Biological Control

No plant lives in isolation. It is part of a food chain involving many other organisms, including insects, fungi, bacteria, and other plants and viruses. Some feed on the plant, some on the organisms that feed on the plant and so on. The plant powers this system by taking nutrients from the soil and converting solar energy by photosynthesis. In an agricultural system, where the human goal is to maximize the food value of the plant for human or animal consumption, any organisms in the system that impede this objective are called pests or diseases. The most common way to reduce their impact on food production has been to use chemical sprays (insecticides and fungicides) that destroy the pests but not the food plants.

Biological control uses a different approach to pest management, focusing on natural enemies of plant pests and diseases to manage their populations. The strategies rely on detailed knowledge of the ecology, the life cycles, and the food chains in each system, developing highly target-specific control strategies that leave the non-target plants, insects, or other animals unharmed.

First modern success

In the late 1880s, the Cottony Cushion Scale insect, a pest brought to North America from Australia, began to devastate the California citrus groves. Scientists searched for a natural enemy in Australia and found the Vedalia Beetle, a member of the ladybug family. It was introduced to the citrus groves and proved extremely successful. This is the classical model for biological control—one exotic species is brought into check by another exotic species with which it will live in harmony, but in much fewer numbers. Exotics are species that did not arise naturally in an area but were introduced through some external intervention.

Classic biological control has been used successfully by researchers at IITA. Examples include control of the cassava mealybug, cassava green mite from South America, or mango mealybug from Asia. For organisms that have invaded another continent, this type of approach is highly promising. It sometimes also gives appreciable results when natural enemies are exchanged between different regions on the same continent.

Other Approaches

Not all pests are exotic. Many are indigenous; they have found rich niches in agricultural crops where they cause problems. They may have wild host plants in the same area, but the density of planting of crops makes these so much more attractive for feeding or egg laying. Indigenous natural enemies usually exist, but are not capable of keeping these particular pests below tolerable levels. In many ways these pests present much more difficult challenges for biological control.

Researchers employ a host of strategies; often looking for means to strengthen local, natural enemies or to produce them en masse as biopesticides. Fungi, insect viruses, even competing but harmless strains of the same pest are being tried, often with great success.

In Africa

The challenge in Africa, where most farmers work on very small plots and have little cash to purchase any control agents, biological or otherwise, is to develop systems that are sustainable, affordable, and easy to use or maintain. The inherent species richness and diversity of the landscape and consumer acceptance of slightly blemished produce often offer conditions that are more conducive to successful biological control than is the case in say the US or UK.

Biological Control Case Study

Cassava Mealybug

Cassava (also known as manioc) came to Africa from South America in the 16th century. In the following four hundred years its starchy, thickened roots became the main staple food for hundreds of millions of Africans, providing up to 70% of their daily energy intake.

Challenge

When cassava came from the Americas many of its indigenous insects (mites and plant diseases alike) were left behind. But in the 1970s a terrible pest was observed simultaneously in both the Republic of Congo and what is now the Democratic Republic of Congo. It was the cassava mealybug and it appeared to have been accidentally introduced from Latin America. In its area of origin, the mealybug is a rare insect, but in Africa it spread rapidly over the entire cassava growing area of the continent. It had no natural enemies and within a decade became the most important pest insect on cassava, causing crop losses of up to 80%.

Intervention

IITA scientists, working with teams from CIAT our sister institute in South America and with the Commonwealth Institute of Biological Control (CIBC) in Trinidad, studied how the mealybug was kept under control in South America. Eventually a tiny wasp (smaller than the head of a pin), which laid its eggs on the mealybug, was discovered. As they grow inside the mealybug, the wasp larvae kill the mealybug.

This could be the key to control that scientists were looking for, but first they had to be sure it would not get out of control if it were released on the African continent, causing some other, unpredictable environmental damage. In conjunction with CABI Bioscience the candidate wasps were quarantined in the UK where they were tested to see how specific they were to the mealybug host. If the wasps could parasitize other important species in Africa, they might be too dangerous to release there. The tests showed the wasps were highly specific to the mealybugs and so some were imported into Nigeria for mass rearing and eventual release into the wild.

Impact

The results were spectacular. All over the cassava belt of Africa the wasps controlled the mealybugs very quickly and today, more than a decade later the mealybugs and wasps live in a natural balance with mealybug populations down to maximum 10% of what they had been at the peak of the infestation. Today cassava grows with little mealybug damage.

For the farmers of Africa the economic impact has also been spectacular. Every pound of donor investment in the mealybug control work has returned between 200 and 500 pounds in terms of annual cassava production alone. The extra benefits to the environment and human health from this environmentally sound solution with no costs to farmers are difficult to calculate, but are nevertheless very real.

Biological Control Case Study

Desert Locust

The desert locust, a grasshopper, is the most feared pest of farmers living around the worlds' major deserts. It has caused incredible devastation in the tropical world. Normally it lives in what is called a solitary phase, a scattered individual that feeds on wild plants but does not act en masse.

Challenge

The real problem arises when the insects transform into the gregarious phase and form locust swarms, moving collectively to devour entire fields in a few hours before moving on. Broad-spectrum synthetic insecticides, often sprayed from the air have been the only effective control but at a terrible ecological price and with the potential to harm human health. Scientists have looked at many strategies for management, including looking for the trigger mechanism that causes the locusts to swarm in the first place.

Intervention

In the late 1980s, an IITA research team, together with scientists from CABI Bioscience, took a very different approach. They focused on a natural pathogen that was specific to the desert locust, or at least to the grasshopper family. Their candidate was a fungus called *Metarhizium anisopliae.* It worked very well against several types of grasshoppers, including the desert locust. Extensive tests also showed that the fungus did not affect non-target species including several groups of beneficial and economically important insects. The fungus occurs naturally in Africa and has no effects on humans or animals. The trick was to produce it in quantity and then develop a delivery system to target the grasshoppers and locusts. The scientists found that mixing live fungal spores with oil would keep the spores from drying out. The mix can be sprayed from the air during locust swarms or from the ground using small, hand-operated sprayers.

Impact

Unlike chemical sprays, which act almost immediately, the fungal spray, now trademarked under the name Green Muscle (the oil–fungus mix has a dark green colour), takes longer as the fungus has to colonize the host grasshoppers first. Six days after a single application in test plots the grasshoppers began to die. Unlike many chemical insecticides, the fungus remained active for a long time and after two weeks up to 95% of grasshoppers had been killed. There was no reinvasion of the treated plots. In fact the dead grasshoppers provided the perfect medium for the fungus to continue to multiply, thus prolonging the protection it gave to the fields.

The story is not over. While the new biopesticide, which has been duly tested and registered, is effective, it is still relatively expensive to produce and cannot be produced in quantity by small-scale, artisanal methods. Commercial companies, including one in South Africa, have now been licensed to produce Green Muscle in quantity but there is still much work to be done. The Food and Agriculture Organization of the United Nations has ranked Green Muscle as the top insecticide in the two categories of human and environmental safety. In the absence of desert locust swarms, the product is being used on a large scale against other locusts and grasshoppers in Africa and as another product in Australia.

Biological Control Case Study

Cassava Green Mite

Another unwelcome migrant from Latin America, a spider mite, began to affect cassava in Africa around the same time as the mealybug. When the mealybug was brought under control this so-called cassava green mite became a significant pest.

Challenge

The research team decided to follow an approach similar to that used for the cassava mealybug. They would look for a natural enemy of the green mite in its home territory in South America. In Colombia scientists found that another mite, rather than a wasp, was the main natural enemy of the green mite. They collected a vast range of candidate mites, hoping to narrow the group to a few candidates that might work in Africa. After undergoing quarantine and testing against non-target species, some were introduced into Africa but they failed to establish and soon died out. The green mites continued to thrive and damage cassava crops. This experience pointed out how difficult effective biological control can be to achieve.

The solution was to look in regions climatically similar to those where the green mite was established in Africa. Such conditions were found in Brazil. Two of the species from Colombia that had been tried and failed were also found in Brazil. The Brazilian mites did indeed establish in Africa but their spread was very slow.

Intervention

Ten years after the first work, another predatory mite was found that both established itself in Africa and spread rapidly in farmer's fields. Studies of these mites showed that they did not have voracious appetites and it was thought that might be a disadvantage and that they might not be very effective at controlling the green mite. Now scientists believe that this trait is an advantage, allowing enough green mites to survive to prevent the dying off of the predatory mites. So far the predatory mite has only been found on cultivated cassava and on no other plants (unlike the first mites that were tried). In addition to feeding on the green mites, it seems to feed on pollen and on the sap that exudes from cassava leaves.

Impact

The introduction of the predatory mite—called *T. aripo*—has not only reduced the damage caused by green mites throughout the cassava regions of Africa, it has contributed substantially to the science of biological control and to the knowledge of how mites work in complex food systems. Again this classic biological control costs farmers nothing and once established, is self-sustaining.

Biological Control: Other Successes

Mango Mealybug

West African mango trees were invaded by the mango mealybug, an exotic visitor from Asia. The same scientific team that solved the cassava mealybug problem used a similar approach with the mango mealybug. They found natural enemies in India. After testing to ensure they would not harm nontarget organisms, they were reared and released. They continue to control the mango mealybug.

Water Hyacinth

The water hyacinth was brought to many parts of the world from South America during colonial times as an ornamental plant. It is, however, one of the world's most obnoxious waterweeds when not controlled. Unfortunately it thrived in ponds and lakes in the tropics to such a great extent that it became more than a nuisance. In Lake Victoria, the second largest fresh water lake in the world, masses of water hyacinth covered parts of the lake near the shoreline, disrupting fishing. Intakes to water supplies and power plants were clogged and the ecological balance of the lake was changed.

IITA was part of a major effort to clean up water hyacinth on Lake Victoria. Two weevil species had been identified as biological control agents and IITA, in conjunction with the National Biological Control Unit of Uganda, embarked on a program to introduce the weevils to the waters of Lake Victoria. According to the Ugandan officials, the offspring of weevils obtained from the IITA African Center for Biological Control in Cotonou, Benin had destroyed 60% of the water hyacinth plants on the lake in a very short time. There was no need to used chemical controls.

Cowpea Thrips

IITA scientists have discovered a possible control agent for thrips, which is a severe pest of cowpea. Cowpea is a nutritious grain legume that farmers grow in large quantities in the dry savanna regions of West Africa. IITA scientists believe that the parasite which controls the thrips was probably an exotic introduced accidentally to West Africa from India.

Water Lettuce

Before water hyacinth began to dominate waterways in West Africa, a floating plant called water lettuce was a major weed. After the success of water hyacinth control using weevils, IITA scientists turned their attention to water lettuce. Zimbabwe provided another weevil, which proved successful in controlling the weed. At the height of weed infestation, parts of rivers in Benin had almost total weed cover. Since the introduction of the weevils, the river cover has been reduced to negligible amounts in the same areas. The impact on fishing communities along the rivers in Benin where the control is being used is substantial and the project also shows the value of "south–south" collaborations.