that these HACs, similar to the earlier multimerized versions, are lost during mitosis more frequently than normal chromosomes, perhaps because of their structure or relatively small size. Some of this instability can be attributed to the behavior of circular chromosomes, which spontaneously form double-ring structures and undergo cycles of breakage (*9*). Linearizing the circular chromosome and adding telomeres may add more stability (*10*). In general, the lower limits on chromosome size are not understood, nor are the limits that may apply to the relative sizes of the centromere, pericentromeric regions (adjacent to centromeres), and gene cargo areas. It is also not yet known how the compact size of artificial chromosomes might affect the regulation of gene expression, particularly when genes are placed near the centromeres or pericentromeric regions. It should be possible to further increase the size of the artificial chromosomes, alter the relative sizes of their components, and add genes and telomeres to better understand their performance.

Future applications of HACs will likely focus on introducing long genes or multigene clusters into cell lines or individuals. Such artificial chromosomes may enable the creation of versatile cell lines that better model human disease or can be used to produce pharmaceuticals and vaccines (*11*). Moreover, the implications of the work by Gambogi *et al.* are not limited to what can be done in animals. The principles of centromere design, use of yeast for engineering, and cell fusion to transfer large molecules should be applicable across kingdoms. In higher plants, a CENP-A tethering method for engineering centromeres has already been demonstrated (*12*), and cell-cell fusion is achievable after removal of the cell walls (*13*). It may soon be possible to include artificial chromosomes as a part of an expanding toolkit to address global challenges related to health care, livestock, and the production of food and fiber. ■

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ECOLOGY

Collateral impacts of organic farming

Clustering organic cropland can reduce pesticide use on nearby conventional farms

By **Erik Lichtenberg**

Organic and conventional farms are frequently located close to one another because of suitable climate and soil conditions, proximity to marketing channels, ownership, and other local factors. Yet proximity does not necessarily make for compatibility. Drift from pesticide sprays or pollen from genetically modified crops can threaten organic certification status (*1*). Conversely, insects, fungal spores, and weed seeds from flower strips maintained for natural pesticide control in organic fields can be sources of pest infestation in conventional fields (*2*), as can mobile insect pests that are inadequately controlled in organic fields. On page 1308 of this issue, Larsen *et al.* (*3*) used field observations from Kern County, California, to show that being surrounded by organic fields can help reduce the use of pesticides by organic crop producers but increases their use on conventional fields. Clustering organic cropland has the potential to mitigate the collateral impact on pesticide use for conventional cropland.

When pests are mobile, collective action may be the only efficient or effective way to achieve control. Collective strategies can differ qualitatively from control strategies that make sense on an individual farm basis. For example, in California, efficient control of alfalfa weevil (*Hypera postica*) relies on the suppression of mobile adults before reproduction rather than the juveniles that actually cause crop damage (*4*). By contrast, eradication of boll weevil (*Anthonomus grandis*) requires the use of intensive sprays of early-season trap crops to kill weevils emerging from dormancy on a county-wide basis, followed by no attempts to control any survivors to avoid selecting for resistance (*5*, *6*). Unfortunately, individual incentives often fail to align sufficiently to enable voluntary collective action (*7*). Furthermore, differences in practices allowed in conventional and organic farming can make collective pest control infeasible, even when individual farmers would like to coordinate actions.

"When pests are mobile, collective action may be the only efficient or effective way to achieve control."

The potential for pest spillovers between organic and conventional fields has been established in principle, with simulations suggesting that pests in organic fields can migrate to nearby conventional ones (*8*), but the extent to which they occur is not well documented in practice. To address this knowledge gap, Larsen *et al.* used field observations from neighboring organic and conventional fields in Kern County, California, between 2013 and 2019. Located at the southern end of the San Joaquin Valley, Kern County produces a wide variety of high-value crops, including grapes, citrus, almonds, pistachios, carrots, tomatoes, potatoes, stone fruits, pome fruits, watermelons, and alfalfa and other forage. Many have a short growing season and are highly susceptible to damage from insects and diseases. Some number among the most pesticide-intensive crops grown in the United States. Conventional and organic fields are intermingled throughout the county, with some growers operating both conventional and organic fields.

Larsen *et al.* analyzed data on roughly 14,000 individual fields that were derived from public records, including Kern County's digitized maps of agricultural fields and the crops grown on them, records of pesticide applications (required under California law), and records of fields with organic certifications provided by the California Department of Food and Agriculture. They then conducted careful statistical analyses to investigate how pesticide use in both conventional and organic fields varies with the prevalence of organic fields nearby.

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Disease can be a major problem in vineyards such as this one in Kern County, California. Inadequate disease control in one field can cause outbreaks in nearby fields.

Their models indicate that organic fields are associated with increased applications of insecticides (both alone and combined with fungicides) on nearby conventional fields and decreased applications of insecticides on nearby organic fields. The level of insecticide use on conventional fields decreases the further away they are from nearby organic fields. On average, Larsen *et al.* estimate that a 1% increase in organic acreage within a 2.5-km radius is associated with a small but statistically discernible (0.03%) increase in pesticide use in conventional fields and a 10-fold larger (0.3%) decrease in pesticide use in organic fields. Because there are many more conventional than organic fields, the overall effect of a 1% increase in organic acreage is positive (0.02%).

An earlier simulation that combined biological and chemical control of insects in pea and bean fields suggested that pests could be best managed if organic and conventional fields were spatially segregated (*8*). Larsen *et al.* explored this hypothesis by simulating alternative landscape configurations and found that when organic fields occupy a small share of acreage and are scattered across the landscape, expansion of organic farming increases overall pesticide use, with increases in pesticide use on nearby conventional fields outweighing decreases in nearby organic fields. Consistent with the previous simulation (*8*), clustering organic farms close together lowers pesticide use on both organic and conventional farms, and thus overall. Such clustering would also make collective pest control technically more feasible and provide incentives for cooperation.

Kern County is atypical of US agriculture more generally, which is devoted to bulk commodities rather than fruits and vegetables. Larsen *et al.* used published county-level data on acreage treated with pesticides and farms certified as organic to investigate how broadly applicable their Kern County findings might be. Although their results were subject to considerable statistical uncertainty, they were consistent with a pattern of pesticide use increasing at low levels of organic acreage and then decreasing as organic acreage expands.

The analysis that Larsen *et al.* conducted documents how pesticide use can depend on the characteristics of neighboring farms, but it does not elucidate the mechanism that those patterns arise from. They show that farmers' decisions about pesticide use are influenced by the presence of nearby organic fields, but it is unclear why. Which mobile pests are involved, where they originate in the landscape, or how and why they move across the landscape are poorly understood. Similarly unknown is how farmers choose which crops to grow in which fields, or the basis for the pest-management strategies that they follow. The approach taken by Larsen *et al.* is akin to drawing inferences about the prevalence of disease by observing which medications were taken. Such inferences are necessarily limited because the same medication can often be used to treat more than one disease.

There is a continuing need for both ecological and economic fieldwork to elucidate the mechanisms at play. It is important to know the mobile pests that farmers are trying to control and the factors that determine spatial patterns of organic and conventional fields, as well as choices among alternative pest-control strategies. As organic farmland continues to expand, adverse interactions of the kind studied by Larsen *et al.* are likely to grow. Effective action to minimize such spillovers requires a greater understanding of how they arise. ■

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