Pesticide Action Network Europe

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Pest resistance to pesticides: a dead-end street

"We cannot solve our problems with the same thinking we used when we created them"



Photo: Henry Lai / Unsplash



Photo: USGS (public domain)

The EU is currently discussing legislative proposals that will weaken pesticide regulation. The Food and Feed Safety Omnibus X proposal from the European Commission plans to keep harmful pesticides on the market for longer and expand the options for the emergency use of dangerous and banned pesticides. Over the last years, lobbyists from intensive agriculture have been complaining about growing pest resistance to pesticides, and a shrinking crop protection toolbox. Yet, as often happens where major financial interests are at stake, the EU policy arena has been flooded with misleading claims and disinformation. The aim of this briefing is to give an overview of the root causes of pesticide resistance, while highlighting effective and available long-term solutions.

Introduction

The use of substances as pesticides in agriculture dates back to ancient civilisations. In Ancient Greece, sulphur was already used to protect crops. But pesticide production and use has thrived with the development of organic chemistry, in particular after World War II marking the beginning of an era of synthetic pesticides.[1] The intensification of agriculture and the growing reliance on mineral fertilisers contributed to making the crops more susceptible to pests, and often making them more attractive to pests. Pest pressure increased along with the perceived need for chemical crop protection.

The use of synthetic pesticides to combat pests (i.e. living organisms that affect crop growth and/or quality) seems to be an easy and quick solution. However, before long, plant and animal pests develop resistant to pesticides, through genetic mutations that help them overcome the toxicity of pesticides. Farmers are then advised to use higher doses of the same pesticide, switch to different pesticide substances, or use mixtures of several pesticides to combat resistant pests.

This creates the well-known 'pesticide treadmill': the need to use an ever-increasing number and quantity of pesticides against the same pest, as resistance emerges over and over again. Rather than offering a real solution, this approach, promoted by the pesticide industry, perpetuates and worsens the problem by promoting the use of even more pesticide cocktails and deepening farmers' dependence on chemical pest control.

Meanwhile, the pesticides end up destroying biodiversity, degrading soil life and fertility, reducing nutrient availability and their uptake by the plants. They also harm the beneficial organisms that naturally combat pests. As a result, plant health and resilience is weakened and crops become even more vulnerable to pests and diseases.

The pesticide industry benefits greatly from this treadmill, as companies sell more pesticides, to the detriment of farmers' incomes. The pesticide industry has also invested heavily in creating industry-sponsored scientific institutes that promote pesticide cocktails and recommend the use of multiple pesticides as a minimum to be applied for a given pest. It also plays on farmers' fears and uncertainty, creating a sense of urgency that pesticides are in short supply[2].

Fortunately, solutions exist. Prioritising the use of preventative and non-chemical methods and practices, as the pesticide legislation requires[3], would reduce the need for most pesticide uses, and save farmers money. Yet these options are not adequately promoted or implemented by the European Commission and Member States and are largely disregarded by European farmers.

Box 1 - Comparison: pest resistance in 2010 vs. 2026

Pest Category	Estimated Resistant Species (c. 2010)	Confirmed Resistant Species (2026)
Arthropods (Insects/Mites)	~553 species	**632 species[4]**
Weeds (Plants)	~195 species	**275 species**
Fungal Pathogens / Other	~100+ species	**150+ species**
Total Global Pests	**~850+ species**	**>1,050+ species**

More than 1,000 pest species have evolved resistance to at least one chemical pesticide. When tracking the data from 2010 through 2026, scientific databases divide these pests into distinct categories (arthropods, weeds, and plant pathogens) to monitor their cumulative resistance[5,6].

[1] Umetsu and Sirai (2020) - Development of novel pesticides in the 21st century.
[2] https://www.theparliamentmagazine.eu/partner/article/why-the-food-and-feed-safety-omnibus-comes-at-a-critical-moment-for-eu-agriculture
[3] Article 14 from the Directive on the Sustainable Use of Pesticides (SUD) foresees that in the EU, farmers are to implement the principles of Integrated Pest Management as from 2014.
[4] The global database officially tracks 632 unique arthropod species that have developed resistance to more than 364 different chemical compounds, spanning over 18,800 documented cases; Payumo *et al.* (2024) - An Assessment Model for Agricultural Databases: The Arthropod Pesticide Resistance Database as a Case Study; Whalon *et al.* (2018) - Analysis of global pesticide resistance in arthropods.
[5] Hurtado (2018) - Insecticide Resistance Management: A Long Term Strategy to Ensure Effective Pest Control in the Future
[6] Gould *et al.* (2018) - What Happens If We Run Out? Pesticide Resistance Needs Attention, Large-Scale Study

Resistance

Resistance to pesticides has been known for a long time. For instance, in the Netherlands, as early as in the 1970s, insects could no longer be controlled with pesticides in tomatoes and cucumbers grown in greenhouses due to resistance. For a period of time, it even seemed like the greenhouse cultivation of these crops would have to stop. The introduction of biological control has saved greenhouse cultivation[7] and is now used on almost all such tomato and cucumber crops by professional growers.

As for the use of antibiotics, experience demonstrates that regular use of pesticides inevitably leads to pest resistance in pests. The most effective response to resistance is to switch from chemical pest-control methods to non-chemical methods and practices, based on prevention, such as fostering the development of beneficial organism populations, or using mechanical treatments.

The pesticide industry, on the contrary, who has an interest in maintaining its most profitable products on the market, has designed systems to fight resistance by applying increasingly more chemical pesticides with a variety of modes of action. In 1984, an initiative (the Insecticide Resistance Action Committee, IRAC[8]) was launched by agrochemicals companies to provide a coordinated response by the pesticide industry to the problem of insecticide resistance of certain insects[9]. This strategy promoted a 'multiple chemicals' solution and was replicated for other families of pesticides, including herbicides and fungicides[10]. For example, the Herbicide resistance Action Committee (HRAC) and Fungicide Resistance Action Committee (FRAC) provide recommendations on how to combine chemicals with different modes of action. As a result, this 'multiple chemical strategy'(MCS) has now been applied for more than 40 years by many farmers in Europe and abroad, and has been fully endorsed by regulators. The European and Mediterranean Plant Protection Organisation (EPPO)[11] and the European Food Safety Authority (EFSA)[12] have also embraced it. Yet, resistance to pesticides has kept increasing for virtually all organisms (insects, fungi, plants) during the same 40 years (Figure 1[13]), on a scale that the industry itself admits[14] is a common phenomenon on farms worldwide".

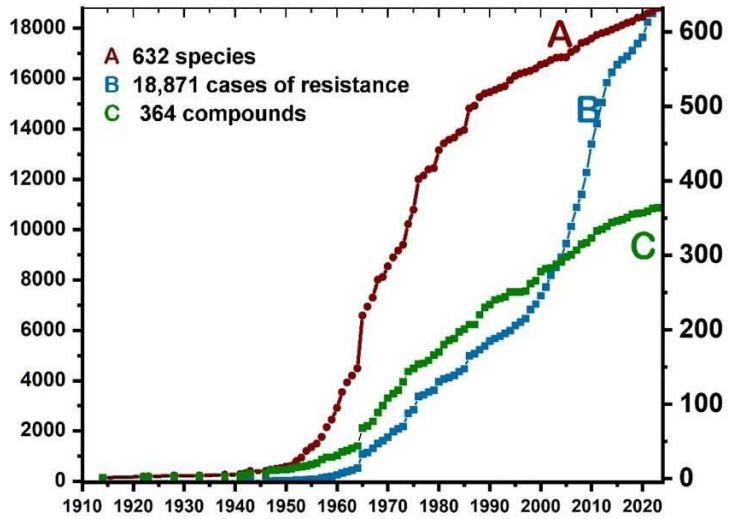


Figure 1. Evolution of pesticide resistance from 2014 to 2024. Species, compounds and cases of resistance (Payumo et al. 2024)

[7] https://www.koppert.nl/over-koppert/ons-bedrijf/%23onze-geschiedenis
[8] https://irac-online.org/
[9] Sparks *et al.* (2021) - Insecticide resistance management and industry: the origins and evolution of the Insecticide Resistance Action Committee (IRAC) and the mode of action classification scheme
[10] Herbicide Resistance Action Committee (HRAC) https://hracglobal.com/tools/2026-hrac-global-herbicide-moa-classification, and Fungicide Resistance Action Committee (FRAC), https://www.frac.info/fungicide-resistance-management/by-frac-mode-of-action-group
[11] https://www.eppo.int/
[12] https://www.efsa.europa.eu/en/supporting/pub/en-1060
[13] BROOKE BOREL, WHEN THE PESTICIDES RUN OUT, 302 | NATURE | VOL 543 | 16 MARCH 2017
[14] https://geneticliteracyproject.org/2017/03/16/pesticide-resistance-rising-crop-scientists-look-crispr-bacteria-solutions/

Chemical strategy to combat pesticide resistance has failed

Scientific evidence confirms that the chemical strategy to pesticide resistance has failed and leads EU-farmers to a dead-end. The consequence is that farmers are maintained in a 'chemical mindset', that prevents them from exiting the 'pesticide treadmill', and has negative economic consequences on their business.

Independent scientists challenge the relevance of the 'multiple chemical strategy'(MCS) and put forward that integrated use of agronomic, mechanical, physical and biological alternatives is the most effective strategy to manage pest resistance and control[15]. According to Hicks et al.[16], the system of applying increasingly more pesticides is counterproductive: "*Resistance was correlated with the frequency of historical herbicide applications suggesting that evolution of resistance is primarily driven by intensity of exposure to herbicides but was unrelated directly to other cultural techniques*".

Other scientists working on organisms developing resistance to pesticides, including Gould et al.[17] state that it is an illusion to consider that resistance can be tackled by synthetic pesticides: "*We mostly continue to use pesticides as if resistance is a temporary issue that will be addressed by commercialization of new pesticides with novel modes of action*".

Likewise, Hoy[18] stresses that "*resistance will remain an ongoing dilemma in pest management and we can only delay the onset of resistance to pesticides*". Further, according to this scientist the solution "*involves employing effective agronomic practices to develop and maintain a healthy crop, monitoring pest densities, evaluating economic injury levels so that pesticides are applied only when necessary, deploying and conserving biological control agents, using host-plant resistance, cultural controls of the pest, biorational pest controls, and genetic control methods*".

Comont et al.[19] question the effectiveness of the 'multiple chemical strategy'(MCS): "*We contend that where specialist and generalist resistance mechanisms co-occur, similar trade-offs will be evident, calling into question the ubiquity of resistance management based on mixtures and combination therapies* ".

Whelan et al.[20] point out the pesticide industry's responsibility: "*The agriculture industry recognized the problem of pesticide resistance and responded by developing and enforcing guidelines on resistance management and prevention. These guidelines, (...) do not encourage eradication of pests but instead strive to maintain pests, even with the presence of resistant strains, at a level that does not cause economic damage to the crops*.".

To conclude, the only effective strategy for minimising the occurrence of resistance of organisms to pesticides is the application of non-chemical methods and practices. Only if these non-chemical methods are not operational or not effective enough, as a last resort pesticide active substances can be used (in a restricted way). Starting a protection strategy with spraying pesticides not only has long term negative impacts but is also a violation of the Sustainable Use of Pesticides Directive, which is ineffective in the end, and puts huge costs on society since industry and farmers do not pay for the damage done.

An industry-designed 'solution'.

Industry institutes on pesticide resistance (such as HRAC, FRAC and IRAC mentioned earlier) have been promoting pesticides to combat resistance. Therefore, they promote the use of a diversity of modes-of-action (MoA), attacking the pest from a different angle. Industry advices[21] a minimum of three MoA , promote four

[15] Sowa *et al.* (2022) Homogeneity of agriculture landscape promotes insecticide resistance in the ground beetle Poecilus cupreus.
[16] Hicks *et al.* (2018) The factors driving evolved herbicide resistance at a national scale
[17] Gould *et al.* (2018) - Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance?
[18] Hoy (1998) Myths, models and mitigation of resistance to pesticides.
[19] Comont *et al.* (2020) Evolution of generalist resistance to herbicide mixtures reveals a trade-off in resistance management.
[20] Whelan and Cunningham (2020) - Resistance is not the end: lessons from pest management.
[21] Leadbeater *et al.* (2008) - Proposal on the Revision of EU Directive 91/41. The impact on resistance management and sustainable crop production in Europe.

for all uses, and five for crops with high-frequency treatment (e.g. potatoes, apple). An EPPO working group[22] also defined the minimum number of MoAs based on the industry recommendations, two MoAs in case of low risks for resistance, three for medium risk, and four MoAs as a minimum for high-risk pests. Later these numbers were included in an EPPO Guideline on comparative assessment[23]. One can assume that, with the MCS approach, given the rising resistances, the recommendations for the minimum number of MoAs should rise. Dutch authority Ctgb for instance, in 2019, decided to take a minimum of five MoAs for fungicides, herbicides and insecticides in case of a comparative assessment.[24] As a result enormous numbers of different pesticides will be needed if industry succeeds.

This is not the only tactic used by the pesticide producers to ensure the continuous use of their products. Industry is hammering on the lack of pesticides and 'the empty farmers' toolbox'[25]. Regularly, when the EU discusses a ban on a single substance, the agribusiness predicts 40-80% yield losses, which never materialise[26]. This has fueled a farmers-campaign to maintain all chemicals on the market including the most toxic ones, while claiming that the scope is to facilitate the approval of biopesticides.[27] The EU Commission has translated this industry demand into the 'Food and Feed Safety' Omnibus X proposal. Many of the elements and proposed amendments in the EU Parliament come directly from the industry.[28]

Alternatives to a dead-end street.

Alternatives to the pesticide industry's 'solution' of a chemical-based agriculture are readily available such as IPM, Integrated Pest management[29] , organic agriculture and agro-ecology. Stopping the systematic use of synthetic pesticides will inevitably lead to a fall in pesticide resistance. Non-chemical IPM and organic agriculture alternative practices have been available for decades and are continuously developing, but are scarcely applied. They are also, according to scientific studies, usually more profitable for farmers. While pests quickly circumvent the toxicity of a pesticide, with basic mutations of a specific receptor, it is much more difficult for pests to adapt to measures such as long term crop rotations, or to biocontrol solutions, where biological processes, that are intrinsically bound to the very nature of the pest organisms, are involved.

The main reasons for the lack of uptake of alternatives are the lack of training, and the important level of disinformation on the potential of pesticide-free agriculture. Farmers' most regular crop protection advisers are the sellers of pesticides. The pesticide industry offers easy to apply 'calendars' for spraying as well as advice to farmers. Non-chemical approaches require more knowledge to apply it successfully, and therefore chemical solutions are presented as the 'easiest' and safest farming method.

This 'pesticides first' approach comes at great cost, and this is acknowledged by the EU. The Pesticide Regulation (EC) 1107/2009 states that to ensure the legally promised "*high level of protection*", the principles of IPM have to be applied. In parallel, the Sustainable Use of Pesticides Directive 2009/128/EC, provides clear directions to implement IPM, where synthetic pesticides must be used as a last resort, when all other methods have failed. In the past 12 years, Member States have failed to implement IPM, and cut pesticide dependence.

IPM is first and foremost about prevention. There are many methods of prevention. These include:

- Applying three to seven year crop rotation plans, to avoid soil pests developing.

[22] Rotteveel *et al.* (2011) - Resistance management in Europe: a preliminary proposal for the determination of a minimum number of active substances necessary to manage resistance

[23] EPPO (2015) - Guidance on comparative assessment.

[24] Decision from the Dutch Ctgb on September 25, 2019 on the opposition of PAN Europe to the authorisation of the pesticide TAVAS with two candidates of substitution, metribuzin en diflufenican

[25] https://croplifeeurope.eu/farmers-toolbox/

[26] E.g. for the ban on neonicotinoids in 2018, the intensive farming lobby predicted 50% yield drops for rapeseed which, according to Eurostat, never happened: yields were stable. In the same vein, the ban on Mancozeb in 2021 also did not lead to the predicted yield drops for potatoes.

[27] https://www.copa-cogeca.eu/plant_health

[28] Corporate Europe Observatory, 2020. Traced: How pesticide industry demands made their way into OmnibusX https://corporateeurope.org/en/2026/10/traced-how-pesticide-industry-demands-made-their-way-omnibus-x

[29] Regulation 1107/2009, whereas recital 35 indicates that: "*To ensure a high level of protection of human and animal health and the environment, plant protection products should be used properly, in accordance with their authorisation, having regard to the principles of integrated pest management and giving priority to non-chemical and natural alternatives wherever possible*".

- Ensure a fertile soil for a health crop.
- Reduce the size of the plots to allow natural pest control to act
- Using resistant crop varieties. These are often more traditional varieties.
- Adapt planting and harvesting dates to avoid pests.
- Adapt fertilisation to reduce attractiveness to sap-feeding pests (e.g. aphids on sugar beet).
- Ensure biodiversity to host natural enemies of the pests, such as hedges and flower strips.

These practices can be applied to every crop. Only once they have been adopted should the farmer consider further non-chemical interventions, such as mechanical weeding, biological control, and natural substances. Synthetic pesticides should be used only as a last resort, when pest attacks reach an economic threshold, which is rare in high level IPM.

Box 2 - Fake IPM: How industry tries to maintain the pesticide treadmill

While the principles of IPM are clearly defined in the Directive on the Sustainable Use of pesticides[30], the pesticide industry promotes so-called innovative practices, as part of IPM. In these approaches, where pesticides remain central, farmers remain dependent on agrochemical companies. For instance:

- Treating seeds to protect seedlings, and to avoid the need for any crop rotation is all but IPM: pesticides are used preventatively.
- Drones[31] and other precision application techniques are presented as IPM but they maintain pesticides in a central position.
- Genetic engineering[32] : this approach maintains farmers in a situation of dependence towards seed companies. Furthermore, many genetically engineered varieties produce pesticide substances that favour resistances, and potentially harm the environment.

It is therefore important that European regulators clarify also what IPM is not.

Conclusion

By proposing to provide time-unlimited approvals of pesticides, and allowing derogations for the use of normally banned pesticides, such as reprotoxic or endocrine disrupting substances, the European Commission is proposing to maintain EU farmers trapped in the pesticides treadmill. If endorsed by the European Council and the European Parliament, this will have dramatic consequences on Europeans' wellbeing: they will bear the societal costs, while the pesticides industry will increase its profits. By not shifting away from an approach that leads to ever growing resistances, the European Commission is threatening food security and farmers' income. Instead of following the demands of agribusiness, it is urgent to develop an EU Masterplan to solve the health and biodiversity crises linked to pesticides, and train our farmers to implement already available science-based pesticide-free alternatives.

[30] Annex III of the Directive on the Sustainable Use of Pesticides (dir. 2009/128/EC)
[31] https://anvil.so/post/drone-data-integrated-pest-management
[32] https://biologynotesonline.com/integrated-pest-management-cultural-biological-chemical-genetic-control/