costs and benefits are those borne by an individual or firm that consequently has an incentive to account for them. Costs or benefits are said to be external when they are not fully reflected in the prices faced by the individual or firm. For example, a grower would have no incentive to account for the costs of water quality degradation downstream attributable to excessive tailwater runoff.

Most of the 23 categories of incidental effects identified had both private and external impacts. If the effects are solely private, and water is priced at its "true" or scarcity value (the value determined by the worth of water in its most profitable use), the level of water saving activity will be optimal for society. Conversely, the water user will not account for external impacts, and thus total water use will not be optimal for society.

Methods of estimating both private and external technological costs and benefits are fairly well developed both conceptually and theoretically. The economic impact of incidental water conservation effects that occur on the farm is relatively easily assessed because of data available on the economics of farming, but assessment of the significance and magnitude of external effects is more difficult because of the large requirement for economic and hydrologic information. Although several studies demonstrate that irrigation management practices may determine the salinity of receiving surface and groundwaters, there have been fewer studies of other external effects.

Most of the economically significant on-farm (and some off-farm) incidental costs and benefits of water conservation are accounted for by growers. However, they generally have only weak incentives to economize on water use when the water is both inexpensive and abundant. The artificial nature of many water prices makes it difficult to assess whether the external impacts of water conservation have values that are large enough, when compared with private values, to require further attention.

Recognition of some incidental effects (particularly savings in private costs such as energy) may give growers additional incentives to conserve water. However, water scarcity or relatively high water prices, or both, are the real motivating forces for conserving water in irrigated agriculture.

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Parasitic nematode controls western poplar clearwing moth

Harry K. Kaya ☐ James E. Lindegren

Borers were reduced by one treatment

Larvae of the western poplar clearwing (WPC), usually found in trunks and branches of wild poplar and willow trees, have become pests of birch, poplar, and willow trees in nurseries, parks, and residential areas. Stressed trees, such as those that are newly planted or damaged, are preferred hosts. Most homeowners do not recognize the symptoms of attack by this insect and attribute the decline of the trees to other causes. Although infested trees may recover, they are usually deformed and slow growing and are more susceptible to additional WPC attacks.

The western poplar clearwing, *Paranthrene robiniae*, a moth native to western North America, is wasplike in appearance and size. It has a two-year life cycle. Adult moths deposit eggs singly in bark crevices and wounds. Larvae emerge from the eggs and bore into the trunk or branch, where they feed during two successive summer and fall seasons. Pupation occurs during the next spring, and adults are found from May into July. In southern California, adults have been found in November and from February through May.

The presence of actively feeding larvae can be detected by their sawdust-like frass near the gallery opening. Branches broken by the boring of the larvae and cast pupal cases left at gallery exit sites are also good indications of infestation. The larvae are difficult to control, because they are protected inside their galleries.

Parasitic nematode

The insect-parasitic "coding moth" nematode, *Neoaplectana carpocapsae*, has been effectively applied to other plant-boring insects (*California Agiculture*, January-February 1981 and November-December 1982). This nematode is mutualistically associated with a bacterium, *Xenorhabdus nematophilus*, which occurs in the infective nematode's gut. When the nematode invades the body of the host, it releases the bacterial cells, and the host dies from a bacterial infection 24 to 48 hours later. The nematode feeds on the bacterial cells and host tissues and develops to an adult, which reproduces sexually. Under the right moisture conditions, the nematodes leave the host and are capable of infecting new hosts. The life cycle of the nematode in the host, from infection to leaving the host, takes about seven to ten days.

The nematode-bacterial complex infects only insects and was recently exempted from registration by the U.S. Environmental Protection Agency and the California Department of Food and Agriculture. Other countries, in particular Australia and France, are using this nematode-bacterial complex against a number of tree-boring and soil-infesting insect species.

Application and results

We conducted a field test of *N. carpocapsae* (All strain) application against WPC larvae in 5- to 10-foot poplar and birch trees in residential areas in Davis. (Several homeowners donated severely infested trees for this research.) Fall and spring applications were all made with an atomizer containing an aqueous suspension of 35,000 infective nematodes per ml. Each gallery was treated with 70,000 nematodes (2 ml) or with 2 ml of water (control). Two weeks after application, the trees were cut and galleries examined for live and dead larvae and pupae. Dead larvae and pupae were dissected for presence or absence of nematodes.

Our results showed the effectiveness of the nematode in infecting the borers in birch and poplar trees. In October 1981, one *N. carpocapsae* application to five birch trees heavily infested with borers resulted in 88 percent (n=77) mortality. All 15 borers found in three control trees were alive. In March 1982, 90 percent of the borers (n=10) in one

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Parasitic nematode, cont'd

birch tree treated with the nematode were dead. In April 1982, a poplar tree treated with the nematode also had 90 percent (n=20) borer mortality. Two of the 20 borers were pupae, and both were infected with the nematode. Four control borers were alive. Dissection of the dead borers showed that most (more than 90 percent) contained developing stages of the nematode. Thus, the borer population was effectively reduced after one nematode application in either spring or fall.

In our situation, the trees were so severely infested and deformed that the homeowners were removing and replacing them. In future experiments, the goal will be to save lightly infested trees by controlling the borer larvae before heavy infestation and deformation occur. Newly planted trees would have time to become established, which should provide some protection against later infestation by the WPC moth.

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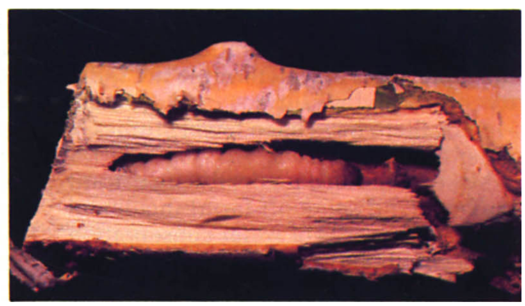
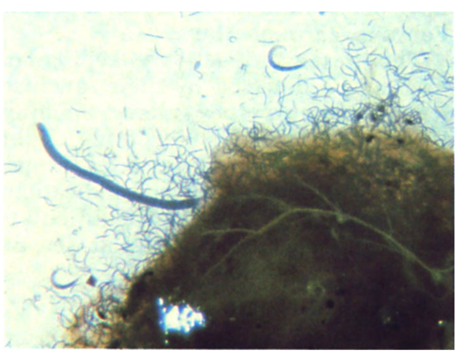
C.S. Papp

Female western poplar clearwing moth with empty pupal case.



Dead western poplar clearwing larva in gallery has been killed by parasitic nematode.



Dissected dead WPC larva contains different stages of the parasitic nematode.

Right: Sawdust-like frass from gallery is a sign of WPC infestation of birch tree.