above levels of concern. For the case of birds, greatest risk is to small birds eating small seeds. Larger seeds pose risks only to large birds.

On-farm seed treatments to canola, millet and wheat pose unacceptable risks to humans, and EPA proposes to cancel these treatments.

Foliar and Soil Treatments

Soil and foliar applications of imidacloprid averaged 800,000 lbs/year between 2007 and 2017. Cotton, oranges, and potatoes received the largest amounts. A major use is treatment of oranges to manage the Asian citrus psyllid, *Diaphorina citri*. About 70% of lettuce, cauliflower and broccoli crops are treated. About 300,000 lbs/year was used in structural pest control, and home consumers applied 40,000 lbs/year. Soil and foliar use of clothianidin was about 300,000 lbs/year, and that for thiamethoxam was 100,000 lbs/year.

Photo courtesy Kathy Keatley Garvey

Neonics can cause problems for honeybees, *Apis mellifera*.

To mitigate risks to birds, mammals, terrestrial and aquatic invertebrates, EPA is proposing to reduce application rates to a number of crops by roughly 10-15%. There are mitigations to reduce risk from pesticide drift and runoff, including buffer zones and vegetative strips at field edges to prevent water contamination.

There are also crop stage application bans. To protect pollinators they propose to ban applications to crops when flowers are present. In fruiting vegetables, there are no applications in the flowering stage. For tomatoes, peppers, chili peppers and okra the pesticide could not be applied 5 days or more after planting.

Again, any mitigation is welcome, but the proposed actions do not go far enough to eliminate the environmental damage.

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ESA 2019 Meeting Highlights

By Joel Grossman

These Conference Highlights were selected from among 2,885 presentations at the Nov. 17-20, 2019 Entomological Society of America (ESA) Annual Meeting in St. Louis, Missouri. The next ESA annual meeting is Nov. 15-18, 2020 in Orlando, Florida. For more information contact the ESA (3 Park Place, Suite 307, Annapolis, MD 21401; 301/731-4535; http://www.entsoc.org).

Pheromones Reduce Arkansas Corn Sprays

Southwestern corn borer (SWCB), *Diatraea grandiosella*, a significant Arkansas field corn pest, has historically been sprayed with insecticides on a calendar basis (prophylactic) regardless of pest presence or absence, said Glenn Studebaker (Univ Arkansas, 1241 W County Rd 780, Keiser, AR 72351; gstudebaker@uaex.edu). "County agents working with extension entomology specialists" established a network of pheromone traps to monitor and map SWCB populations in Arkansas corn-growing areas.

Maps displaying SWCB pheromone trapping data "are uploaded to the Arkansas Row Crops Blog online weekly," said Studebaker. As a result, "approximately 80% of the conventional acreage was not given a prophylactic insecticide treatment."

Exclusion Netting Tops Organic Sprays

Exclusion netting to stop birds from damaging ripening fruit is used by many growers: 45% in grapes; 25% in blueberries; 10% in cherries; and 5% in apples, said David Gonthier (Univ Kentucky, S-327A Ag Sci North, Lexington, KY 40546; gonthier.david@uky.edu). Fine mesh exclusion barriers and row covers are also used by 36% of cucurbit growers, originally to increase heat early in the season and then to extend the growing season; but now also for pest exclusion. In Kentucky berries exclusion netting outperformed organic sprays in metrics such as pest exclusion (multiple species of birds and insects) and marketable yields (up to 200% increase), with no loss of fruit quality.

After pollination in 2019, blackberry plots, which suffer from many pests in Kentucky, were covered with fine-mesh ProtekNet exclusion netting to exclude multiple pests: birds; spotted-wing Drosophila (SWD), *Drosophila suzukii*; scarab beetles such as Japanese beetle, *Popillia japonica*, and green June beetle, *Cotinus nitida*. ProtekNet was selected because it was flexible, does not tear easily, and can survive multiple seasons. Covered rows had "great exclusion" of scarab beetles and birds, with no loss of fruit sugar or quality. Plus SWD exclusion provided "two times higher marketable yields," compared to an organic-approved insecticide, Entrust® (Spinosad).

Using fine-mesh netting rather than bird netting, blueberry growers also obtained marketable yield benefits beyond bird exclusion. Uncovered plots suffered 60% marketable yield losses. Coarse mesh bird exclusion netting produced 80% of marketable yields. With fine-mesh netting, 90% of early blueberries were marketable.

Flea beetle "shot-hole" damage to Mizuna mustard greens was lower with netting than with organic insecticide sprays. ProtekNet exclusion netting and Remay row covers were equal in flea beetle control, but only ProtekNet significantly boosted yields over the no-netting control. In squash and melons where pollination is necessary, netting can be added after pollination; though some growers stock bumblebees inside growing tunnels, and others remove netting just for the flowering period. Weeds can be a problem, so growers are experimenting with weed-suppressive crop residues and mulches under Remay Agribon floating row covers. Fine-mesh ProtekNet exclusion netting is more expensive than row covers, but can last 3-5 years.

Chenopodium Insecticide

Requiem®, "a blend of 3 plant-derived terpenes modeled after a plant extract of *Chenopodium ambrosioides* near *ambrosioides*," has potential for resistance management in IPM programs, said Sek Yee Tan (Bayer Crop Sci, 890 Embarcadero Dr, West Sacramento, CA 95605; sekyeetan@bayer.com). Activity is via "a non-specific mode of action" involving "the degradation of soft insect cuticles that resulted in disruption of insect mobility and respiration." Requiem has been tested in combination with Movento® a systemic insecticide, against *Thrips tabaci* on leeks and onions in Europe. Against thrips on strawberries, Requiem "delivered commercially acceptable control." In cucumber IPM in Spain, Requiem was combined with *Amblyseius swirskii* and *Metarhizium* fungi against thrips.

"Requiem is registered in the USA as a foliar-applied biological insecticide which is targeting whiteflies, thrips, aphids, spider mites and other sucking pests in high value fruits, trees, vines and vegetables," said Donglan Tian (Bayer Crop Sci, 890 Embarcadero Dr, West Sacramento, CA 95605; donglan.tian@bayer.com). "It is considered a reduced-risk insecticide due to low toxicity to mammalian and non-target organisms and is exempt from tolerance in the USA. The activity dissipates rapidly after application and can be applied the day of harvest."

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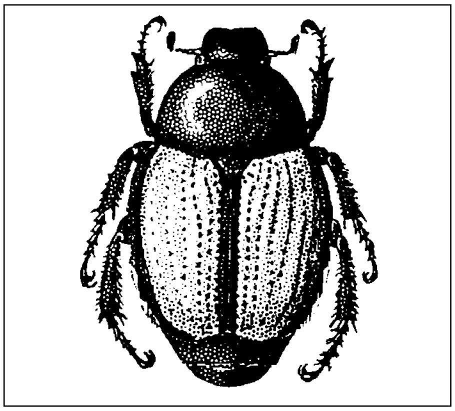
Monarda and Milkweed for Bees and Monarchs

Bumble bees, *Bombus* spp., "are vital pollinators for many plants, including milkweed, *Asclepias* spp., host plant of monarch butterflies, *Danaus plexippus*," said Terryl Woods (Univ Missouri, 1-31 Agri Bldg, Columbia, MO 65201; woodst@missouri.edu). In research farm plots with 10 native wildflower species plus common milkweed, *A. syriaca*, and swamp milkweed, *A. incarnata*, 7 bumblebee species were observed; most frequently the common eastern bumble bee, *Bombus impatiens*, which visited the most floral species (8).

In this central Missouri agricultural landscape, "bumble bees were 8 times more likely to visit" wild bergamot or bee balm, *Monarda fistulosa*, than any other wildflower. "Swamp milkweed, Maxmilian sunflower, *Helianthus maximiliani*; and clover weeds, *Trifolium* spp., were also commonly visited," said Woods. "Milkweed plants located within the diverse wildflower plantings were visited by bumble bees at the same rate as plants in standalone milkweed plantings." In other words, monarch butterfly gardens need not be solid milkweed monocultures; as adding wildflower biodiversity brings both bees and monarchs.

Japanese Beetle IPM and Monarchs

The biopesticide *Bacillus thuringiensis galleriae*, strain SDS-502 (Btg), sprayed for its residual effects against Japanese beetle (JB), *Popillia japonica*, adults feeding on foliage of roses, *Rosa* spp., and linden, *Tilia* spp., and applied as granules against JB larvae feeding underground on turfgrass roots, may have cross-order impacts on monarch butterflies, *Danaus plexippus*, said Daniel Potter (Univ Kentucky, S-225 Ag Sci North, Lexington, KY 40546; dapotter@uky.edu). "Formulations containing Btg toxins were recently registered in the United States (2014) and Canada (2019). These products,



Japanese beetle, *Popillia japonica*

BeetleGONE!® and GrubGONE!® (Phyllom Bioproducts), are being marketed for control of adults and larvae of the JB and other scarabs, and additional beetle pests of turf and landscapes."

Btg advantages include safety to humans and bees, minimal non-target effects, rapid environmental breakdown, and residual effectiveness. Moreover, Btg sprays are good for their main intended purpose of "reducing defoliation by adult JB in urban landscape settings," said Potter. "Granular formulations, however, failed to significantly suppress JB grub numbers in turfgrass in 4 of 5 trials."

"Btg should not be used in gardens with larval host plants of the monarch butterfly or other non-pest Lepidoptera, especially species of conservation concern," said Potter. This is because early instar monarch butterfly larvae (caterpillars) feeding on Btg-treated foliage (spray residues) can suffer 25-30% mortality.

Exclusion Netting and Pheromone Traps

Long-lasting insecticide netting (LLIN) historically effective for excluding malaria mosquitoes can prevent infestations by frequently fumigated food facility and warehouse pests such as red flour beetle, *Tribolium castaneum*, lesser grain borer, *Rhyzopertha dominica*, and warehouse beetle, *Trogoderma variabile*, said Rachel Wilkins (Kansas State Univ, 123 W Waters Hall, Manhattan, KS 66506; rachwilk15@ksu.edu). Incorporating LLIN around food facilities and as a kill mechanism within interception traps may diversify IPM prevention practices and reduce annual commodity losses in the supply chain from unfinished to whole food products.

Interception traps were deployed for two years around three commercial food facilities near Manhattan, Kansas to monitor treatments: 1) control netting only; 2) control netting + SPB (Stored Product Beetle) tab (Insects Unlimited, Westfield, IN); 3) LLIN only; 4) LLIN + SPB tab. [Ed note: SPB lures contain "a grain-oil food attractant and the pheromone for red and confused flour beetles, cigarette beetles, warehouse beetles and rice weevils. It will attract over 20 species of stored product beetles."]

LLIN, as measured by baited interception traps, reduced the number of insects reaching pilot-scale commodity warehouses containing whole wheat and organic, unbleached flour by 9- to 14-fold. "There were 44- to 247-fold fewer progeny in commodities from warehouses with LLIN," said Wilkins. "Overall, LLIN and the use of interception traps may be promising methods to decrease fumigation frequency and other insecticide inputs in the post-harvest environment."

Boric Acid Roach Bait

Borates have a long history of pest control use, and "granular boric acid baits continue to be used extensively, particularly against cockroaches," said Reid Ipser (Nisus Corp, 100 Nisus Dr, Rockford, TN 37853; reidi@nisuscorp.com). "Granule size will influence bait uptake by ants and might influence bait uptake by cockroaches. Inert ingredients and attractants such as oils and sugars can play a role in bait acceptance and boric acid uptake."

In lab trials, American cockroaches, *Periplaneta americana*, ate similar amounts of 5%, 10% and

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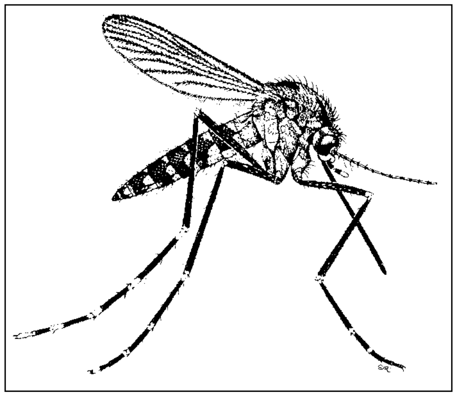
12% boric acid baits and suffered 98-100% mortality in 14-21 days. In other words, American cockroaches have not lost their taste for boric acid baits. But to ensure continued success in cockroach IPM programs, remain cognizant of variables such as bait granule size, inert ingredients and attractants.

Silica-Based Bed Bug IPM

Amorphous silica is a "reduced environmental risk IPM option" that can be targeted to office working space areas where bed bugs are highly aggregated, and integrated with intensive trapping, said Shannon Sked (Rutgers, 96 Lipman Dr, New Brunswick, NJ 08901; shannon.sked@rutgers.edu). Locating bed bug aggregation sites is critical to IPM success, though it is easier said than done. In offices with "persistent" bed bug sightings over a two-year period: "270 interceptors were installed with one interceptor in each cubicle space containing a baited lure." And "six inspections were conducted every 10-20 days over a 90-day period."

Dozens of nymphs could be caught in interceptor traps with very little evidence of bed bug adults or breeding sites. About 93% of the time, areas with beds and furnishings are bed bug aggregation sites; which can be targeted with multiple silica dust treatments. Though if an office chair is a harborage, it is best to get rid of the infested piece of furniture. Since CO_2 is a long-range bed bug attractant, dry ice traps were used to attract bed bugs the night before silica dust treatments.

Insecticidal liquids and dusts are popular bed bug remedies that IPM programs can integrate with non-chemical methods such as vacuuming, heat (no residues) and steam (heated water), said Sabita Ranabhat (Rutgers, 96 Lipman Dr, New Brunswick, NJ 08901; sabita.ranabhat12@gmail.com). Steam and relative humidity connote moisture. So, three insecticidal dust products were compared in the wet and dry states: 1) CimeXa™ ("silicon dioxide as amorphous silica"; Rockwell Labs, North Kansas City, MO); 2) Alpine® (dinotefuran + diatomaceous earth; BASF); 3) Tempo® (1% cyfluthrin + "99% inert ingredients"; Bayer).



***Aedes* sp. mosquito**

Dust products, which are reputed to have longer residuals than liquid sprays, were placed on tiles, treated with steam and dried for 24 hours. Then bed bugs were added to the treatment chamber. Moisture lowered the effectiveness of all three dust products. CimeXa, which is labeled for 45% relative humidity, was the best dust product tested under moist conditions; and is recommended when moisture will be high. Even two months later, CimeXa that had been wetted and dried was still effective. Nonetheless, it is best not to expose dusts to moisture.

Vitamin C Mosquito Baits

Generally Recognized as Safe (GRAS), EPA exempt food grade alternatives to broad-spectrum pesticides can stop disease-vectoring mosquitoes for homeowners, and are the preferred choice of the USA Dept of Defense for foreign army bases, said Emily McDermott (Walter Reed Army Instit Res, 503 Robert Grant Ave, Silver Spring, MD 20910; emily.g.mcdermott.civ@mail.mil). Sodium ascorbate (SA), a naturally occurring vitamin C mineral salt and GRAS food additive with pro-oxidant and antioxidant properties, was formulated at 6-20% as an Attractive Toxic Sugar Bait (ATSB) for mosquitoes.

A sucrose bait spiked with SA caused dose-dependent mortality of the mosquito vectors *Aedes aegypti* and *Anopheles stephensi*. Phlebotomine sand flies were less susceptible to the vitamin C mineral salt. "When SA is oxidized, hydrogen peroxide (H_2O_2) is produced, which is toxic to cells and must be neutralized by catalase," said McDermott. H_2O_2 disappears too fast to be measured in insects, so its production is inferred from "extensive pathology in the midgut" and by measuring catalase. Gallic acid, which neutralizes H_2O_2, increases mosquito survival after bait feeding. The SA/H_2O_2 toxin is flushed out when adult mosquitoes take blood meals, making IPM more challenging.

Fructose sugar increases bait palatability, reducing mosquito survival. Adding 0.25-1% plant essential oils can increase bait attraction, versus sodium ascorbate alone. Essential oil tests are ongoing, and some compounds are repellent. But anisaldehyde stands out as more attractive than geraniol, citral, thujone, linalool or benzaldehyde. IPM programs can use the sugar baits with sodium ascorbate in bait stations or as foliage sprays.

AMF Seed Treatments in Louisiana

Commercial arbuscular mycorrhizal fungi (AMF) products are available, but AMF seed treatments are a new use, said Lina Bernaola (Louisiana State Univ, 404 Life Sci Bldg, Baton Rouge, LA 70803; LBernaola@agcenter.lsu.edu). AMF seed treatments were compared with NipsIt INSIDE, a neonicotinoid seed treatment used on rice against rice water weevil (RWW), *Lissorhoptrus oryzophilus*, a root herbivore causing early-season economic damage.

Rice plant biomass and yield were higher with the AMF seed treatment than with the neonic seed treatment. Rice water weevil populations were higher with AMF seed than with neonic seed; but

AMF increases rice tolerance to weevil root feeding, so AMF plants can sustain higher weevil levels and still out-yield neonic seeds. AMF and rice plants have a mutual or symbiotic relationship. Plants give carbon to AMF; and AMF contribute nitrogen and phosphorous that boosts crop growth and defense responses.

Furrow Fungi Replace Neonic Seed

Neonicotinoid seed treatments such as Gaucho® (imidacloprid), which replaced the banned pesticide lindane, are widely used to combat wireworms, which are the larvae of click beetles (Elateridae) and "major pests of spring wheat around the world," said Anamika Sharma (Montana State Univ, 9546 Old Shelby Rd, Conrad, MT 59425; anamika.sharma@montana.edu). Imidacloprid repels, but does not kill wireworms, and more effective, environmentally friendly management strategies are needed. In Montana's Golden Triangle Area, where over 20 wireworm species live hidden beneath the soil and wheat losses can reach 70%, a more effective planting time alternative to imidacloprid seed treatment is in-furrow application of granules carrying entomopathogenic fungi (EPF).

Because Montana has three pestiferous wireworm species with 1-3 year subterranean life cycles, an IPM alternative to neonic seeds should combine multiple strategems, not just in-furrow EPF granules at planting time. Crop rotations are also effective; as are ploughing, soil drying, resistant cultivars and trap crops.

EPFs tested included *Beauveria bassiana* GHA or ERL836; *Metarhizium robertsii* DWR356 or DWR2009; and *M. brunneum* F52. EPFs were applied as granules, soil drenches and seed coatings; and compared with imidacloprid and water (control). EPF granules applied in-furrow at planting time with a nutritive carrier (e.g. millet, couscous, polenta) to spur fungal growth were more effective than imidacloprid; leading to highest wheat yields, and were easy to apply on Montana's large grain farms. In South Korea, millet is used as the EPF carrier. In Montana, low rates of EPF millet granules (11 kg/ha = 9.8 lb/acre) were as "cost effective" as high rates (2x) in irrigated and non-irrigated wheat in 2017. In 2018 only low rates of EPF were used.

Pheromones Monitor Georgia Stink Bugs

Monitoring brown marmorated stink bug (BMSB), *Halyomorpha halys*, an invasive pest infesting 40 agricultural and 117 ornamental crops in 43 USA states, "incorporate costly, custom-designed black pyramid traps and less costly, more accessible sticky-card traps" with pheromone lures, said Dilani Patel (Univ Georgia, 413 Biol Sci Bldg, Athens, GA 30602; dkp83951@uga.edu). "Monitoring of BMSB is an essential decision-making tool for farmers of BMSB-susceptible crops." So, trap optimization studies were conducted.

Pyramid traps capture more BMSB than sticky card traps. However, both types of pheromone traps provide valid trend data on nymph and adult BMSB populations. "Increasing the frequency of pheromone changes and sticky card changes improves the efficacy of the less costly, more accessible sticky-card traps under high BMSB conditions," said Patel. "Seasonal monitoring with both traps can effectively be done during crop maturation and harvest seasons, when crops are more vulnerable." In Georgia in 2017 and 2018, the first generation of BMSB were present in June and July; and the second generation was in the field in September.

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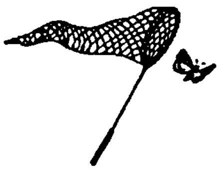

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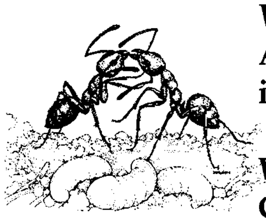

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