Clustering maize plants together can improve their insect resistance

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When maize plants are attacked by insects, those in crowded fields release more linalool, alerting their neighbours and triggering defensive responses. Representative image. | Photo Credit: Markus Spiske/ Unsplash

Maize (*Zea mays*) has long stood at the intersection of human culture and the natural world. Originating from teosinte, a wild grass domesticated in Mesoamerica over 9,000 years ago, it was gradually transformed through centuries of selective breeding by Indigenous farmers. From a small-eared plant with a handful of hard kernels, maize thus evolved into the high-yielding, single-stalked crop recognised worldwide today.

Today, maize is the world's most widely grown grain. Beyond food, it underpins global economies as animal feed, biofuel, and a raw material for countless industrial products.

However, its dependence on large-scale, high-density monocultures leaves it vulnerable to pests and diseases. These challenges have been intensified by climate change, especially rising temperature and unpredictable weather. Experts have projected the average global maize productivity could fall by up to 24% by the late 21st century under SSP585, a high-emissions scenario consistent with continued fossil-fuel use.

Warning signals

In search of sustainable solutions, researchers from Zhejiang University in China in collaboration with partners from the Netherlands and Switzerland have uncovered an unexpected and powerful form of plant communication that could strengthen crop resilience. Their study, published in *Science* in August, focused on linalool, a naturally occurring compound known for a floral, woody scent that's used in perfumes and soaps.

The team's findings were based on examining a plant-soil feedback mechanism — a process in which a plant alters the soil environment, which in turn affects the growth and health of the plants.

Plants use the volatile compound linalool as a kind of warning signal. When maize plants are attacked by insects, those in crowded fields release more of it, alerting their neighbours and triggering defensive responses. The researchers noticed this effect when comparing maize planted at different densities. In the most tightly packed plots, plants in the middle rows suffered far less insect damage than those at the edges. The crowding seemed to boost protection. But this stronger defence came at a cost: plants also grew more slowly and produced less biomass, revealing a trade-off between protection and productivity.

The researchers found a complex mechanism driving this enhanced defence. When a maize plant was exposed to linalool, it activated jasmonate signalling in the roots. Jasmonates are stress-response hormones in plants, central to the "fight" mode that kicks in when plants detect pests, wounding or certain environmental stresses. This in turn upregulated genes that triggered the release of a defensive metabolite called HDMBOA-Glc into the soil.

HDMBOA-Glc enriched particular beneficial bacteria, which finally induced salicylic acid signalling in the neighbouring plants, priming them for a wide range of threats.

The team confirmed linalool's role as the sole trigger for this process using a linalool-deficient maize mutant. In these plants, the entire feedback loop failed to occur. When the team applied synthetic linalool, the defensive responses were restored.

Reporter genes

The researchers also found the response launched by this pathway to be very broad-spectrum. Plants conditioned in high-density soil were much less susceptible to an array of agricultural pests and pathogens. For example, larvae of the destructive fall armyworm (*Spodoptera frugiperda*) were rendered less damaging and grew poorly on these plants. Root-knot nematodes (*Meloidogyne incognita*) formed fewer galls on the roots, a sign of reduced infection. The plants also better resisted the fungus *Exserohilum turcicum* and caused the rice black-streaked dwarf virus (RBSDV) to proliferate and infect less.

These outcomes were repeated across experiments, validating the mechanism underlying the defence response.

"There are several scalable approaches that could be used to identify which maize varieties are more or less responsive to linalool signalling," James Schnable, a renowned maize expert and professor of agricultural genomics at the University of Nebraska-Lincoln in the US, said.

One approach is reporter genes. "We could measure the expression of some of the genes downstream of linalool-triggered signalling, such as *Bx1* and *Bx6*, across large and diverse populations of maize and use this information to both identify specific genes with large effects on the perception and response to linalool and introgress these into current high-performing hybrids using marker-assisted selection," Dr. Schnable added.

"Alternatively, we could use the same data to build a genomic prediction model which would use information on thousands of genetic markers across the genome to predict which maize varieties in breeding programs are likely to exhibit greater or lesser responses to linalool."

Engineering plants

"It appears the linalool-triggered signalling described in this study is altering the growth/defence trade-off, which all crop and wild plants have to navigate," Dr. Schnable said about the broader implications of the findings.

"Plants can prepare strong defences against insects and pathogens, but these defences come at the cost of energy, which could be devoted to growth and crop yield. Or they can invest their resources in growth and yield, but at the cost of being more vulnerable to pests."

He also stressed that maize plants make these trade-off decisions based only on local cues — while farmers typically have broader knowledge of pest pressures and management strategies.

"Now that we know linalool is a signal that feeds into the plant's decisions about how to manage this trade-off, it is relatively straightforward to engineer plants to either be unresponsive to that signal in environments where insect pests are not a problem (increasing crop productivity) or to provide the signal externally, from a farmer, when plants must be prepared for a pest (reducing crop losses)."

The researchers also wrote that farmers could harness the linalool-driven feedback for breeding and to cut chemical use, and to help farmers manage the growth-defence trade-off in high-density cultivation.

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