


Pest species respond differently to farm field size

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Agriculture faces numerous challenges relating to population growth and environmental quality. Strategies to address these challenges are expected to involve a redesign of agricultural production systems to increase productivity and sustainability (1, 2). Notably, changing how cropland is structured within agroecosystems is one redesign opportunity that could have multiple sustainability benefits. Agroecosystems are a complex arrangement of crop and noncrop habitats that support a diverse array of arthropods relevant to sustainable crop production, including pests, natural enemies, and pollinators. Farmers and ecologists have long known that the arrangement and abundance of crops have local impacts on pest infestations, leading to the idea that manipulation of cropland structure could alleviate pressure by pests, promote biological control, and reduce pesticide use (3–7). One aspect of this is that concentrated crop production, either size of fields planted to a single crop or prevalence of a single crop in the landscape, will result in more pest problems. Rosenheim et al. (8), in PNAS, tested this concept using a large, multicrop dataset collected from different agricultural systems to investigate whether the size of fields planted to a single crop or the amount of a crop in the surrounding landscape is positively related to pest abundance. Their key finding is the absence of a consistent relationship between pest abundance and the area of host crop at either the field or the landscape scale. They found negative, neutral, and positive relationships, suggesting that pests vary in their response to crop abundance at both the field and landscape scales (Fig. 1). The results provide a compelling argument that the relationship between pest pressure and the extent of host crop production is context dependent. This suggests that predicting the effect of crop abundance on the intensity of pest problems will require accounting for the ways in which individual pest species interact with their habitats, as well as the effects of landscape composition and configuration on their natural enemies.

The results are important not only because of their relevance to the sustainable intensification of agricultural production systems but also because there has been a long-standing acceptance in the agroecological literature that increasing field size in agricultural monocultures is positively related to pest infestation levels, crop loss, and pesticide use (3, 5, 7, 9). The conceptual framework underlying this putative relationship is based largely on two ecological concepts: the resource concentration hypothesis and the natural enemies hypothesis (10, 11). The former predicts that population densities of specialist herbivores will be higher in large monocultures of their host plants than in diverse stands. The latter suggests reduced biological control of herbivores in large pure stands because these monocultures do not provide suitable habitat and resources for natural enemies. However, the generalization of these concepts to agricultural systems across broad spatial scales and the idea

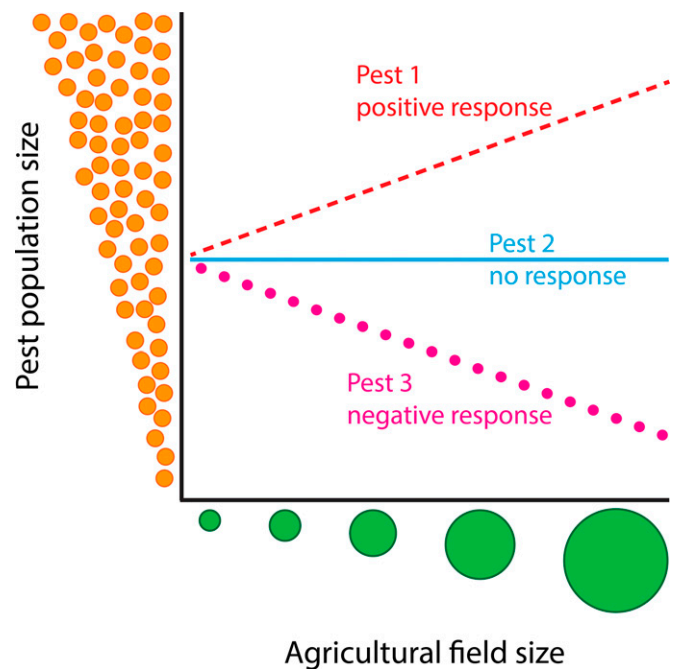


Fig. 1. The size of arthropod pest populations sampled in different annual and perennial crops were related to the size of the agricultural field and the abundance of the same crop in the surrounding landscape. Results showed that different arthropod species responded positively (pest 1) or negatively (pest 3) or had no relationship at all (pest 2) to the size of agricultural fields. Species tended to have similar trends at different spatial scales of crop production.

that large-scale monocultures intensify pest problems lacks rigorous theoretical or empirical support (8). Field studies in agricultural crops, primarily involving small plots, as well as studies in natural systems and modeling studies have shown that the effects of increasing field size on pest population density can be inconsistent (12–17).

Rosenheim et al. (8) took advantage of existing data compiled by independent crop advisors or farm staff during regular sampling of pest populations or crop injury to inform decisions regarding pesticide applications. The dataset comprised >20,000 field-year observations spanning

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five crops and 14 pest species that included a wide range of field sizes within and across cropping systems in three countries. It also included the number of insecticide applications applied to the focal fields during the cropping season and the proportional amounts of the focal crop and natural habitats within the surrounding landscape. To account for variation in pest pressure due to farming practices and other relevant sources of variation, the authors included, in their analyses, appropriate covariates associated with intense agricultural production. Results showed that the effects of field size on pest population pressure and pesticide use were positive, negative, or neutral, depending on the crop and pest species. Their findings are consistent with those of modeling studies in which pest movement, behavior, habitat quality, and suitability of the crop as a host were found to alter the effect of field size on pest abundance (11, 16–18). Variable responses to field size are not surprising, given that the insect pests included in this study vary greatly in their life histories, overwintering habitat, plant host range, and dispersal capability, as well as their interactions with the crops. Additionally, farmer decisions to apply pesticides to an individual field are based on numerous farm-level management considerations in addition to pest abundance (19).

To extend these results, the authors (8) estimated the prevalence of host crops in the nearby landscape to examine the relationship between local crop production patterns and pest infestation intensity. For each focal crop, the amount of the same crop in the local landscape was measured and related to pest pressure. It is important to consider that the methods and landscape areas used to estimate crop composition surrounding the focal fields differed among crops, ranging from simple proportions of fields adjacent to focal fields to remotely sensed crop data collected at 1- to 2-km distances from the focal fields where pest data were collected. Although these differences may limit some general inferences about landscape-mediated crop-pest relationships, the division of analyses by host crop suggest that pest pressure responded similarly to field size and to abundance of the same focal crop in the landscape. Pests that positively or negatively responded to increasing focal-field size tended to have the same response with increasing abundance of the same crop nearby. The similarity of these trends suggests that crop fields and similar host crops within the local landscape share ecological processes that drive pest population dynamics. This is important because high concentrations of similar host crops within the larger agricultural landscape are thought to increase risk from arthropod pests.

For any given pest species, the size of the population that develops within an individual field is determined, in large part, by the ability of the insect to colonize the field,

as well as by reproduction and mortality within the field, in addition to an array of abiotic factors, including those related to agricultural practices. The rate at which a field is colonized is influenced by the dispersal capability of the pest species, as well as the size of the immigrating population and the distance of the field from the source of immigrants, both of which are influenced by the abundance and location of host plants in the relevant landscape. Pest mortality due to natural enemies is an important source of population suppression. There is a large body of literature documenting that the responses of within-field natural enemy populations to crop field size and landscape composition/configuration can also be positive, negative, or neutral and are similarly influenced by the enemies' specific life history and behavioral traits (7, 20). Thus, future efforts to understand and predict effects of field size and landscape structure on pest pressure can be expected to benefit from an accounting of the specific life history and behavioral included traits of both the pest and its natural enemies.

Envisioning effective approaches to make working farmlands more sustainable is a major challenge confronting agriculturalists worldwide. With multiple serious issues at hand, like mitigating greenhouse gas emissions, water use and quality, and reducing fertilizer inputs, farmers are tasked with increasing productivity while reducing the externalities of agricultural practices on humans and the environment (21). Within the field of crop protection, the challenges are many. But there are opportunities to make progress, especially where there is a good understanding of the fundamental processes undergirding problems. Applying approaches similar to those of Rosenheim et al. (8) will be useful to identify taxa and cropping systems in which pests have predictable responses to crop concentration, particularly those systems with a negative relationship. Leveraging this knowledge will be challenging, but annual crops provide an opportunity to test proactive structuring of crop fields and landscapes. In annual cropping systems, farmers could manipulate field size and rotate concentrated production of individual crops to reduce logistical constraints of production while reaping the benefits of reduced pest pressure. Clearly, this simplified approach ignores the intricacies of using deliberate crop placement to manage multiple pest species. For example, most cotton produced in the United States is challenged by a multitude of arthropod pests throughout the season that vary in life history traits, natural enemies, and responses to spatial concentration of the crop. Evaluating the trade-offs of crop consolidation for a complex of pests presents a difficult challenge that will require aggregation of large datasets across production regions and a deep knowledge of pest ecology to determine best management practices that limit pest pressure while meeting crop-specific sustainability goals.

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