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Climate Change and Crop Chemicals: Why Pest Pressure Is Changing

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Spray a field today and you are running an experiment whose rules keep changing. The insect in your sights may be eating faster, breeding more often, and surviving in places it could not have a generation ago. The chemical in your tank may break down sooner in the heat, or simply work less well on a weed that grew up under a richer carbon dioxide sky. None of this is speculation. The evidence has been piling up for more than a decade, and it points to the same uncomfortable conclusion: the old, dependable relationship between climate, pests, and the chemicals we use against them is coming apart.

Warmer fields, hungrier insects

Insects are cold-blooded, so their internal clock runs on temperature. Warm them up and almost everything speeds up: feeding, growth, the journey from egg to adult, and the number of broods packed into a season. That simple physiology has outsized consequences at field scale. Insects already eat somewhere between 5 and 20 percent of the world's major grain crops. A 2018 analysis in Science estimated that for every additional degree Celsius of warming, those losses climb a further 10 to 25 percent (Deutsch et al., 2018).

Add it up and the projected damage is striking. At 2 °C of warming, the same study put the extra pest-driven losses at 46 percent for wheat, 19 percent for rice, and 31 percent for maize (Figure 1). The heaviest hits land in the temperate grain belts of Europe, North America, and China, not the tropics. The reason is counterintuitive but well grounded: tropical insects already live close to their thermal best, so extra heat pushes them past it, while temperate insects still have headroom to accelerate (Deutsch et al., 2008).

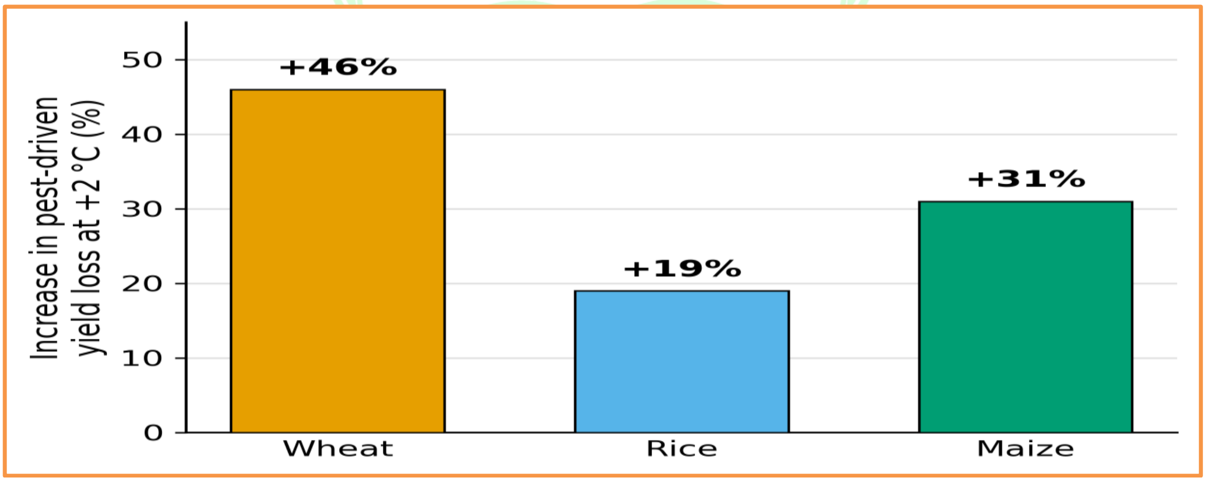

Figure 1. *Projected increase in pest-driven yield loss for the three main grain crops under 2 °C of warming, relative to current losses. Insects already consume an estimated 5–20% of these crops; warming raises losses a further 10–25% per °C, with temperate grain belts hit hardest. Data from Deutsch et al. (2018).*

The maps are being redrawn

Heat does not only make insects busier; it lets them live in new places. By compiling records for hundreds of pests and pathogens, researchers found that these organisms have crept toward the poles at an average of 2.7 kilometres a year since 1960 (Bebber et al., 2013). That is roughly 160 kilometres of net movement over six decades (Figure 2A), enough to drop established pests into farming regions that never had to manage them. Mild winters matter as much as warm summers, because they let more individuals survive to spring and, in many species, squeeze in an extra generation before harvest. Warmer springs also shift the timing of emergence, which can throw pests out of step with the natural enemies that would otherwise keep them in check (Skendžić et al., 2021).

When the chemistry quietly fails

Here is the part that gets less attention. Climate change is not only altering the pests; it is altering how our chemicals behave once they leave the nozzle. Higher temperatures, stronger sunlight, and shifting moisture all speed up volatilisation and degradation, so a given product reaches a lower concentration in the crop and lasts a shorter time. A 2015 review concluded that the likely response is more frequent applications at higher doses, just to hold the line (Delcour et al., 2015).

The plant side of the equation moves too. As carbon dioxide rises, many weeds grow thicker leaves with fewer stomata, which means less of a sprayed-on herbicide gets absorbed. Glyphosate, the world's most-used herbicide, has repeatedly proved less effective on certain perennial and invasive weeds grown under elevated CO_2 (Ziska, 2016). Temperature can cut either way: a warmer leaf sometimes lets more chemical through, but it can also speed the plant's own metabolism enough to break the herbicide down before it works.

This blurs a line farmers care about. When a spray underperforms, it is tempting to call it resistance and reach for a different product. But some of what looks like genetic resistance is really the environment quietly sabotaging the chemistry. One review named this "conditional resistance," a drop in sensitivity driven by conditions rather than evolution (Matzrafi, 2019). The distinction is not academic. Misread it, and you switch chemistries when you did not need to, burning through modes of action and hastening the real, heritable resistance you were trying to avoid.

The resistance accelerator

Climate change also speeds up genuine resistance, and the mechanism is elegant in a grim way. Take the diamondback moth, the most destructive pest of cabbage and its relatives worldwide, already resistant to dozens of insecticides and responsible for several billion dollars in losses a year. It can only persist year-round where winters are mild. As winters warmed over the past 50 years, its overwintering range expanded by about 2.4 million square kilometres (Ma et al., 2021). That matters because a pest surviving all year stays put long enough to evolve under constant chemical pressure, instead of dying off and being recolonised each spring by fresh, susceptible migrants. The same study found pesticide resistance averaging 158 times higher at overwintering sites than at seasonal ones (Figure 2B). Warming, in effect, hands pests a longer runway to outrun our chemistry.

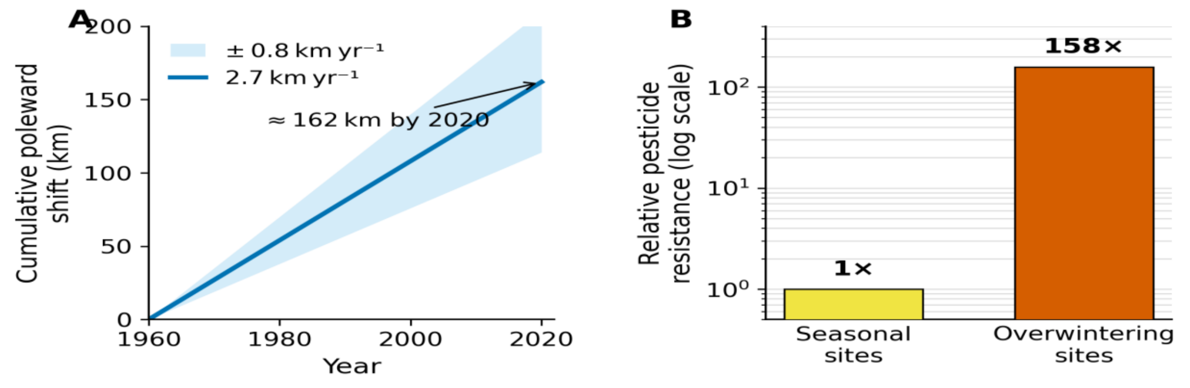

Figure 2. *Two signatures of a changing pest world. (A) Crop pests and pathogens have shifted poleward at an average of 2.7 ± 0.8 km per year since 1960, about 160 km of net displacement over six decades (Bebber et al., 2013). (B) For the diamondback moth, mean pesticide resistance is roughly 158 times higher where the moth now survives winter than where it occurs only seasonally; warming has expanded its year-round range by about 2.4 million km² in 50 years (Ma et al., 2021). Note the logarithmic scale.*

Weeds, the quiet competitor

It is easy to fixate on insects, but weeds are the bigger drain. Across the major crops, weeds cause the largest potential yield losses of any pest group, around a third of attainable yield, ahead of insects and pathogens (Oerke, 2006). And herbicides are exactly the tool that climate is undermining, both through faster breakdown in the field and through the CO_2-driven changes in weed physiology described above. There is a competitive twist as well: rising CO_2 and heat reshuffle the balance between crops and weeds, sometimes favouring the weed, which means more pressure on a chemical toolkit that is already losing some of its edge.

What this changes on the ground

I want to be careful not to slide into doom here, because the science does not actually support it. What the evidence supports is that one particular model of crop protection is ageing out: the calendar-based, fixed-rate spray applied on the assumption that a known chemical at a known dose does a predictable thing to a known pest. Climate change is loosening every one of those assumptions at the same time.

The realistic response is adaptation, and most of it is already known. Closer monitoring of both weather and pest populations lets growers spray on the pest's schedule rather than the calendar's. Models that link climate scenarios to pest risk can flag a new generation or a range expansion before it becomes a crisis. Rotating modes of action and leaning harder on integrated pest management, including biological control and resistant varieties, takes weight off any single chemical. On the chemistry itself, better adjuvants and formulations can improve uptake and slow degradation, partly offsetting what the heat takes away (Matzrafi, 2019; Skendžić et al., 2021).

What ties these together is humility about a system we used to treat as fixed. For most of the chemical era, crop protection could assume a stable backdrop, and that assumption is the real casualty. The pests are not waiting, the chemistry is shifting under the sun, and the spray programme that worked last decade is quietly becoming a worse bet. The encouraging part is that none of this is hidden. We can measure the warming, track the pests, and watch the efficacy curves bend. The harder part is acting on what the numbers already show.

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