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On the paradox of pesticides

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ABSTRACT

The paradox of pesticides was observed experimentally, which says that pesticides may dramatically increase the population of a pest when the pest has a natural predator. Here we use a mathematical model to study the paradox. We find that the timing for the application of pesticides is crucial for the resurgence or non-resurgence of the pests. In particular, regularly applying pesticides is not a good idea as also observed in experiments [3,7]. In fact, the best time to apply pesticides is when the pest population is reasonably high.

1. Introduction

The paradox of pesticides says that pesticides may dramatically increase the population of a pest when the pest has a natural predator. Right after the application of the pesticide, of course the pest population shall decrease. But the pest may resurge later on resulting in a population well beyond the crop's economic threshold.

In the experiment of [9], pesticides (pyrethroids) are applied in apple orchards for the main goal of killing flying insects (lepidopteran and dipteran pests). The side effect of this is that later on the populations of other pests (phytophagous mites: panonychus ulmi and tetranychus urticae) feeding on the apple tree's leaves resurge above the crop's economic thresholds, while the populations of these pests on the leaves not sprayed with the pesticides remain low (below the crop's economic thresholds). These phytophagous mites are the preys of some predator mites (phytoseiid predator typhlodromus caudiglans and stigmaeid predator zetzellia mali). The pesticides kill both the leaf eating mites and the predator mites. One of the predator mites (typhlodromus caudiglans) is almost wiped out by the pesticides, and resurges very slowly. The population of the other predator mite (zetzellia mali) is only slightly affected by the pesticides, but it alone cannot control the resurgence of the leaf eating mites. The pesticide damage to the populations of the leaf eating mites is not as severe as that to the population of the predator mite (typhlodromus caudiglans). After the spraying of the pesticides, the dynamics described above lasts 11 weeks. The phenomena just described have been well documented in many experiments [1,2,4–6,8,12,14,16].

In the experiment of [3,7], pesticide effects on arthropods in the rice field are studied. There are four groups of arthropods: herbivores, detritivores, predators, and parasitoids. Herbivores eat rice plants, detritivores eat detritus in the rice field, and predators and parasitoids eat herbivores and detritivores. Pesticides can kill every group of arthropods. Since they move around faster and more often, predators contact the pesticides more often, and therefore are killed more. This leads to more abundance of herbivores. A new scheme for spraying pesticides was introduced in [7], that is, applying pesticides only when the pest densities

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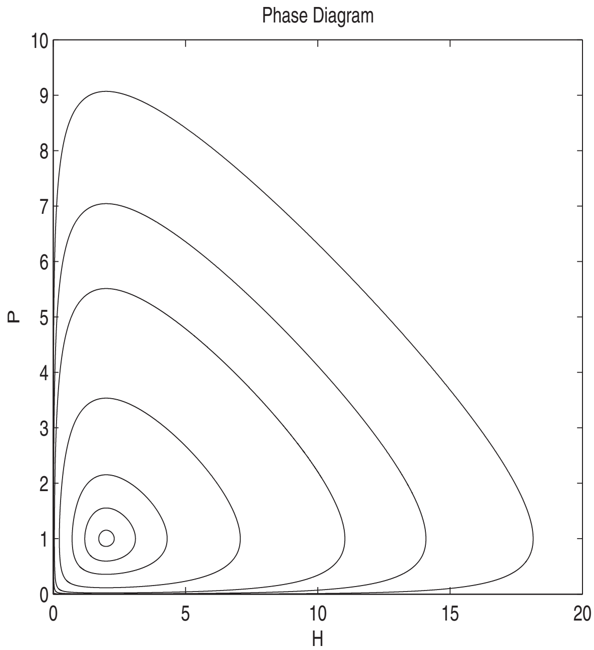

Fig. 1. The phase plane diagram of (2.3)–(2.4), $a = b = d = 1,\ c = 0.5,$ with different starting points of (H, P): (1.8, 0.9), (1.4, 0.7), (1.0, 0.5), (0.5, 0.25), (0.2, 0.1), (0.1, 0.05), (0.04, 0.02).

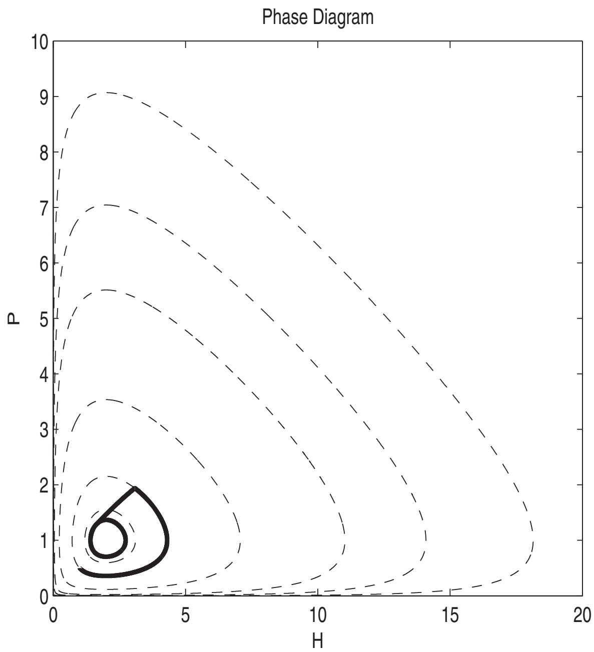

Fig. 2. A pesticide forced orbit of (2.1)–(2.2), $a = b = d = 1,\ c = 0.5,\ T = 3.5,\ \epsilon = 0.07,\ \alpha = 1.4,\ \beta = 0.7$. In this case, the pest population decreases and maintains at a lower amplitude oscillation.

are high enough, rather than applying regularly. In contrast to regularly applying pesticides every week, the new scheme dramatically reduces the density of herbivores among all arthropods, which are the main destroyers of the rice field; enhances the densities of predators and detritivores; and slightly reduces the density of parasitoids.

Mathematical modeling on pest resurgence has also been studied, e.g. in [11], a time-discrete model generalizing the Nicholson–Bailey model [13], is studied and concludes that the paradox of pesticides could be caused essentially by the interspecific relationship and the intraspecific density effect.