ReMIX
Species mixtures for redesigning European cropping systems

POLICY BRIEF / APRIL 2021

Contribution of intercropping to pesticide use reduction

About ReMIX

The goal of the ReMIX project, funded by the EU's Horizon 2020 Programme, is to exploit the benefits of intercropping to design more diverse and resilient arable cropping systems. Together with farmers, ReMIX has designed productive, diversified, resilient and environmentally friendly cropping systems that are less dependent on external inputs. Intercropping delivers high quality food and sustainable returns to the farmer.

This policy brief addresses the potential of intercropping to control diseases, weeds and insect pests and hence reduce the dependency on pesticides. Weeds, pathogens and insect pests all need to be taken care of simultaneously by farmers. Herbicides, fungicides, and insecticides aim at one of the three only and often only at certain classes of weeds, pathogens and insects. This often results in the need for multiple pesticide applications. Intercropping is a promising solution for a sustainable pests, diseases and weeds control both in low and high input agriculture.

Benefits of intercropping

Based on field trials in 11 multi-actor platforms across 10 European countries, ReMIX identified additional management methods to reduce pesticides through species mixtures. Meta-analyses conducted in ReMIX provide strong support for the effectiveness of intercropping for weed, disease and insect pest control independent of the N-input level. Thus, contrary to common belief, mixtures help to control pests, diseases and weeds both in low and high input agriculture and they are an important lever in reducing dependence on pesticides.

» Intercropping has to be combined with adequate disease resistance. Combining resistances and crop mixtures will result in reduced pathogen population size and thus in higher durability of disease resistance in the field. Intercropping is therefore a valuable tool to enhance the effectiveness of resistance breeding and could help to greatly reduce the need for fungicides.

» Using crop mixtures will reap mixture benefits against multiple pests. However, there is a need for adequate machinery for successful mixture production as well as a concerted breeding effort for species and varieties adapted to mixed cropping.

» It is also important that farmers are given advise on which mixtures to test and how to test them, depending on their specific farming conditions. ReMIX developed various extension tools, such as the serious game and the agrodiversity toolbox. This toolbox was further expanded with the help of the Crop Diversification Cluster.

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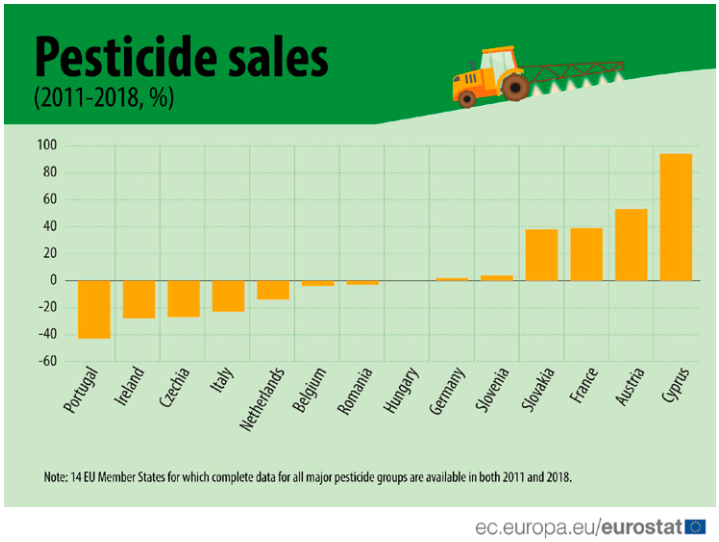
The challenge

For decades, pesticides have been a cornerstone of European agriculture. The term «pesticides» encompasses herbicides, fungicides, insecticides, and other chemicals aiming at reducing populations of living organisms that cause damage to crops. Pesticides are usually effective against their specific target and relatively easy to use for farmers. However, concerns have grown over adverse side-effects, as well on human health (Sabarwal et al., 2018); biodiversity (Brühl and Zaller, 2019); and associated hidden costs (Bourguet and Guillemaud, 2016). Soils and water are commonly contaminated in all major agricultural areas in Europe (Silva et al., 2019). In addition, resistance to pesticides has been reported for a growing number of species of weeds, animal pests, and fungi (Hawkins et al., 2018). This leads to technical bottlenecks for farming systems where preventive measures are lacking or insufficient.

In order to limit negative impacts of pesticides, the European Parliament adopted the «pesticide package» in 2009. Despite these efforts, no significant reduction of pesticide use has been observed in Europe (**Fig. 1**), and pesticide use is stable at around 360 millions kg per year in the EU (Eurostat, 2018). To picture this number, it is equivalent to the mass of water of 144000 Olympic swimming pools.



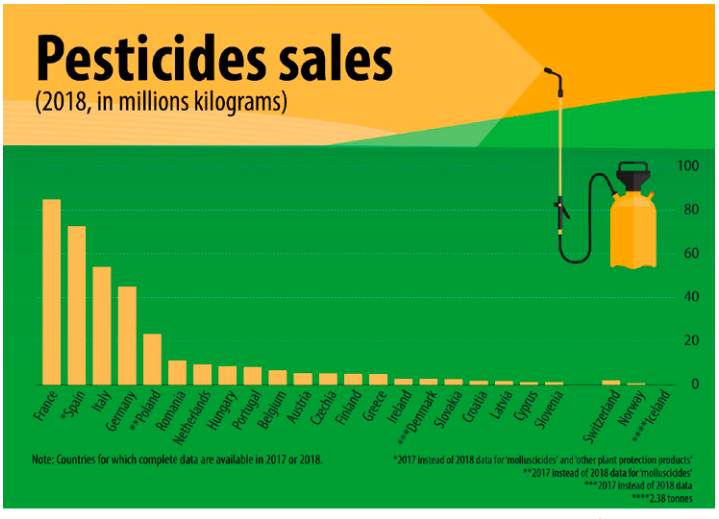


Fig. 1. **Left**: Changes in pesticide sales (%) between 2011 and 2018 for European state members for which complete data are available both in 2011 and 2018 (ec.europea.eu/eurostat).
Right: Pesticides sales in 2018 for European state members for which complete data are available in 2017 or 2018 (ec.europea.eu/eurostat).

“The Green Deal”

aims at halving the use and risk of pesticides by 2030. This will require to replace crop protection strategies based on pesticide use by Agroecological Crop Protection. This is based on the redesign of farming systems and aims to promote the ecological functioning of agroecosystems by directly or indirectly optimizing interactions between plants, animals and micro-organisms above- and below-ground. In this framework, an important way to increase agroecosystem biodiversity is to grow several species in a field simultaneously (species mixtures).

In a multi-actor approach involving farmers at all levels (**Fig. 2**), the H2020 ReMIX project tackled practical questions and co-design to develop ready-to-use practical solutions adapted to producing mainly grain cash crops under diverse EU pedo-climatic conditions. Results show the high potential of species mixture to contribute to pesticide reduction through an ecological control of plant pathogens, weeds, and animal pests. Concrete recommendations are formulated to help design policies promoting species mixtures to benefit from a wide range of ecosystem services, among which pest regulation.

Fig. 2. Guy Menon, a French organic farmer of the ReMIX Southwestern French Multi-Actor platform in his barley-lathyrus mixture with lathyrus for human consumption in direct selling, and barley for animal feed. This mixture prevents weed infestation, significant injuries caused by animal pests and diseases, and lathyrus lodging (credit: Laurent Bedoussac, Toulouse University, UMR AGIR, INRAE/ENSFEA).

ReMIX findings

Researchers in ReMIX conducted a global meta-analysis to quantify the effect of intercropping on weed biomass in annual arable grain intercrops. A meta-analysis is a combination of a systematic review of literature and statistical analysis of the data to reach an overarching conclusion. Meta-analyses are indispensable if a research field has produced many results, and all the collected data are to be considered. In contrast to typical literature reviews that may be based on a biased selection of results from the literature, the specific aim of a meta-analysis is to identify all the relevant data pertinent to a research question and draw unbiased conclusions. For the first time, the meta-analyses in ReMIX synthesized existing data on weed, disease, and insect pest control systematically.

» In the meta-analyses, a total of 223 crop combinations were found and analyzed for their effects on weeds, 196 cases for diseases and 546 for insects. For weeds, diseases and insects 86, 79 and 68% respectively of the reported mixtures resulted in reduced infestations, while increased infestations were found only in 2, 3, and 8% of the cases (Stomph et al., 2020; **Fig. 3**).

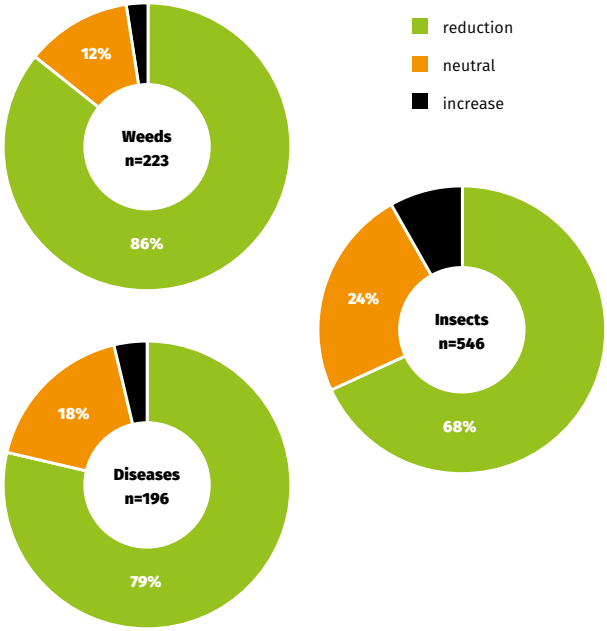


Fig. 3. Proportion of species mixture cases identified through an unbiased literature review conducted for meta-analyses that resulted in reductions (green), increases (black) or no change (orange) in infestation of weeds, diseases, and insects.

ReMIX findings

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The meta-analyses showed that findings were consistent across different groups of species combinations, such as maize/legume and small grain cereal/legume. Intercrops where one crop was added to the other rather than replacing it had stronger weed suppression than intercrops replacing each other. For the latter, a mixed arrangement gave stronger weed suppression than a row design, while spatial arrangement did not affect weed suppressive ability in additive designs. Both simultaneous and relay intercropping (i.e. one crop is sown later and also harvested later), were equally effective. The results confirm that intercropping is a useful approach for suppressing weeds in annual crop cultivation (**Fig. 4**).

Fig. 4. Weed suppression through competition. Plots were neighbouring each other.

2

Besides the example shown in Figure 4, a good example of how crop associations reduce the use of herbicides is the combination of winter oilseed rape and companion plants. On rapeseed, herbicides are traditionally applied at sowing. Adding frost-sensitive legumes (such as Mediterranean clover and Spring vetch) permits to dispense with herbicides. During autumn, these companion plants grow fast and inhibit weed emergence and growth. Only when winter temperatures are not cold enough (>-1°C) to destroy the companion plants, farmers may need to use a selective herbicide. This happens, for example, every three years in the Atlantic regions. Tested in Spain, France and Denmark, this association has shown its benefits in regions where winters are cold enough to destroy companion plants. This agroecological solution is now used by farmers in several European countries.

3

To make full use of mixture effects against diseases, intercropping has to be combined with adequate disease resistance. For instance, the disease reduction effect of species mixtures is substantial (in the order of 30–40% or more; Zhang et al., 2019), but its efficacy is by itself not sufficient to keep a crop disease free. Just like with COVID 19, the probability that mutations to virulence in plant pathogens occur increases with the population size. Therefore, combining resistances and crop mixtures will result in higher durability of disease resistance in the field. Intercropping is therefore a valuable tool to enhance the effectiveness and thus success of resistance breeding leading to greatly reduced needs for fungicides.

Policy recommendations

Weeds, pathogens and insect pests all need to be taken care of simultaneously by farmers. Herbicides, fungicides, and insecticides aim at one of the three only and often only at certain classes of weeds, pathogens and insects. In contrast, mixtures can simultaneously deal with these challenges. While the amount harvested per crop in the mixtures will vary depending on the specific pedoclimatic conditions of a site, overall, mixtures provide higher yield security as the probability is higher that at least one of the components may perform well as compared to single crops. The meta-analyses conducted in ReMIX provide strong support for the effectiveness of intercropping for weed, disease and insect pest control independent of the input levels. To enhance the success of mixtures in reducing pesticide inputs while maintaining or even boosting productivity it is recommended that:

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Farmers are given advise as to which mixtures to test and how, depending on their specific farming conditions. For this, some of the extension tools such as the ReMIX serious games and the agrodiversity toolbox developed in ReMIX, and expanded with the help of the diversification cluster are very valuable.

2

Species have to be adapted to mixed growing with respect to agronomic compatibility and resistance complementarity. Therefore, breeding for mixed cropping has to be put high on the agenda to achieve pesticide reductions while maintaining or increasing crop productivity.

3

Joint research by farmers, the industry, and researchers has to be further supported to develop suitable machinery for mixture production and separation.

In conclusion, the results obtained in the ReMIX project highlight the key role that mixed cropping can play in pesticide use reduction, within a general framework of Agroecological Crop Protection. We believe that intercropping should be promoted and supported by public policies in order to tackle priority issues, such as the ones addressed by the Green Deal.

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