Hort4EUGreen

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SUSTAINABLE USE OF PESTICIDES AND THEIR RESIDUES MONITORING

Methods to minimize chemical pesticide dosages

Volume 3

University of Agronomic Sciences and Veterinary Medicine of Bucharest

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"Enhancing practical skills of horticulture specialists to better address the demands of the European Green Deal"

Bucharest, 2025

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Volume 3. Methods to minimize chemical pesticide dosages

Arzu Aydar, Okray Orel

Summary

The module titled "Methods to Minimize the Chemical Pesticides Dosages" concisely encapsulate the key concepts, strategies, and techniques that can be employed to reduce the reliance on and the amount of chemical pesticides used in agricultural practices. This is particularly pertinent in the context of sustainable agriculture, where the goal is to balance pest control with environmental protection and human health. Below is an overview of the module summary. The module presents the smart application techniques for plant protection products application, insisting on methods that reduce the pesticides residues, as the targeted application, the variable rate application, and also insist on pollinators protection measures. The units also insist on the future application techniques and the reduction of diffuse and point sources for protection of water resources and protection of soils.

The module reinforces the critical importance of minimizing chemical pesticide dosages for sustainable agriculture and is a call to action for continuous improvement, research, and collaboration in the pursuit of sustainable pest management solutions.

Learning outcome descriptors

By the end of the Module, the trainees should be able to:

- Understanding the modern methods of plant protection, the equipment and techniques applied in sustainable agriculture,
- Comprehend the meteorological conditions impact on environment , plant and operators safety;
- Analyze the innovative plant protection advancements and the emerging technologies, that preserve the environment, especially the pollinators.

General and transferable skills

1	Analyzing and evaluating different spraying techniques and equipment for their effectiveness and environmental impact
2	Understanding the technical aspects of various plant protection products and their application
3	Developing an understanding of eco-friendly practices in pesticide application and plant protection.
4	Continually updating knowledge and skills in response to evolving research and technology in the field.

Knowledge, understanding and professional skills

1	Comprehensive knowledge of different spraying equipment, including traditional and advanced systems such as smart sprayers
2	Understanding various techniques for applying pesticides and how these techniques impact the effectiveness and environmental footprint of the application
3	Deep understanding of the importance of sprayer calibration in minimizing pesticide residues and ensuring effective application
4	Ability to make informed decisions regarding the choice of equipment, pesticide products, and application techniques based on a variety of factors.

Unit 3.1. Optimizing spraying efficienc

Arzu Aydar, Okray Orel,
Lilyana Koleva

The application of pesticides plays a vital role in contemporary agricultural practices, particularly in plant protection. When used judiciously, pesticides aid in managing plant pests and diseases, thereby contributing to higher crop yields. The employment of these agrochemicals can substantially improve both the quantity and quality of agricultural produce. However, this has also escalated environmental risks in recent times. A considerable portion of agricultural production costs is attributed to pesticide usage.

An effective spraying that target harmful organisms can be achieved by an even coverage on the intended surface. Any portion of the spray that fails to adhere to this target area is deemed a loss. These losses from pesticide application encompass those to the air, soil, and through drift.

In the context of chemical plant protection, excessive use of pesticides or the use of suboptimal spraying equipment can lead to significant concerns for both human health and environmental well-being. The primary goal of Plant Protection Products (PPP) spraying is to maximize the effectiveness of pest and disease control while minimizing input costs and environmental impact.

Spraying efficiency in plant protection involves the precise application of pesticides to ensure optimal coverage with minimal waste. Effective spraying practices not only address pests and diseases accurately but also minimize the release of chemicals into the environment, thereby preserving ecological stability. The advantages of effective spraying are threefold: (1) Economically, using fewer pesticides leads to cost savings. (2) Environmentally, applying fewer chemicals results in less runoff and drift, which in turn lowers the contamination of soil and water. (3) Health-wise, reducing the loss of chemicals decreases the exposure of both farmworkers and consumers to these substances.

Factors effective in optimizing spraying efficiency and reducing losses can be grouped into six groups:

- Equipment (Sprayer);
- Pesticide application techniques;
- Target surface;
- Plant protection products;
- Meteorological conditions;
- Operator.

Recent technological advancements have significantly contributed to enhancing spraying efficiency.

Precision agriculture enables a precise application, reducing overlap and missed areas with the support of GPS technology and facilitate targeted spraying, especially in more difficult-to-reach areas, ensuring thorough coverage, by the use of drones and UAVs.

Smart Spraying Systems allows adjustments of pesticide applications rates based on real-time field data, with the help of variable rate technology (VRT) while various sensors and AI help detecting pest presence and apply pesticides only where needed, minimizing wastes.

Recent equipment optimization includes new nozzle design, that can optimize droplet size and spray pattern, improving target coverage and reducing drift, as the anti-drift nozzles, that enhance deposition on plants.

Calibration and maintenance of spraying equipment is regulated within EU starting 2009, by the Directive 2009/128/EC of the European Parliament and of the Council, establishing a framework for Community action to achieve the sustainable use of pesticides (EC, 2009). According to the law `*professional users shall conduct regular calibrations and technical checks of the pesticide application equipment*`, to ensures equipment delivers the correct rate of pesticide and to prevent malfunctions and ensures consistent performance.

Best spraying practices are another factor significantly enhancing efficiency. Understanding the importance of right timing is one of major factors of best practices, both from the point of view of pest lifecycle, as applications must coincide with vulnerable stages of pest development and from the point of view of weather conditions, as wind speed, temperature, humidity, rainfall and atmospheric stability affect the PPP drift and coverage.

Regarding the operators training, Dırectıve 2009/128/EC also state that `*Member States shall ensure that all professional users, distributors and advisors have access to appropriate training by bodies designated by the competent authorities*`. Trained personnel can make informed decisions about application rates, techniques, and timing and ensures safe handling of chemicals, protecting themselves and the environment.

IPM strategies (presented in Handbook 2, on www.hortgreen.com website) can reduce the reliance on chemical controls, both by utilizing natural predators or biological agents or using cultural practices, as crop rotation, resistant varieties, and proper field sanitation.

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3.1.1 Sprayers

Arzu Aydar, Okray Orel,
Roxana Ciceoi

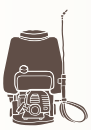
In modern agriculture, the use of Plant Protection Products (PPPs) such as pesticides is essential for maintaining crop health and ensuring high yields. Sprayers play a crucial role in the efficient and effective application of these PPPs, being the primary tools designed to distribute these chemicals uniformly across crops and only where needed (targeted application), reducing wastage.

Various types of sprayers are used for the application of PPPs, each suited to different agricultural needs, scales of operation, and types of PPPs. The main types of sprayers include:

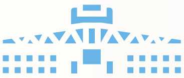
Handheld sprayers, that are designed for small gardens or limited areas, being manually operated, and requiring physical effort to pump and spray.

Backpack sprayers, still for reduced areas, but are larger than handheld models, worn on the back, for a higher mobility of the operator and can be either manually operated (pump action) or battery-powered.

Knapsack sprayers, similar to backpack sprayers but often equipped with a lever-operated pump that can be worked while carrying the sprayer on the back.



Compression or tank sprayers, are devices that feature a tank, a pump, and a wand with a nozzle, being suitable for both small-scale and medium-scale applications.


Boom sprayers are used in large-scale farming, being mounted on tractors or trucks, featuring a long boom with multiple nozzles for wide coverage.


Airblast sprayers, designed for orchards and vineyards, use air currents to disperse fine droplets over a larger area.


Mist blowers are ideal for dense foliage or hilly terrain, the mist settling on both sides of the leaves, improving coverage.

Drip sprayers, use the drip irrigation systems for the direct application of PPPs to the soil or root zone, minimizing airborne drift and reduce water usage.


Ultra-Low Volume (ULV) sprayers deliver PPPs in very small, concentrated amounts, often without water dilution and are used for specific pest control situations, typically in greenhouses or for indoor pest control.

Drone sprayers are ideal for precision agriculture, being remote-controlled drones equipped with tanks and nozzles for targeted application.


Wheeled (pull-behind) sprayers are designed to be towed behind a garden tractor or ATV, usually used in hobby gardens.

Each type of sprayer has its specific advantages and is chosen based on factors like the size of the area to be treated, the type of PPPs being applied, the topography of the land, and the type of crops grown. The development and adoption of new technologies, such as drone sprayers, reflect ongoing advancements in precision agriculture and the increasing focus on sustainable farming practices.

For large scale horticulture, where the majority of food is produced, many types and models of sprayers are used, for the field, vineyards, orchards, and greenhouse spraying (Figure 3.1). The working principles of these sprayers (hydraulic sprayers, air-assisted sprayers, pneumatic sprayers, foggers, etc.), their way of delivering the sprayed liquid to the target (air assistance, electrostatic, controlled drop applications, etc.), and directing equipment directly affect the effectiveness of spraying.

a)

b)

Figure 3.1 (a) Orchard and (b) Field Sprayers

3.1.2 Pesticide application techniques

Okray Orel, Ionut Siviu Beia,
Yeasemin Sabahoglou

In terms of the effectiveness of spraying, it is important to choose an application technique that can meet all requirements such as target pests, characteristics of the target plant, pesticide properties, equipment compatibleness, and cost.

There are many pesticide application techniques for both the field and the orchards. Some of the more common of these techniques, which have different effects, are given below:

Band application

Pesticide is applied on parallel lines and one or more gaps between them (Figure 3.2).

Figure 3.2 Band Application

Broadcast application

The uniform application of the pesticide over the entire field (Figure 3.3).

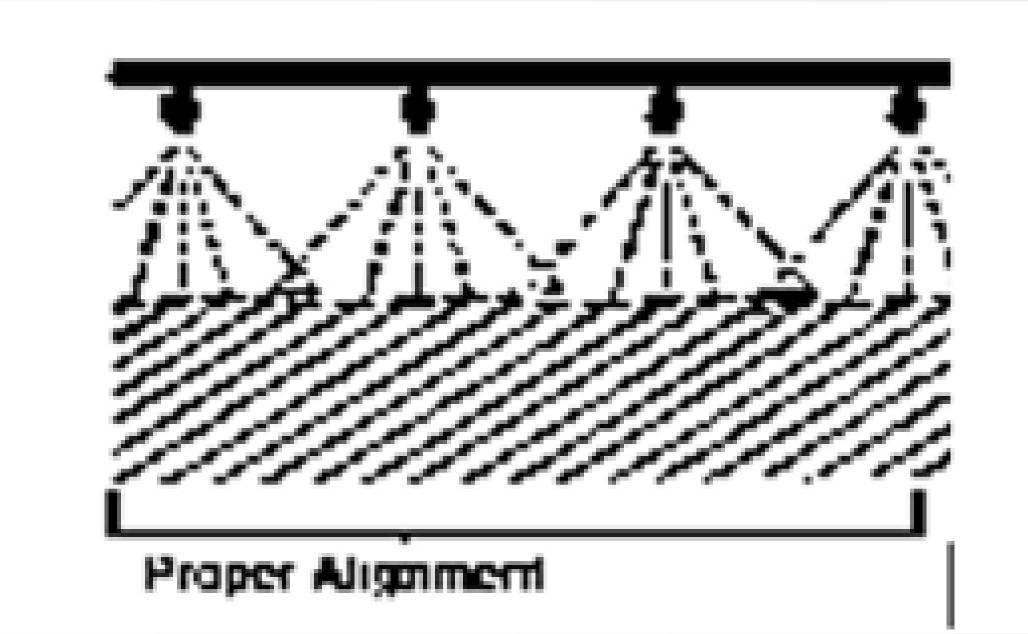


Figure 3.3 Broadcast application

Basal application

The application of herbicides to the lower region of tree or shrub-type plants (Figure 3.4).

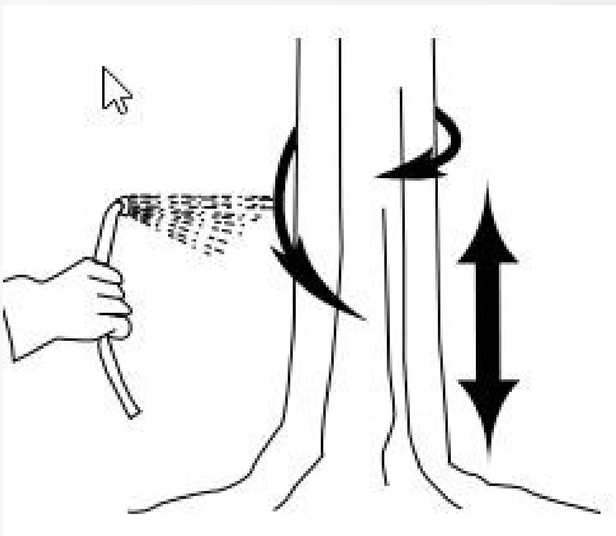


Figure 3.4 Basal Application

Crack and crevice application

The application of small amounts of pesticide to cracks and crevices in covered areas.

Directed application

Applications made to minimize contact with non-target organisms, especially by targeting harmful factors (Figure 3.5).

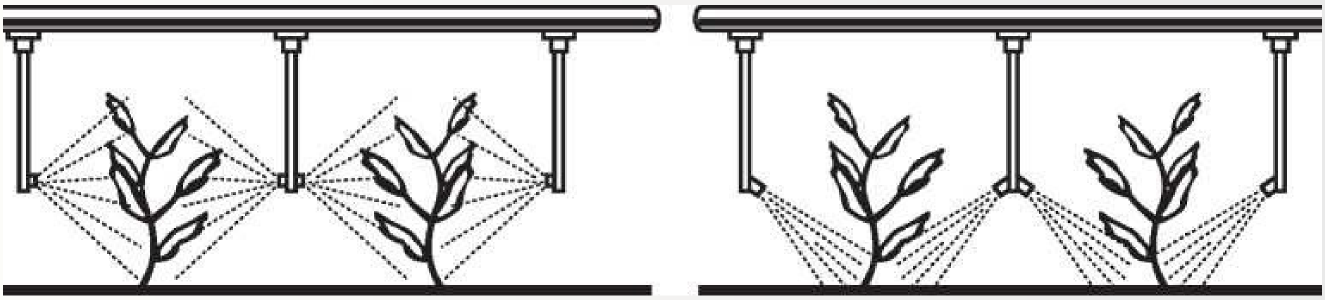


Figure 3.5. Directed application

Foliar application

The application of the pesticide by targeting the areas where the leaves are located on the plant (Figure 3.6).

Figure 3.6. Foliar application

Rope, Wick and Wiper application

This technique is used in weed spraying because of the height difference between the plant and weed. The pesticide is applied with equipment that can pass over the weeds that are longer than the plant while making a wiping motion (Figure 3.7).

Figure 3.7. Rope, wick and wiper application

Soil application

The application of pesticide directly to the soil surface or into it (Figure 3.8).

Figure 3.8. Soil application

Soil incorporation

The applications where the pesticide is transferred into the soil with soil cultivation or irrigation equipment.

Soil injection

Pressurized application of pesticide just below the soil surface (Figure 3.9).

Figure 3.9. Soil injection

Tree injection

The application of concentrated pesticide under tree bark (Figure 3.10).

Figure 3.10 Tree injection

Indoor (closed-area) spraying

The application of pesticides in closed areas such as greenhouses (Figure 3.11).

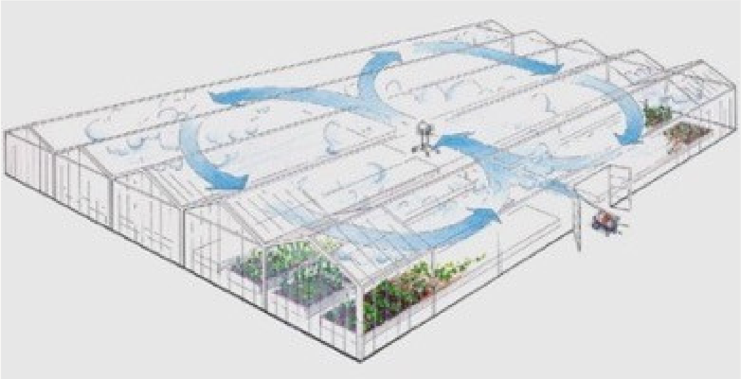


Figure 3.11 Indoor (closed-area) spraying

Spot spraying

The direct and targeted application of pesticides in restricted areas (Figure 3.12).

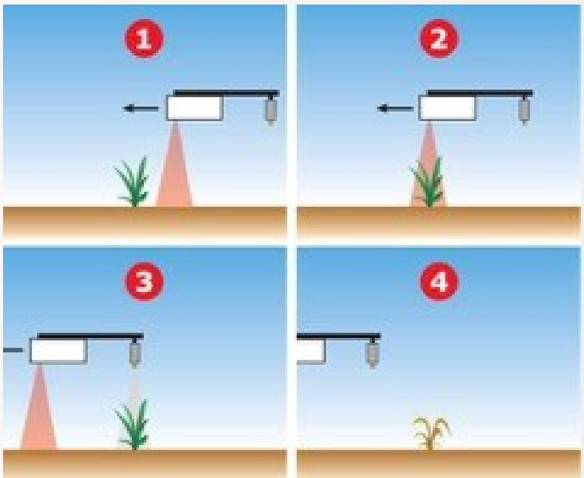


Figure 3.12. Spot spraying

For every type of application technique, water is a common carrier for pesticides. Carrier water volume or application rate is identified according to the sprayer, vegetation, biology of harmful microorganisms, and environmental factors. In general, the application rate is categorized as high volume, low volume, and very low volume.

A wide range of drop diameters (>1000 l/ha for orchards and >600 l/ha for fields) are used in high-volume applications. While all parts of the plant get wet to a large extent; the losses due to run-off are also high accordingly. According to the applications made in other volume classes, less need for advanced technologies in equipment and farmer habits are the reasons why these volume applications are preferred.

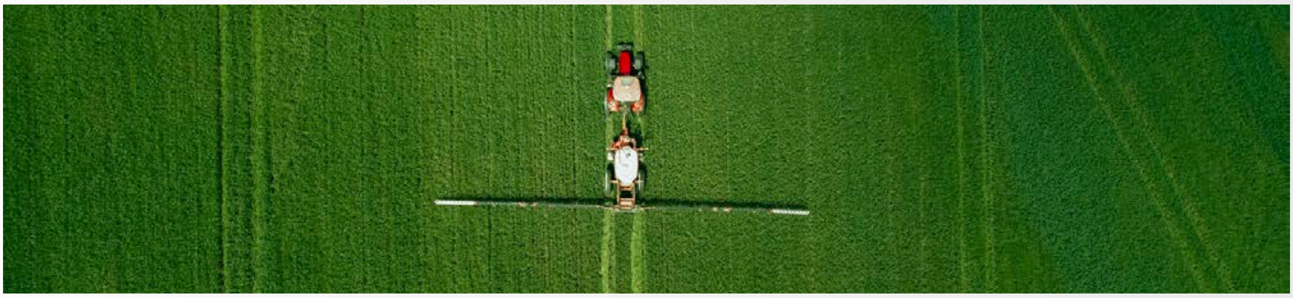
In low volume applications (200-500 l/ha for orchards and 50-200 l/ha for fields) lesser amounts of water are needed to provide adequate coverage on many target surfaces. The coverage can be improved by using a drop that has a smaller diameter and increasing the number of drops. This results in a decrease in run-off losses, but small drops increase the drift potential. Advantages can be achieved in terms of time, labor, and cost with low-volume applications compared to high volume.

In very low volume applications (50-200 l/ha for orchards and 5-50 l/ha for fields) very small drop diameters and low carrier water volume are used. A uniform distribution can be achieved on target surfaces. Spraying that needs to be completed in a very large area in a short time, some specific harmful factors, lands that are difficult to enter and exit, and water supply restrictions play a role in the preference of this application.

3.1.3 Target surface

Arzu Aydar, Okray Orel,
Rumen Tomov

The canopy and foliage vary from plant to plant and crop to crop. Obtaining sufficient information about the harmful factor is important for the identification of the target surface. i.e the area where the pest causes damage to the plant (under the leaf, green sections, root area, etc.). The application time to be determined depending on the factor is another important point. The coverage and drop diameter requirements on the target surface are determined by the size and mobility of the factor.



To optimize pesticide applications to the canopies of crops, especially perennial crops, spray volume should be adjusted throughout the year to match the changes in canopy volume and density. At present, international consensus has emerged on the prospects and potential of variable injection sprays in increasing the utilization of pesticides, reducing pesticide residues, and reducing environmental risks. In addition, variable sprays can be adjusted in real-time based on changes in influencing factors.

3.1.4 Meteorological conditions

Okray Orel, Roxana Ciceoi

Meteorological conditions play a significant role in the efficiency of Plant Protection Products (PPPs) spraying. Variables such as humidity, temperature, wind, and rainfall can greatly influence the application and effectiveness of PPPs.

Humidity. To optimize the application and minimize the risk of volatilization, it is preferable to spray when humidity is above 60%, ensuring that the active ingredient is projected downwards rather than being retained and transported in the air. However, very high humidity, above 95%, is not ideal for spraying as the products could be carried away by water (Sencrop, 2023). When treating plants with PPP, most of the active ingredient typically contacts the plants or the ground. The plants are meant to absorb this substance, yet a significant amount can turn into vapor and enter the air. This process, known as **volatilization**, involves the transformation of a substance from its solid or liquid form into a gas, which then mixes with the atmosphere. The amount of the active ingredient lost to volatilization can range from a minimal to a substantial percentage of the total applied. Volatilisation depends on: (1) weather conditions (hygrometry, temperature); (2) application techniques; (3) the type of crop; (4) cultivation practices; (5) the characteristics of the active ingredient (Sencrop, 2023).

Wind speed is of most importance meteorological factor affecting drift. Wind speed can vary in different periods of the day. For this reason, pesticide applications should be made in periods where constant wind speed and direction are provided. Table 3.1 shows general pesticide application recommendations depending on wind speed (Deveau and Beaton 2011).

Table 3.1. Wind conditions and application recommendations

Beaufort ScalE	Force C	Force 1	Force 2	Force 3	Force 4
Description	Calm	Light air	Light breeze	Gentle breeze	Moderate breeze
Signs	Smoke rises vertically	Smoke drifts and showing direction of wind	Leaves rustle with wind felt in face	Leaves and twigs constantly moving	Small branches moved, dust raised
Spraying guidelines	Medium or Coarse sprays only	Acceptable conditions	Ideal conditions	Acceptable conditions	Do not spray

In order to control drift, the wind direction should be constantly monitored and buffer zones of at least 30 m should be created between sensitive areas and the spraying area.

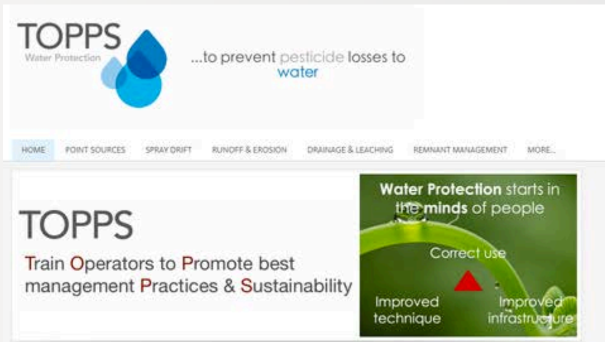
Temperature also plays a crucial role in the application of PPPs. Elevated temperatures, specifically over 25° C, can cause the active ingredients in PPPs to evaporate more rapidly upon application, thus reducing their effectiveness. This relationship between temperature and evaporation rate of pesticide droplets can be calculated using the Delta T spraying indicator, which accounts for the combined effect of temperature and relative humidity (Agrio.app, 2023). High air temperature and low relative humidity are the conditions that pose the greatest risk for drift. On the other hand, temperature inversions, when temperatures rise with height from the ground, can lead to the long-distance drift of PPPs, which is particularly risky during the evening hours and should be avoided to prevent off-target dispersion.

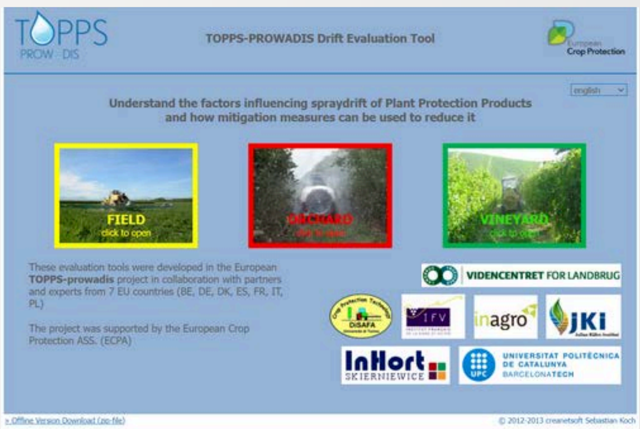
Technological advancements in hyper-local weather monitoring allow for more accurate and site-specific meteorological data, which can be instrumental in planning the timing of PPP applications. By using detailed local weather forecasts, farmers can identify optimal spraying conditions and thus minimize the environmental impact while maximizing the effectiveness of PPPs.

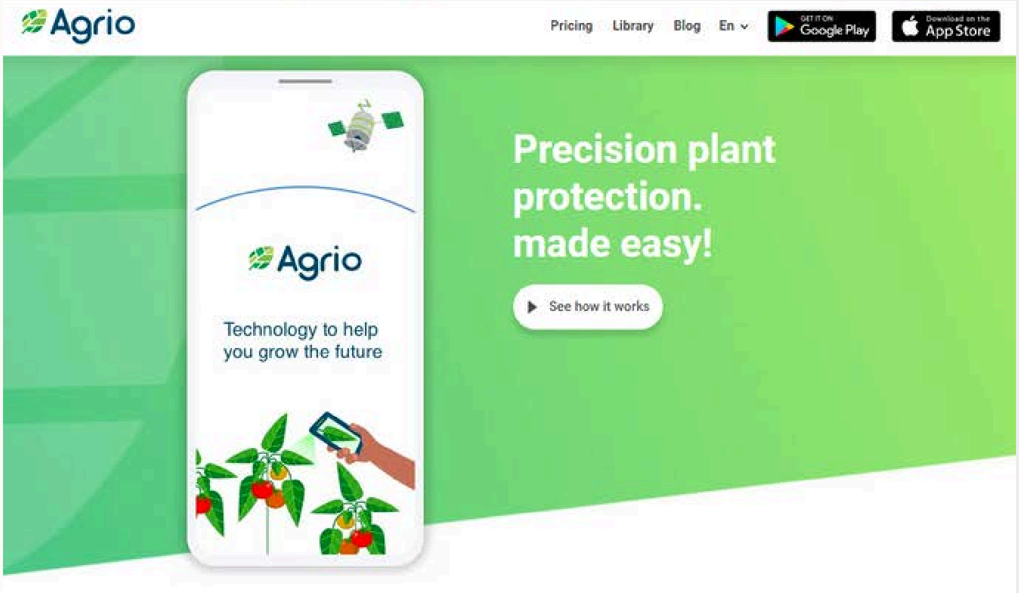
The TOPPS - Life project was selected among the best 10 Life projects that was funded.

The project, focused on reducing PPP to water, was funded by EU through the Life program and the ECPA (European Crop Protection Association). The project started November 2005 and ended October 2008. It was designed as a multi stakeholder project and included 15 EU member states, 12 local partners and 9 subcontractors, which executed the project. It was so successful, that other three continuation projects were founded.
More information can be found on http://www.topps-life.org/

TOPPS-PROWADIS Project developed a Spray Drift Evaluation Tool, providing an insight of the relevant factors influencing the spray drift risk, the key mitigation measures and how the risk may be reduced.
The tool is not a scientific model and its main purpose is to provide a basis for a general understanding for spray drift and its reduction.
The tool is available at https://topps-drift.org/.







Agrio is an artificial intelligence-based precision agriculture solution designed to support crop advisors, farmers, and gardeners. It assists with the remote monitoring, identification, and treatment of plant diseases and pests in fields, farms, and gardens.

The app is free to use and available for download on both Android and iOS devices, offering a range of services from agrometeorological advisories to alerts about the start of the rain season and extreme weather. Agrio also provides the option to receive weather alerts and farming advice in multiple languages, catering to a global audience of agricultural professionals. It also have payed plans, for professional farmers.

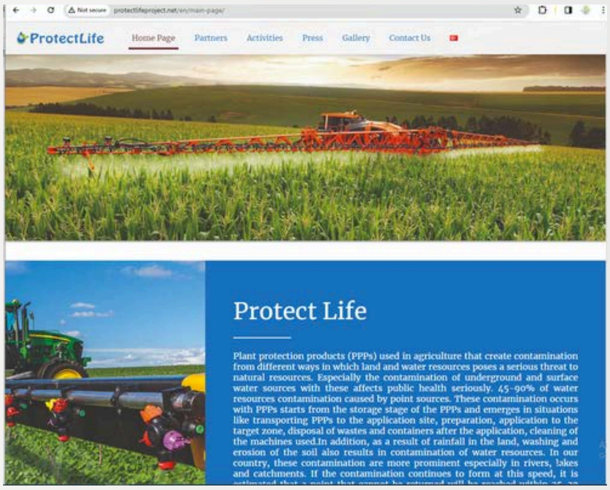
Agrio also includes a Library and a blog, abundant in useful information.

Similar applications, that assist farmers with crop monitoring, plant disease identification, and agronomic decision-making based on weather conditions include:

1. **Climate FieldView** - Developed by The Climate Corporation, it offers field monitoring, weather predictions, and data analysis to optimize field management.
2. **Plantix** - A plant disease and pest identification app that provides treatment advice and a community platform for farmers to exchange information.
3. **Farmers Edge** - A comprehensive farm management platform that includes weather monitoring, field-centric data, and predictive modeling.
4. **CropX** - An app that combines soil monitoring technology with weather data to provide insights on irrigation and crop management.
5. **Granular** - An agriculture software that provides farm management solutions, including field operations efficiency and crop productivity analytics.
6. **ScoutPro** - A crop scouting app that helps in identifying weeds, diseases, and insects and provides management solutions.
7. **AgriWebb** - A livestock and pasture management tool, which also offers weather information relevant to grazing and feeding decisions.
8. **Agrovir** - is a comprehensive farm management software that enables the digitization of entire farming operations.
9. **Agworld** - A collaborative farm management app that allows for planning, budgeting, and optimization of farm activities with a focus on crop inputs and weather conditions.
10. **Farm Dog** - An app that aids in scouting and record-keeping to help manage field conditions and pest pressure.

CASE STUDY

ProtectLife is an ERASMUS+ project, implemented by almost the same team as Hort4EUGreen.
While working for `Prevention of water contamination from point sources with plant protection products by improving extension specialists' vocational competences`, the project developed several written and video materials, available on the project website & YouTube page.



The primary objective of the ProtectLife Project was to formulate Best Management Practices (BMPs) tailored to the specific local conditions of Turkey, with the intention of mitigating the contamination of water resources by point sources of Plant Protection Products (PPPs). Subsequently, the project aimed to enhance the expertise of agricultural engineers, specifically those employed in Provincial Directorates of Agriculture, through the application of these BMPs. These engineers, operating in the field, bear the responsibility of disseminating the BMPs to farmers engaged in the utilization of PPPs. Within the scope of this initiative, there exists a pertinent requirement to elevate the professional skills of these extensional agricultural engineers, particularly in the domains of understanding the risks associated with PPPs contamination and the methods to prevent such occurrences.

Unit 3.2 Sprayer calibration

Okray Orel, Zhelyu Avramov

3.2.1 Forward speed measurement

For a proper calibration, 4 factors must be checked seriously:

- Forward speed (km/h),
- Nozzle type, nozzle flow rate (l/min) and operation pressure (bar);
- Application rate (l/ha),
- Pesticide amount to be added to sprayer tank (l).

In order to obtain the desired application rate, it is very important to know exactly the forward speed of the tractor. Because there may be deviations from the speed seen in the speedometer due to the spin on the wheels.

For this purpose, a distance not less than 100 m must be measured and marked, and this distance must be passed at the spraying speed and the elapsed time must be recorded in seconds (Figure 3.13)

Figure 3.13. Steps of Forward Speed Measurement

The forward speed is calculated from the equation below;

$$\text{Forward speed}\left(\frac{km}{h}\right)=\frac{\text{Distance (m)}\times 3{,}6}{\text{Duration (s)}}$$

i.e. If 100 m is travelled in 46 seconds, the forward speed of the sprayer;

It should be considered that the application rate of the pesticide is reduced proportionally when the forward speed of the tractor is increased, and optimal working speeds should be preferred (Figure 3.14).

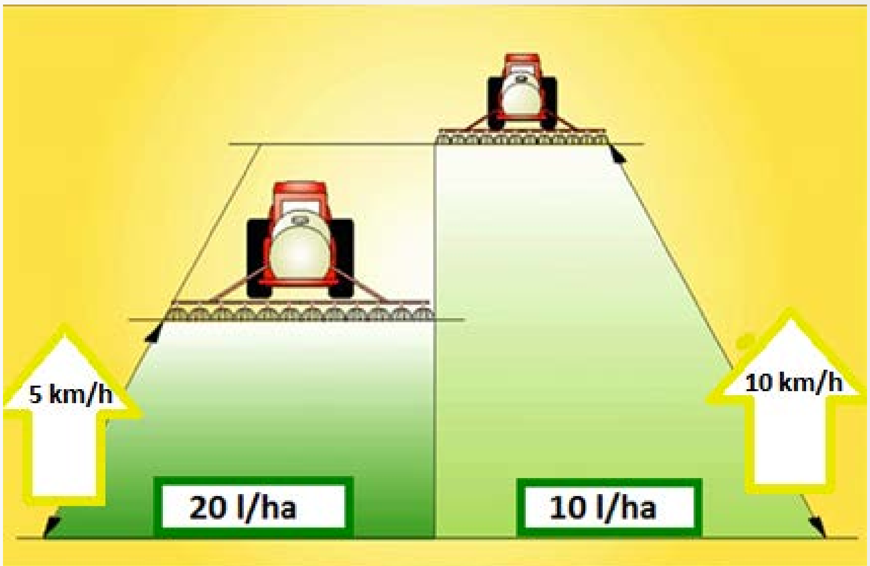


Figure 3.14 Effects of forward speed on application rat

3.2.2 Measuring the nozzle flow rate

Okray Orel, Slavcho Slavov

The application rate, the pesticide and water mixture that the sprayer will spray into the area, is directly dependent on the amount of liquid coming out of each nozzle of the sprayer. After determining the appropriate nozzle type and working pressure, it is absolutely necessary to measure the nozzle's flow rate. The distance between the nozzles may vary depending on the type of sprayer, but they should all be at an equal distance on the boom. In addition, nozzles' spraying angles should be considered (Figure 3.15).

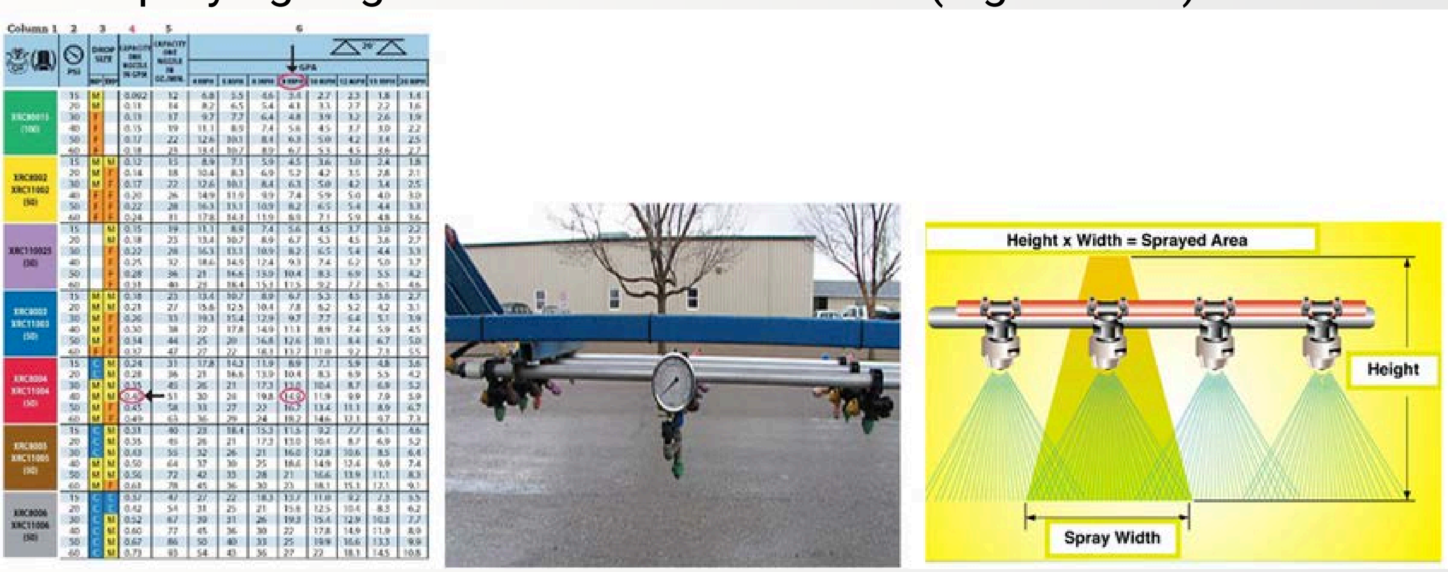


Figure 3.15. Nozzle type and pressure

The sprayer should be operated at the appropriate pressure and clean water should be sprayed for 1 minute to measure the nozzle flow rate. The sprayed water should be measured by collecting it in containers placed under the nozzles. This measurement should be done for all nozzles if possible, or at least for a few nozzles on the right, left and middle parts of the boom (Figure 3.16).

Figure 3.16. Measurement of Nozzle Flow Rate

In addition, these measurements should be repeated before each spraying. Because possible blockages, abrasions, and physical errors in the structure of the nozzle can cause the flow rate to change.

3.2.3 Calculation of application rate

Okray Orel, Yeasemin Sabahoglou

The application rate can be calculated with the equation below after measuring the forward speed and flow nozzle rate:

$$\text{Application Rate}\left(\frac{1}{ha}\right) = \frac{\text{Nozzle flow rate}\left(\frac{1}{dak}\right) \times \text{Nr.of Nozzles} \times 600}{\text{Swath Width (m)} \times \text{Forward speed}\left(\frac{km}{h}\right)}$$

Swath Width(m) = Distance between nozzles×Nr.of Nozzzles

i.e.: if flow rate for a nozzle is 2.5 l/min and the boom has 20 nozzles;

$$\text{Application Rate} = \frac{2{,}5 \times 20 \times 600}{0{,}5 \times 20 \times 7{,}8} = \mathbf{385\ l/ha}$$

If the actual application rate is 5% higher or lower than the recommended or calculated rate, pressure and forward speed rate should be readjusted.

The mixture should be sprayed on the bands in band spraying, unlike broadcast spraying. So, the application rate must be calculated with the equation below :

$$\text{Application Rate}\left(\frac{1}{ha}\right) = \frac{\text{Nozzle flow rate}\left(\frac{1}{min}\right) \times 600}{\text{Band Width (m)} \times \text{Forward speed}\left(\frac{km}{h}\right)}$$

Spraying must be done periodically to reduce pesticide residue on targets and efficient spraying. The calibration must be repeated if any change happens in working conditions. Since the abrasion in the nozzle can affect the output and total application rate increases calibration is essential (Figure 3.17).

Figure 3.17. Calculation of application rate.

Unit 3.3 Drift management

Okray Orel, Yeasemin Sabahoglou

Spray drift is the quantity of PPPs that is carried out of the sprayed area by the action of air currents during the application process (Figure 3.18). Droplets are able to drift to places that be situated in human, animal, plant, and water sources during the application of plant protection products. Thus, losses have occurred in terms of the health of life and the environment. In addition, insufficient biological efficiency due to drift at the control of disease, pest and weed in the target area and exposure to pesticide residues of sensitive plants in non-target areas cause economical losses.

The factors that affect the drift of plant protection products are application technique, droplet diameter according to the nozzle type and pressure, wind speed and direction, weather temperature and humidity, and physical and chemical properties of pesticides. Although preventing to drift of plant protection products is not possible, drift can be minimized by applying good drift management. Good drift management is achieved by selecting of correct application technique, suitable nozzle type, operating pressure, forward speed and application rate (Sabahoğlu and Aydar, 2013).

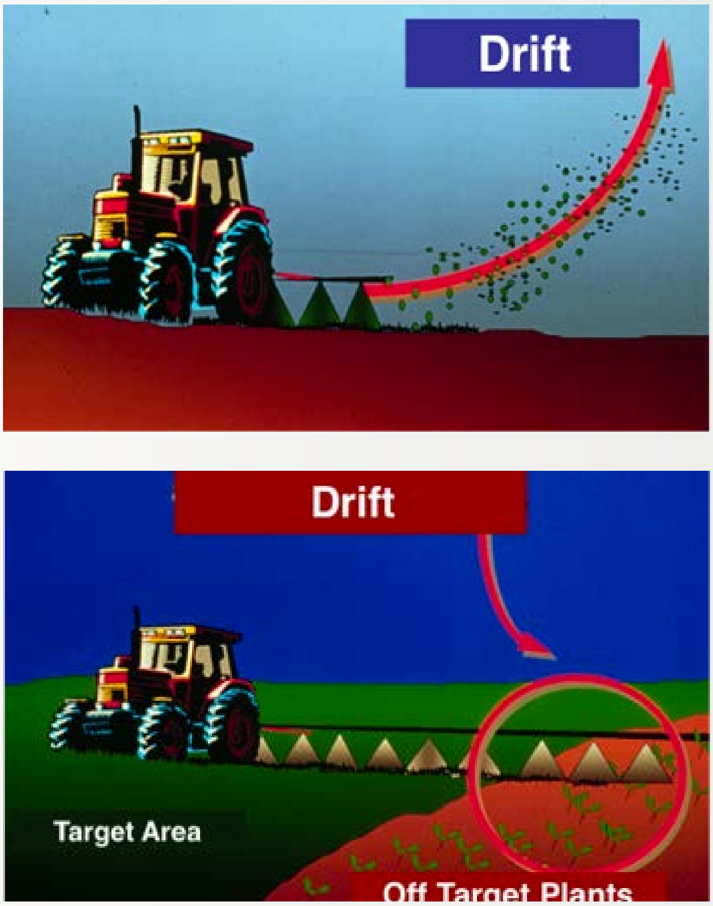


Figure 3.18. Drift during the pesticide application

The main strategies to reduce spray drift in pesticide applications are nozzle selection to increase droplet diameter, proper boom-nozzle configuration, optimum weather conditions, anti-drift nozzles, air assistance, and shield covers.

The most important factor affecting drift is droplet diameter. Small drops do not have enough weight to fall quickly. For this reason, they hang in the air and are drifted over long distances by air movements. Drop size classification according to volumetric mean diameter values prepared by ASABE (American Society of Agricultural and Biological Engineers) is given in the Table 2.

Table 2. Drop diameter classifications according to ASABE S-572 Standard

Category	Symbol	Color Code	Approx. VMD Range (microns)
Extremely Fine	XF	Purple	<60
Very Fine	VF	Red	60-145
Fine	F	Orange	145-225
Medium	M	Yellow	226-325
Coarse	C	Blue	326-400
Very Coarse	VC	Green	401-500
Extremely Coarse	EC	White	501-650
Ultra Coarse	UC	Black	>650

Large drops reach the target faster. In other words, while large drops fall faster, they are less affected by the wind. The higher a drop is dropped, the stronger it is exposed to wind and the greater the chance of drift. Table 3 shows the travel distances of the drops at a wind speed of 5 km/h.

Table 3 Travel distances of droplets at 5 km/h wind speed (ASABE)

Drop diameter (μm)	Falling time from 3 m (s)	Lateral movement distance at 5 km/h wind speed (m)
5	3600	5000
20	252	350
100	10	13
240	6	8.5
400	2	2.6
1000	1	1.5

The selection of nozzle type and size is the most important technical parameter for all pesticide applications. Advanced nozzle designs have superior drop size characteristics. Anti-drift nozzles are designed to produce larger drops at the same flow rate and operating pressures compared to standard nozzles. The number of drops smaller than 200 μm can be reduced by 50-80% with this type of nozzle. Thus, these nozzles can create droplets that tend to drift less than standard nozzles (Figure 3.19).

Figure 3.19. (a) Standard nozzle, (b) Low drift nozzles

Field application with air assistance is a technique that reduces drift and increases efficiency. The risk of drifting the drops with the wind is reduced with these air-assisted sprayers. The effectiveness of the droplets to stay on target surfaces and their penetration towards the inner section of the plant increases. This makes it possible to achieve better adhesion and good coverage on the target (Figure 3.20).

Figure 3.20. Effect of air assistance (Hardi)

Adding different types and sizes shields (or covers) on the sprayer booms is an effective technique to reduce the drift potential of the sprayers, too. These can be designed like mechanical protective shields, either completely covering the sprayer boom or in the form of protective shields placed over each nozzle separately (Fig. 3.21, 3.22). Protective systems can ensure effective spraying even at wind speeds that are too high to be sprayed with conventional sprayers by reducing the drift effect of the wind, and increase the number of operable days for spraying application (Özkan et al., 1997).

Figure 4.21. Shielded cover

Figure 3.22. Shielded cover

Effective drift management strategies include using the appropriate equipment and application techniques, such as choosing the right nozzle type and size, adjusting spray pressure, and controlling droplet size. Additionally, understanding and monitoring weather conditions — particularly wind speed and direction, temperature, and humidity — are essential to reducing drift. The selection of PPPs with properties that minimize drift potential and adherence to buffer zones can further mitigate risks.

In essence, drift management is about maximizing the efficacy of PPPs while safeguarding the surrounding environment and public health. It requires a combination of best practices, technology, and a thorough understanding of meteorological and agronomic factors.

Unit 3.4 Smart sprayers

Okray Orel, Yeasemin Sabahoglou

3.4.1 Electrostatic Sprayers

Electrostatic spraying is a technique developed to minimize the environmental risks of pesticides. This technique performs well on the developing uniform drop size and drop distribution on the target surface, and coverage ratio. Thus, electrostatic sprayers greatly reduce the use of pesticides and off-target losses.

The electrostatic spraying technique is based on the principle of pulverization of electrically charged drops to generate an attraction force between the leaves on the target plant and the sprayed drops. The most important component in this technique is the high-potential electrostatic nozzle (Sabahoğlu and Aydar, 2015) (Figure 3.23).

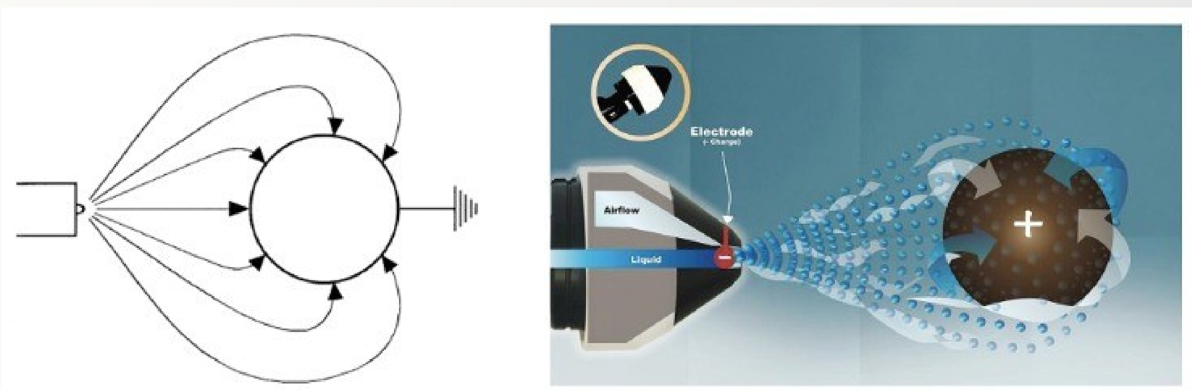


Figure 3.23. The trajectory of the charged drops and the target

While the pesticide is pumped from the tank to the nozzles for droplet formation, the electrical area between the electrode and the liquid sprayer induces the drop and charges it (Figure 3.24). This situation based on the attraction force between negatively charged drops and positively charged objects facilitates the movement of the drops toward the target surface. The drops surround the plant's leaves, branches, and fruits and reach both sides with this continuous line of natural gravity. The drops lose their electrical charge when they contact the plant surface (Jia et al., 2013).

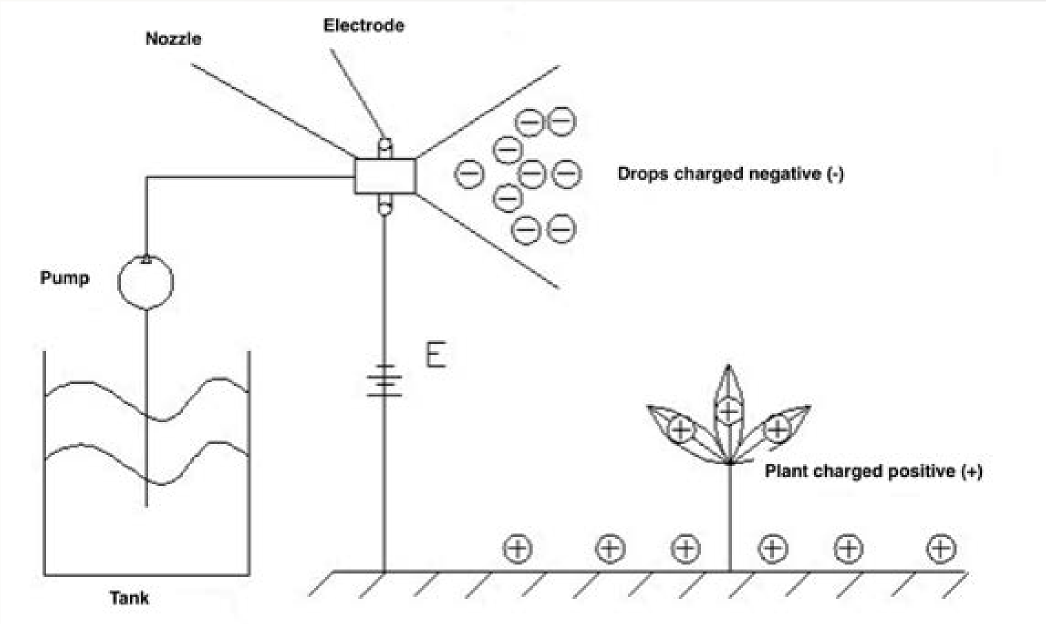


Figure 3.24. The working principle of electrostatic sprayer (Jia et al., 2013)

Electrostatic sprayers with different tank capacities are produced for vineyard, orchard, field and greenhouse applications and are used in practice. The performance of an electrostatic sprayer is evaluated by considering the distribution of the sprayed pesticide, the coverage, the off-target losses, and the amount of pesticide on the target surface (Sabahoğlu and Aydar, 2015) (Figure 3.25, , 3.26 and 3.27).

Figure 3.25. Elektrostatic orchard sprayers (ESS sprayer)

Figure 3.26. Elektrostatic field sprayers (ESS sprayer)

Figure 3.27. Elektrostatic sprayers in greenhouse (Kabassima and Parrela, 1995)

3.4.2 Shielded Sprayers

Okray Orel, Yeasemin
Sabahoglou

Shielded sprayers are generally designed to prevent droplets from depositing onto a crop, and can reduce drift by more than 90 per cent compared to a conventional boom. Shielded spraying applications are based on banded application principle. Banded applications require accuracy to uniformly deliver the product to the intended target area. Shielded sprayers have traditionally been used for inter-row spraying in farming systems where wider row spacings are common.

However, shielded sprayers are now being used in areas with much narrower crop row spacings, particularly in some of the higher-rainfall areas (Gordon, 2010) (Figure 3.6). This use in narrower crop spacings has been in response to increased levels of resistance to selective herbicides.

Other products registered for use in herbicide-tolerant crop varieties, which may be applied as an over-the-top application, could also be applied through shielded sprayers.
Shielded sprayers for orchards have been specifically developed for weed control between rows of trees in orchards. The sprayers' adjustable width and wide reach make them ideal for use in orchards established for many

types of fruit and vineyards. These sprayers eliminates spray drift and allows for the sprayers to be used even in windy conditions (Figure 3.28).

Figure 3.28. Shielded sprayer for field crops (a) in wider row spacings (b) in narrower row spacing

Figure 3.29. Shielded sprayer for orchards (Micron sprayer)

3.4.3 The sprayers with ultrasonic sensor & LİDAR

Okray Orel, Yeasemin Sabahoglou

Nowadays, orchards and vineyards are sprayed mainly with axial fan “mistblower” orchard sprayers, which offers efficient exploitation under a wide range of variable orchard conditions. The spray plume generated by axial fan orchard sprayers is prone to spray drift; thus large losses to the atmosphere and ground can occur. The potential for adapting the characteristics of the air stream generated by an axial fan sprayer to different tree canopies is limited. Spray applicators and the public are interested in more efficient pesticide application equipment and strategies to reduce pesticide usage. One way to improve pesticide application efficiency is to use sensor technologies to identify target trees and then apply the precise amount of pesticide needed for adequate insect and disease control (Sabahoğlu and Aydar, 2017).

The different shapes and sizes of tree canopies, even among the same variety in the orchard, require continual calculation ofTRV (tree row volume) and adjustment of the applied dose of pesticide to optimize the spray application efficiency (Stanjko et al., 2012). The range of non-invasive optical and ultrasonic sampling techniques have been devoloped measurement of plant structures. In particular, the development of a compact, tractor-mounted light and range detection system (LIDAR) has made it possible to take quick, detailed readings of crop structure (Wangler et al., 1993). The ultrasonic sensors and proportional electro-valves with the corresponding software and automation, which allowed real time modification of the sprayed flow rate adapted to the crop structure of the orchard (Gil et al., 2007).

Unlike the traditional systems that spray the whole area, the spray flow rate for tree crops is interrupted when no foliage was detected by means of ultrasonic or optical sensors and electric valves inthe ultrasonic sprayers as described in Figure 3.30 (Escola et al., 2007) .

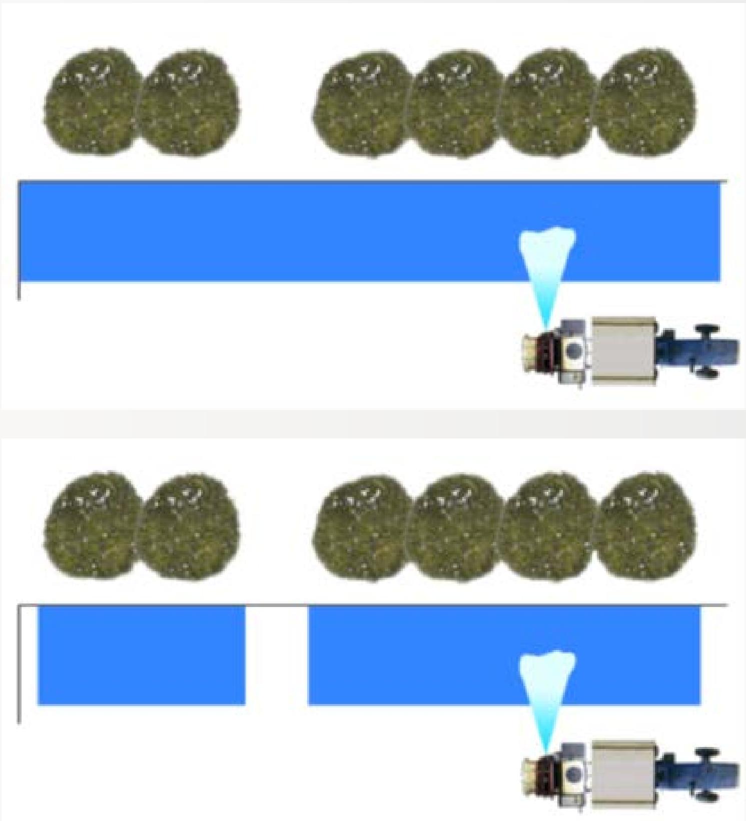


Figure 3.30. Spray flow rate adjustment models in tree crops.
a) Conventional application b) Selective application (Escola et al 2007)

The use of herbicides has a significant impact on the environment. Spot-spraying aims to reduce the environmental impact by only spraying parts of the field that contain weeds, instead of the conventional full-field spraying. Spot-spraying can reduce herbicide usage by up to 70% while maintaining 100% weed control (Ruigrok et al., 2020). These systems differ green vegetation from soil and crop residues based on spectral information in the visible and near-infrared wavebands. The target is to identify the presence or absence of green plants, while the system provides the classification of plant species or groups of species, such as crop, grass-weeds, broadleaved weeds, and perennial weeds (Figure 3.31). (Allmendinger et al., 2022)

Figure 3.31. Spot-spraying with weed detection

3.4.4 Tunnel Sprayers

Okray Orel, Rumen Tomov

Tunnel sprayers have one or two tunnel-shaped enclosures. Each enclosure covers one or two rows of fruit trees or grapevine as shown in Figure 3.32. Some models have no fans blowing droplets into the canopy, while others have fans creating air-assistance to enhance the deposition of droplets deeper into the canopy. The fans are usually rotary types on a vertical shaft and are located on opposite corners of the tunnel. Each fan directs the air at an angle to create a clockwise or counterclockwise air current inside the tunnel.

Tunnel sprayers significantly reduce airborne spray drift and eliminate contamination of soil from pesticides. Reductions in pesticide losses from 25 to 50% were reported for tunnel sprayers when compared to standard orchard sprayers (Thériault et al., 2001). In general, they provide a better deposition of pesticide into the canopy and an improved uniformity of deposition in all parts of the canopy. They reduce pesticide consumption because the tunnel sprayer can be designed to capture and recirculate any spray excess passing through the crop canopy.

The main limitations with the tunnel sprayer come from the variability of tree shape and size and the lower working speed of the machines compared to conventional sprayers. Furthermore, tunnel sprayers are cumbersome and difficult to drive in and out of the grove.

Figure 3.32. Tunnel sprayers

3.4.5 UAV Sprayers

Okray Orel, Adrian Asănică,
Andrei Moț

Unmanned aerial vehicles (UAVs) for plant protection is a new plant protection practice and is characterized by high efficiency and a high utilization rate of pesticide. There are some advantages compared to conventional spraying technologies. It can effectively solve problems causing by high-stalk crops, manual and ground mechanical operations on paddies and steep, mountainous terrains. It is also an efficient way to monitor and control large-area pest and disease outbreaks, reduce the use of rural labor and pesticide (Figure 3.33). Furthermore, the plant protection UAV that operates at low altitude and low loading can suspend in the air to achieve high-precision position with GPS. Additionally, the downward airflow generated by rotors helps to increase penetrability of droplets on canopy to improve the pesticide effect (Lan and Chen, 2018).

The effectiveness of spray of high plants such as corn crops is increased with strong downwash generated by UAV rotors. Downwash is the core driver of droplets to corn canopies, and this can be varied by changing operation height and speed to adjust the distribution spray onto canopies. Therefore, if UAV downwash can be properly characterized, it should be possible to take measures to increase target-receiving and reduce drift (Yang et al., 2022).

speed of the machines compared to conventional sprayers. Furthermore, tunnel sprayers are cumbersome and difficult to drive in and out of the grove.

Figure 3.33. UAV Sprayer

Unit 3.5 Reduction of diffuse and point sources

Roxana Ciceoi, Arzu Aydar,
Adrian Asănică

3.5.1 Water contamination

Water contamination by pesticides is an environmental issue that has garnered significant attention due to its implications on ecosystems, human health, and biodiversity. Pesticides, designed to control pests and enhance agricultural productivity, often find their way into water bodies, leading to contamination of rivers, lakes, groundwater, and even drinking water. This contamination is not only a consequence of agricultural activities but also of urban and suburban land use where pesticides are used for lawn care and pest control. The ingress of pesticides into water systems typically occurs through two primary mechanisms: surface runoff and leaching. Surface runoff happens when rainwater or irrigation water flows over the land, picking up pesticides from agricultural fields, golf courses, residential lawns, and other treated areas, and eventually depositing these chemicals into streams, rivers, and lakes.

Leaching, on the other hand, involves the downward movement of pesticides through the soil profile, eventually reaching groundwater sources. The propensity for pesticides to contaminate water through these routes depends on various factors including the chemical properties of the pesticide (like solubility and persistence), soil characteristics, topography, and the amount of precipitation (Stone et al., 2014).

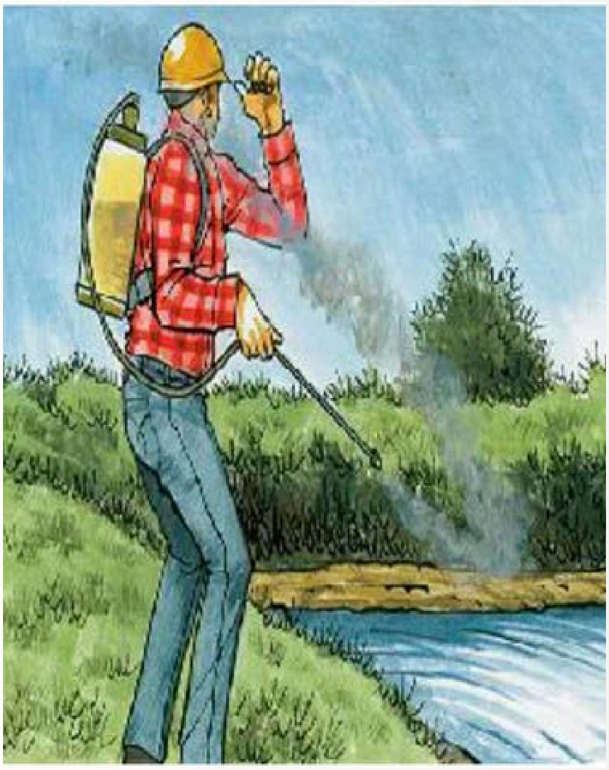
The ecological impacts of pesticide contamination in water bodies are diverse and profound. Aquatic life, especially fish, amphibians, and invertebrates, is highly susceptible to the toxic effects of many pesticides. This toxicity can lead to decreased biodiversity and disruptions in aquatic food webs (Lima-Fernandes et al., 2019). Furthermore, the bioaccumulation of certain pesticides can have far-reaching effects up the food chain.

For human populations, pesticide contamination in water poses significant health risks. Pesticides in drinking water, even at low concentrations, have been associated with various health issues, including endocrine disruption, reproductive problems, and an increased risk of certain cancers (Bocquené and Franco, 2005). The World Health Organization has established guidelines for maximum pesticide levels in drinking water to mitigate these risks. In the United States, for instance, the Environmental Protection Agency (EPA) regulates the use of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Safe Drinking Water Act (EPA, "Regulations on Pesticide Use and Water Quality").

These regulations aim to limit the environmental impact of pesticides and ensure the safety of drinking water.

Advancements in agricultural practices, such as precision agriculture, IPM, and the development of less harmful pesticide alternatives, are also crucial. Precision agriculture involves the targeted application of pesticides, reducing the volume and frequency of pesticide use (NRC, 2010).

Education and awareness are equally important. Informing farmers and the general public about the risks associated with pesticide use and the importance of following best practices can lead to more responsible pesticide application and handling.



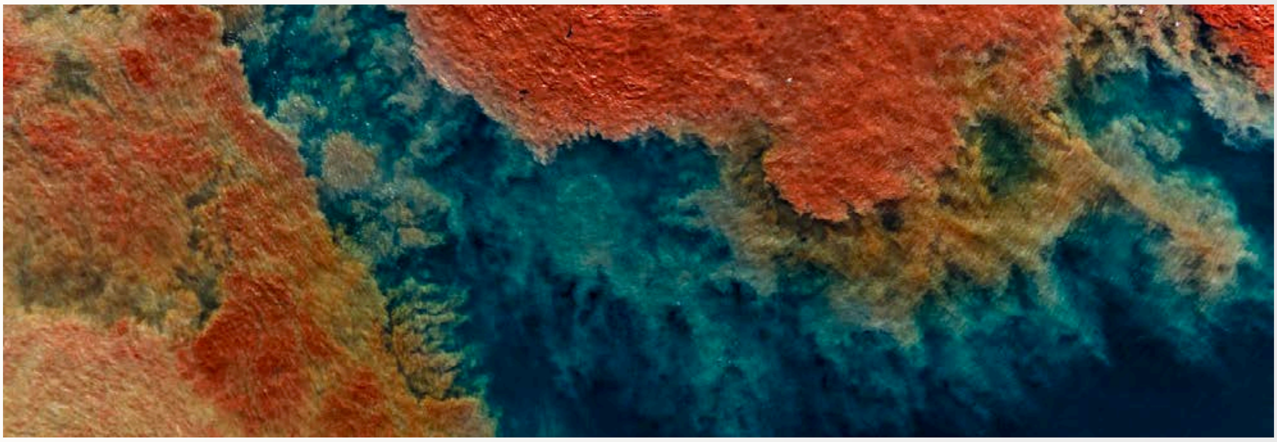
(Source: Srivastava et al. 2018)

While pesticides play a vital role in modern agriculture and urban settings, their impact on water quality cannot be overlooked. Balancing the need for pest control with environmental conservation and public health safety is essential. Through stringent regulations, advanced agricultural practices, and increased public awareness, it is possible to mitigate the negative effects of pesticides on water quality.

For the unintended losses to water exist two main routes of contamination:

- **Point sources**, which are mainly related to inappropriate handling of the PPP during transport, storage, filling, cleaning, management of remnants and empty packages disposal.
- **Diffuse sources** are mainly related to losses from treated fields due to runoff, leaching and discharge through drainage. Diffuse sources are influenced to a large extent by factors such as field topography, soil and extreme weather conditions soon after the applications as well as the physicochemical properties of the pesticide itself (Breach, 2008).

In studies describing the different entry routes of pesticides to soil and surface waters, it is stated that point sources constitute the largest percentage. The results show that point-source PPP contamination varies between 40-95% (Bach et al., 2005).



Minimizing contamination from point sources it has been developed a series of Best Management Practices (BMPs). They address three strategic perspectives: correct behaviour, improved infrastructures and equipment (risk mitigation enablers). These perspectives were applied to the working processes in 6 steps (Figure 3.34):

- Transport
- Storage
- Before spraying
- During spraying
- After spraying
- Remnant management

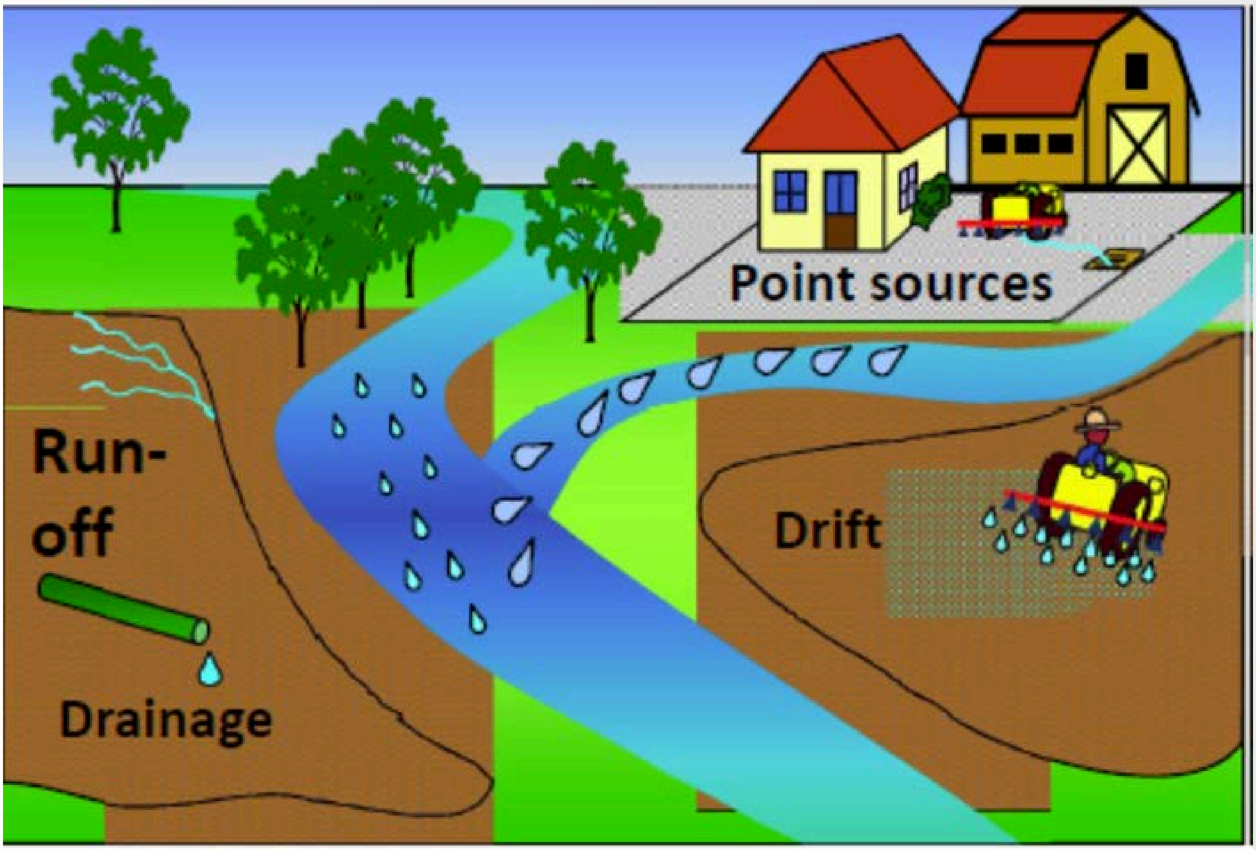


Figure 3.34 Entry routes of plant protection products into surface water (TOPPS)

Transport from PPP suppliers to the farm store by the farmer is the first step in a series of processes where there may be risks for point source contamination. These are prerequisites in order to not contaminate store, not to produce clean-up remnants of spills, ensure no leakage and not end up with unwanted stock.

Storage of PPPs is an extensively regulated issue in terms of personal and to an increasing extent environmental safety. It's linked to farm buildings and hence to infrastructure. It includes separating the storage facilities from the sewage going to the water channels and keeping the leaks within the boundaries of the warehouse.

Before spraying is a key element in preventing risks associated with PPP use in general and for the risk of PPPs entering surface water. It contains pre-implementation activities within the scope of good agricultural practices, safely transporting a sprayer filled with diluted PPP from the filling area to the application area and the conditions to be considered along the areas where surface waters are present and areas close to sensitive areas while the sprayer is moving in the road condition.

During spraying activities, the following elements are key to; minimal effective use of PPP amounts, optimized crop protection result, and reduced pollution risk in the process itself and regarding diffuse source pollution.

After the spraying process is the management of the PPP fraction left at the end of the spray process. This includes; spray left-overs (surplus spray liquid), non-sprayable solution (total residual volume (both non- and dilutable fraction), external sprayer contamination and cleaning processes of the sprayer in order to eliminate the risks.

The management of remnants involves several key strategies aimed at minimizing waste production in the context of environmental conservation and human health protection. This process encompasses the collection and recycling of wastes through segregation based on their distinct properties. Additionally, it entails the thorough cleaning of areas and equipment, such as sprayers, used in the application of Plant Protection Products (PPPs). A crucial aspect of this management is the enhancement of operator awareness regarding the adherence to good agricultural practices at each phase of PPP implementation.

3.5.2. Soil contamination

Marian Mușat, Mária Mortl, Eszter Takacs, Zhelyu Avramov

Soil contamination by Plant Protection Products (PPPs) is an increasingly pertinent issue in the context of sustainable agriculture and environmental stewardship. The widespread use of PPPs, essential in modern agricultural systems for pest control and crop yield enhancement, has raised significant concerns regarding their impact on soil ecosystems and functions.

The European Food Safety Authority (EFSA) has been actively involved in assessing the risks posed by PPPs to in-soil organisms. A critical aspect of this assessment is understanding the exposure of soil organisms to PPPs through contact and oral uptake, which can have various ecotoxicological effects. The EFSA, in collaboration with the Joint Research Centre (JRC) of the European Commission, has developed guidance and a software tool, Persistence in Soil Analytical Model (PERSAM), for conducting soil exposure assessments. This tool helps in calculating predicted environmental concentrations (PECs) of PPPs and assesses potential risks to non-target soil organisms using Toxicity Exposure Ratios (TER). The risk assessment takes into account soil characteristics and environmental variables that vary across the European continent, influencing the availability of PPPs and their toxicity upon soil biota (Urionabarrenetxea et al., 2022, Ocklefordet al., 2017).

The Food and Agriculture Organization of the United Nations (FAO) has highlighted the global impact of PPPs on soil functions and ecosystems. An assessment at the global level has been conducted to evaluate the effects of PPPs on soil biodiversity, soil functions, water quality, and soil erosion. This assessment provides a high-level, global-scale scientific opinion on these effects and contributes to the understanding of sustainable soil management in the context of PPP usage (FAO and ITPS, 2017).

The ecological models developed for risk assessment highlight the multi-faceted nature of PPP impacts on soil ecosystems. These models consider factors like bioconcentration, bioaccumulation, and metabolism of pesticides in various soil organisms, including aquatic species. They also address population-level effects and the recovery of invertebrates after exposure to insecticides. This comprehensive approach to risk assessment is crucial for understanding the full spectrum of PPP impacts on soil and associated ecosystems (Laras et al., 2022)

The sources and mechanisms of soil contamination by PPPs are diverse. One of the primary sources is PPP **direct application** in agricultural practices. PPPs are used extensively for crop protection, and their application can lead to the accumulation of residues in the soil. This accumulation affects not only the target organisms but also non-target species, which can be sensitive to certain pesticides. Another significant source of PPP in soil is the **irrigation water**. Studies have shown that in Europe, a considerable percentage of groundwater has poor chemical status due to agricultural practices, with nitrates and plant protection products being major stressors. This contamination often occurs through leaching and runoff from treated agricultural fields, which carry PPP residues into groundwater systems and than back in the soil surface, during irrigation (Suciu et al., 2020).

The management and regulation of PPPs are critical to minimize their adverse effects on soil ecosystems. Scientific assessments and tools developed by organizations like EFSA and FAO play a vital role in guiding policy and regulatory decisions. These efforts aim to balance the benefits of PPPs in agricultural productivity with the imperative to protect soil health and biodiversity, ensuring sustainable and responsible use of these products.

3.5.3. Flora and fauna contamination

Liliana Bădulescu, Andreea Barbu,
Monica Badea

Flora and fauna contamination, particularly through water pollution, has extensive effects on biodiversity. Water pollution leads to algae blooms, displacing aquatic life and shutting down water supply systems due to toxicity. Pollutants like lead and mercury, ingested by aquatic organisms, can cause diseases like cancer and hepatitis in animals and humans. Ecosystem destruction is another major consequence, with nutrient-rich pollutants fostering excessive algae growth, which competes with plants for resources, alters the marine environment, and depletes oxygen levels. Rising water temperatures from pollution also contribute to the depletion of coral reefs.

Pollution affects the breeding capacity of animals, potentially leading to the loss of entire species. Water pollutants from various sources, including fertilizers, industrial waste, and mining activities, contaminate drinking water, affecting both terrestrial and aquatic wildlife. This leads to a disruption in the food chain, as animals consume pollutants, passing toxins up the chain to predators, including humans.

The ecological risk assessment of PPPs is crucial for understanding their impact on various ecosystems. Ecotoxicological models play a vital role in this context, Ecotoxicological models play a vital role in this context, evaluating the potential risks and effects of PPPs on living organisms. These models consider a wide range of factors, including bioconcentration, bioaccumulation, and the metabolism of pesticides in aquatic organisms. The assessment of the population-level effects of PPPs on aquatic invertebrates and other species is an important part of this process. Such evaluations help in understanding the full spectrum of ecological impacts and guide the development of regulatory policies and sustainable agricultural practices.

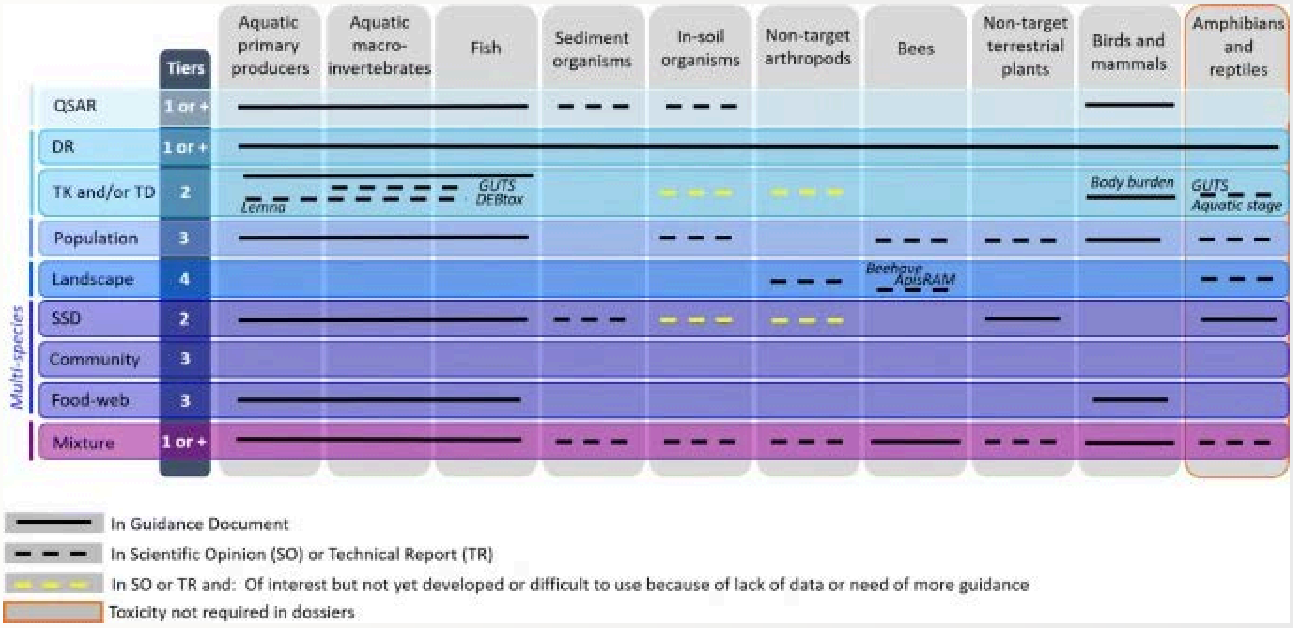


Fig. 3.35 Graphical abstract of modeling for ecological risk assessment of plant protection products

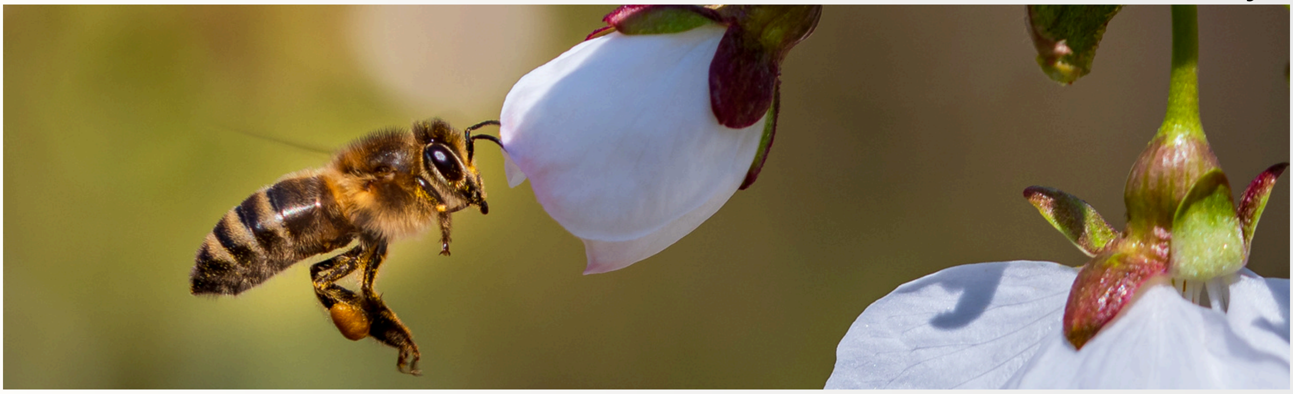
3.5.4. Pollinators protection measures

Roxana Ciceoi, Oana-Crina Bujor,
Violeta Alexandra Ion

The significance of pollinators in our ecosystems cannot be overstated. These organisms, primarily bees, but also butterflies, birds, and bats, play a crucial role in the pollination of many crops and wild plants. However, the use of PPPs in agriculture poses a significant threat to these pollinators. The challenge lies in implementing measures that protect pollinators from the potentially harmful effects of PPPs while maintaining effective pest control. PPPs are designed to protect crops from pests and diseases, but their indiscriminate use can be detrimental to non-target species, including pollinators. Exposure to PPPs can lead to direct mortality or sub-lethal effects such as disorientation, reduced reproductive success, and impaired foraging behavior in pollinators. Such impacts not only threaten the survival of these species but also jeopardize biodiversity and the sustainability of food production systems.

According to the EU Commission, the 2030 EU Biodiversity Strategy and the EU Pollinators Initiative have pledged to overturn the decreasing trend of pollinators by the year 2030.
Europe boasts a remarkable diversity of insects that are vital for pollinating both agricultural crops and wild flora (EC Pollinators, 2023), that plays a crucial role in maintaining healthy ecosystems and our overall wellbeing.

Over the past few years, there has been a significant reduction in both the number and variety of wild insect pollinators like bees, butterflies, hoverflies, and moths across Europe. Numerous species are currently facing the threat of extinction. The absence of pollinators puts our food supply at risk and could lead to a decline and eventual loss of many plant species. This poses a serious risk to the survival of natural habitats, human health, and the economy.



The 2030 EU Biodiversity Strategy, along with the EU Pollinators Initiative, has established dedicated goals to counteract the diminishing numbers of wild pollinators by the year 2030, the initiative being focused on:

- Enhancing understanding of the reasons behind the reduction in pollinator populations, along with the implications of this decline,
- Advancing the conservation of pollinators and addressing the underlying factors contributing to their reduction,
- Engaging the broader community and fostering strategic planning and collaboration at various levels.

The main strategies for pollinator protection are:

- **Timing of application,** during times when pollinators are less active, (early morning or late evening), reduces the risk of direct exposure. Avoiding application during flowering periods when pollinators are most active is also crucial.

- **Choice of PPPs**, by preferring the substances that are less toxic to pollinators and avoiding the dangerous ones.

- **Application techniques,** such as low-drift nozzles and shielded sprayers can minimize drift during application, reducing the likelihood of PPPs reaching non-target areas frequented by pollinators.

- **Buffer zones** between treated areas and pollinators habitats can provide a safety margin.

- **IPM** strategies emphasize the use of non-chemical pest control methods and the judicious use of PPPs, reducing the reliance on chemical treatments, thereby diminishing the risk to pollinators.

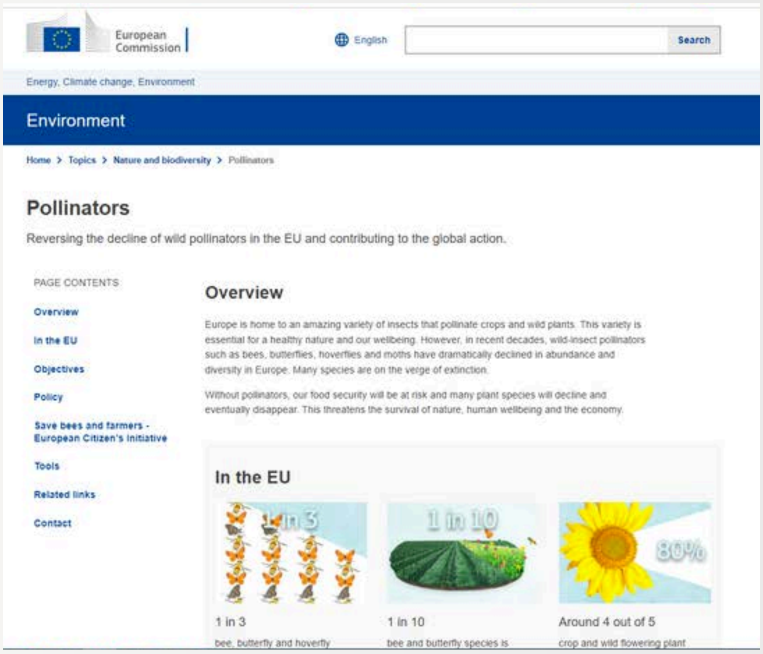
- **Education and training**for farmers and applicators, about the importance of pollinators and the risks posed by PPPs is vital. Training should include best practices for PPP application, including the proper calibration of equipment and adherence to label instructions.

- **Monitoring and research** into the impacts of PPPs can inform more effective protection strategies, includes data about the development of new PPPs that are less harmful to pollinators.

- **Regulatory measures** can play a significant role by imposing restrictions on the use of certain PPPs known to be harmful to pollinators and by enforcing compliance with PPP application guidelines.

- **Promotion of pollinator-friendly practices** by encouraging the cultivation of pollinator-friendly plants and the preservation of natural habitats in agricultural landscapes can provide alternative food sources and refuge for pollinators.

The EU Energy, Climate change, and Environment Strategy offers up-to-date information on EU Pollinators Initiatives and tools available to save the bees, as EU Pollinator Information Hive and Pollinator Park.



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