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Guidance document

Plant Protection Products

Risk mitigation measures to reduce the drift and run-off contamination of surface water bodies

Technical Committee on Nutrition and Animal Health
Advisory Section for Plant Protection Products, March 15, 2017

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Purpose of the document

The labels of the plant protection products often include a phrase about the need to protect the aquatic organisms by means of a non-treated buffer strip in order to reduce the effects deriving from the drift and run-off phenomena.

There are different case studies, depending on the crop typology and active ingredient. Often it is difficult to describe with a simple phrase the different risk mitigation solutions that can be implemented. On the one hand, this entails that the farmer might interpret in a wrong way the meaning of the phrase and not implement the necessary precautions to protect the aquatic ecosystem. On the other hand, who supervises the correct use of the plant protection products might misinterpret the meaning of the phrase included in the label and sanction, actually, who behaved correctly.
The scope of this document is to harmonize the indications that should be included in the label. The indications are defined through a careful analysis of the different measures leading to the risk mitigation for the aquatic organisms and of the latest technology developments in the field of agricultural machinery.

In particular, in addition to the provisions set out in the Regulation (EU) No 547/2011 with regard to labelling requirements for plant protection products, the document provides solutions and indications to include in the label also the reduction percentage of exposure both by drift and run-off which is necessary to reach the so-called “acceptable risk”. The percentages and the efficacy regarding the main drift and run-off mitigation measures are included in the document and they are considered both individually and in combination. The document does not suggest new values to perform model calculations but, in view of the percentage of exposure reduction deriving from the evaluation process, it proposes a series of mitigation measures that, applied on the field, can lead to that reduction value. The proposed values have been derived from published studies and experiences carried out in Italy.
In addition, the values have been compared and kept in line with the work of the European group MAgPIE (*Mitigating the Risk of Plant Protection Products in the Environment*, in the process of being published).
The purpose of this document is to provide reliable and practice oriented indications by assessing only relevant and observable mitigations. The distances on the field are measured by stride and the machinery-crop-field combinations are countless; therefore, it is necessary to provide clear guidance on the method as well as mitigation values that comply with the field tests.
In attachment to this document technical sheets can be found. To the different drift or run-off reduction percentages (mitigation) are associated the possible mitigation measures that can lead to such reduction. Once it is established that a certain mitigation is required, it is then up to the farmer to choose in each case the most appropriate mitigation measure or combination of measures which best satisfy the different business needs. Some mitigation values included in the technical sheets are referred to in this document in the examples of calculation of the total mitigation (psaragraph 5.3, Combinations of mitigation measures).

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1 INTRODUCTION

This Guidance document is addressed to those who are responsible for the environmental risk assessment of the plant protection products and to the institutions involved in applying the mitigation measures regarding the contamination risk of surface water bodies associated with the use of plant protection products.

The authorization process of the plant protection products provides that the use of each product is assessed also in relation to the contamination risk of surface water. Such contamination can take place in three main ways: run-off, drift and drain-flow.
The drift and run-off contamination risk is deemed to be priority in the Italian operating and environmental conditions.
Drift is defined as the transportation outside the treated field of a part of the drops composing the sprayed solution, transported as particles suspended in the moving air mass. Therefore, the drift does not include the transportation of the plant protection product through the atmosphere in gaseous form, which is generally defined as volatilization.

Run-off of a plant protection product is the transfer of it through the surface run-off water from the treated area to a water body. It takes place when the intensity of the water supply (rain or irrigation) is higher than the infiltration rate in the soil.
It can mainly occur for the following reasons:
- reduction of the soil infiltration, as a result of the formation of an impermeable layer (crust) on the soil surface;
- soil saturation, due to the presence of an impermeable layer in the most superficial layers of the soil (for ex. tillage sole or mineral matrix). In this way some standing water is generated on the soil surface and it can result in a surface run-off flow or in a subsurface run-off;
- concentration of water along the talwegs of soils. This type of run-off is always recognizable because of the clear signs of erosion on the soil surface.

The main factors that can influence the transfer of plant protection products by means of run-off water are:
- the characteristics of the products used, in particular their persistence and solubility in water;
- the distance of the treated area from the surface water bodies;
- the presence of organic matter and the land cover;
- the intensity and distribution of rain;
- the slope and shape of the field. The soils with slope and significant remarkable length are more subject to the run-off;
- the characteristics of the soil. Well-structured clay-rich soils and those with a high level of organic matter retain and facilitate the dissipation of the plant protection products.

The contamination risk assessment of surface water aims at ensuring that the use of a plant protection product does not compromise the quality of surface water and the aquatic ecosystems. If the assessment establishes that under normal conditions of use the specific plant protection product represents an “unacceptable” risk for the aquatic environment, then *risk mitigation measures* able to reduce the inputs of plant protection product in the surface water and, consequently, the exposure of aquatic organisms, should be implemented.

The use of effective and economically sustainable risk mitigation measures allows therefore the use of plant protection products that, even though having critical aspects from the environmental profile, are sometimes necessary to achieve the goals of crop protection.
Furthermore, the large-scale deployment of risk mitigation measures can help maintain a high quality status of the natural resources, with certain social and economic benefits for the agricultural sector.
The deployment of risk mitigation measures is provided not only within the assessment process of the plant protection products, but also within the context of the Directive 2009/128/EC establishing a framework to achieve the sustainable use of plant protection products and of the National Action Plan for the sustainable use of plant protection products adopted by the Italian Ministerial Decree of January 22, 2014 (Official Journal of 02/12/2014). The agricultural sector should consider the need to implement mitigation measures not as a further management burden, but as an opportunity to modernize and reorganize the agricultural territory, enhancing the value of grassed headlands, hedges and areas with spontaneous or semi-spontaneous vegetation. These structures can turn into effective mitigation measures and carry out also an important safeguarding function for the beneficial arthropod fauna and the biodiversity.

2 DEFINITIONS

2.1 Relevant water bodies

In order to protect the aquatic life, all the natural or artificial, permanent or temporary surface water bodies have to be considered relevant for the implementation of mitigation measures due to the risk caused by plant protection products, <u>with the exception of</u>:

- <u>ditches</u>, drains and other artificial hydraulic structures in cultivated fields for excess meteoric water to be collected and conducted, without their own water and with water which is present only temporarily;
- <u>feeder canals for irrigation</u>: water bodies whose water is to be used only in cultivated fields;
- <u>shallow water bodies</u>: water bodies where the bottom level is at least 1 m higher than the crop treated.

Rice fields do not fall within these water bodies as they are subject to a specific environmental protection and assessment.

2.2 Buffer areas, buffer strips

It is important to give a clear definition of this kind of area in view of the importance that it often has in the mitigation measures, both because it is indicated in the precautionary statements for the environment (**SPe-phrases**) and because it is a measure that can be easily checked on the field.
A buffer area is "a non-treated area that divides a treated area from a water body or from a sensitive area to be protected".
In literature there are various terms to refer to this area, for instance *safety distance, bare soil buffer zone, unsprayed buffer zone (Regulation (EU) no. 547/2011), no spray zone, buffer zone, buffer strip, vegetated buffer strip, riparian buffer, conservation buffer strip.*
In order to be defined as such, the necessary and sufficient condition for a buffer area is to be non-treated.
In the characteristic case for the protection of a watercourse in a cultivated territory, the *buffer area* corresponds to a buffer "strip" along the banks, hence the common equivalence between *buffer area* and *buffer strip*.

It follows that in this Guidance document *"Non-treated buffer area"* corresponds to *"Non-treated buffer strip"*. This terminology has been adopted by the Italian Ministerial Decree of March 10, 2015 (Official Journal of 03/26/2015) regarding the guidelines for the protection of the aquatic environment and the reduction of the use of plant protection products in the Natura 2000 sites and in the protected natural areas.
A *non-treated buffer strip* is defined as such because it always interposes some space between the source releasing the pollutant (spray boom, atomizer, treated soil) and the element to protect (water body, sensitive area); if in this area a turf is grown or a vertical barrier is introduced (e.g. a hedge), the ability of the strip to retain the plant protection product is increased. A *buffer strip* is then an effective safety area where the plant protection product cannot be applied. Its aim is to reduce the quantity of product which, as a result of **run-off or drift**, from the treated area may reach the element to protect.

Many types of buffer strips are possible and they can be classified by using 4 identification keys: cultivated (yes/no), vegetated (yes/no), duration (permanent/temporary), origin (artificial/spontaneous).
Therefore, in particular it is possible to have a:

1. *Non-treated buffer strip*: non-treated plot of crop or non-cultivated area (edge of the field, headland).

2. *Vegetated buffer strip*: area covered with turf, specifically prepared and managed with an anti-runoff function. It needs to have a uniform and continuous green cover which is permeable and without any furrows; it cannot simply be an area at the edge of the field where agricultural machinery passes by, as it is usually too compacted to allow the infiltration of water.

Such buffer strips can be permanent or temporary and have either artificial or natural origin.
In this Guidance document there is a distinction between non-treated buffer strip (*bare soil buffer zone*), always indicated as *buffer strip,* and ***vegetated buffer strip***.
The details about the management of the *buffer strip* are set out in the Appendix.

2.2.1 Buffer strip width

The width of the buffer strip, vegetated or not, is based on the distance between the treated area and the element to protect. In this Guidance document *the end of the treated area is considered to correspond to the last line or row of the crop*.
In case of a water body, it is measured starting from the edge of the bank (Fig. 1).

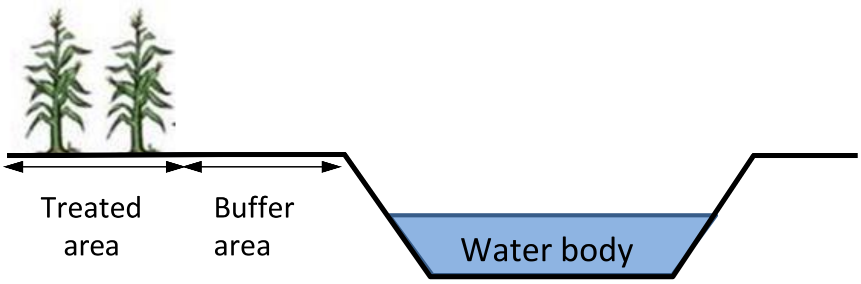

Figure 1. The width of the buffer strip of a water body is measured starting from the edge of the bank.

In the normal conditions regarding Italy, the width of the buffer strip should be between 1 m (e.g. in case of herbaceous crops) and 15 m (e.g. in

case of tree crops) to be reasonably applicable. However, in particular conditions, longer widths are not excluded, provided that widths of more than 30 m do not seem economically sustainable within the Italian context.
Furthermore, due to Italy's unique environment, the areas with almost no surface water bodies and, therefore, not affected by the problem regarding the protection of aquatic organisms have to be taken into account. The risk mitigation measures that will be indicated on the label and which concern very toxic products for aquatic organisms will be assessed on a case-by-case basis. Strict risk mitigation measures involving buffer strips of more than 20 m for horticultural crops, cereals and grapes or more than 30 m for tree crops should be evidenced through field experimental studies that demonstrate the actual possibility to reduce the expected exposition by using more mitigation measures.
These studies should be performed by using mitigation measures realistically applicable on the Italian territory in such a way that they do not involve an overall mitigation of more than 99% for horticultural crops, cereals and grapes and of more than 98.75% for tree crops (corresponding to a 30 m buffer strip together with a further mitigation measure of 70%).

2.3 Calculation of the mitigation

If a certain measure mitigates (reduces) the run-off or drift, it means that the mass of plant protection product transferred to the water body or, in general, to the sensitive area, is reduced.
Therefore, the mitigation reduces the concentration (C).
For instance, if a certain mitigation measure reduces the concentration in a water body from 10 μg/L (C_A) to 1 μg/L (C_B), the mitigation M has

been: $M(\%)=100 \times (C_A-C_B)/C_A=100 \times (10-$

$1)/10=90\%$.

Similarly, the final concentration C_B can be calculated by means of the initial concentration C_A and the mitigation M (%).

$C_B=-((M\times C_A/100)-C_A)=-((90\times 10/100)-10)=1$ μg/L

The final concentration can also be expressed as a percentage of the initial concentration:

$C_B(\%)=-(M\%-100)=-(90-100)=10\%$

All the mitigation values suggested in this G*uidance document* should be considered as average, guideline and summary values in comparison to a very wide variability because the agri-environmental conditions of the Italian territory are very changing. In addition, the values can be reviewed on the basis of new experimental data and concrete feedback (see Section 6.5 - Recommendation 5).

2.3.1 Combination of mitigation measures

If more mitigation measures are combined in a series (one after the other) it is possible to calculate a total mitigation value. In this Guidance document a recursive method with a recurring formula is used. Given an initial input (that may be considered as the zero output, O_0), the output (O_i) becomes after each mitigation (M_i) the input for the next one. With this method, which does not include any parameters, the total mitigation may not exceed 100% and it does not depend on the order of the single mitigation measures. In Table 1 the recursive calculation is included as a table and a formula to be easily implemented in Excel.

Table 1. Recursive calculation scheme and calculation example of the total mitigation (M_{tot}=76%) resulting from 4 measures with a single value of 43%, 32%, 17%, 26%.

Step	Input %	Mitigation %	Output %	
1	O_0	M_1	O_1	$O_1 = O_0 – O_0 \times M_1/100$
2	O_1	M_2	O_2	$O_2 = O_1 – O_1 \times M_2/100$
3	O_2	M_3	O_3	$O_3 = O_2 – O_2 \times M_3/100$
4	O_3	M_4	O_4	$O_4 = O_3 – O_3 \times M_4/100$
$M_{tot} = O_0 – O_4$				**$M_{tot} = O_0 – O_4$**
Step	**Input %**	**Mitigation %**	**Output %**	
1	100	43	57	57 = 100 – 100 × 43/100
2	57	32	39	39 = 57 – 57 × 32/100
3	39	17	32	32 = 39 – 39 × 17/100
4	32	26	24	24 = 32 – 32 × 26/100
M_{tot} = 76				**76 = 100 - 24**

3 RUN-OFF MITIGATION MEASURES IN FLAT SOILS (SLOPE < 2%)

3.1 Vegetated buffer strip

With a vegetated buffer strip the run-off is considerably reduced. By means of the vegetation, in particular when dense, permanent and rich in grass weeds, the buffer strip can remove sediments, organic matter and other contaminants from the run-off water. The mitigation is due to the combined action of the soil bacterial communities and the vegetation. The vegetation acts both directly (absorption of contaminants and flow slowdown) and indirectly by means of some modifications brought to the soil (increase of the porosity and of the organic matter) which facilitate the infiltration and adsorption of the contaminants to the colloids.

The vegetated buffer strip is not a headland or a maneuvering area, as the agricultural vehicles passing by can create soil compaction areas that hinder the vegetation growth.

A type of vegetated buffer strip is the “Riparian buffer strip”. The term “riparian” indicates that the strip (wooded or grassed) is permanent and occupies an area generally available to the water body and sometimes subject to agricultural activities. This area is mitigation effective only when it is covered by uniform and continuous vegetation or by crops with a uniform land cover.

The effectiveness of a vegetated buffer strip depends on the characteristics of the territory and on environmental factors, in particular on the slope and rainfall intensity.

Depending on the slope, in the assessment process the possible mitigation measures for the flat soils (slope <2%) and the soils with slope (slope >2%) shall be taken into account.

In Germany, benchmark values that essentially reflect the EXPOSIT model are used (Winkler, 2001). This model contains an empirical equation which allows to calculate the run-off percentage reduction (*RE*) in presence of a vegetated buffer strip with different widths (FOCUS, 2007):

$$RE\ (\%) = 100 – 10^{(-0.083 \times \text{buffer strip width} + 2.00)}$$

The values adopted by Germany on the basis of experimental and model data appear to be more precautionary than the theoretical values obtained with the EXPOSIT model and in substantial agreement with the experimental data available in Italy for areas with slope < 2%. Therefore, in the assessment process, the reduction percentages included in the Table 2, in the column *Mitigation for vegetated buffer strip*, will be used.

Table 2. Percentage value of the mitigation for buffer strip and for vegetated buffer strip of different width (flat soils: slope < 2%).

Buffer strip width (m)	Mitigation for *buffer strip* (*) (%)	Mitigation for *vegetated* buffer strip (%)
0	0	0
3	20	40
5	25	50
10	45	90
20	**55**	**95**

*Two types are possible: a= non-cultivated area; b= non-treated plot of crop (see Section 2.2)

Some experiences carried out in France show that in field vegetative filter strips, therefore not in the immediate vicinity to a water body, have an effectiveness of 81-98% (see MAgPIE vol. 2, *in the process of being published*). In the absence of specific studies, the run-off mitigation values can be also applied to the *buffer areas* within in field vegetative filter strips, not in the immediate vicinity to the water body.

3.2 Furrow

A furrow lies between the edge of the cultivated field and the water body to protect. The correct placement of the furrow is critical for its functionality and, in any case, it should be placed orthogonally to the run-off flow. It has to be opened before or immediately after the application of the plant protection product, have a depth of at least 40 cm and be properly maintained for at least 45 days after the last treatment. If the furrow is combined with the vegetated buffer strip, it has to be placed before the strip itself, so that the run-off water runs through the strip with a slow laminar flow, likely to be less concentrated.

The creation of the furrow is not usually a significant operational problem and it can guarantee a reasonable mitigation of the most significant run-off events and a very good one for the events with lower intensity.

Run-off mitigation in presence of a furrow: 20%.

3.3 Mitigation measures for plant protection products applied to the soil

3.3.1 Burial

It is performed by including the plant protection products (as herbicides and soil pesticides) in the soil by means of **mechanical operations (i.e.** rotary tillage**, application in the seeding furrow)** or with irrigation (e.g. with a distribution of 5-10 mm, **drip irrigation, etc**.

It is a technique used primarily in the horticulture sector, even though it is more demanding in comparison to other types of application.

According to the experiences acquired in different European countries, the burial allows to reduce the quantities transported through run-off between 25% and 50% in case of products that are not adsorbed much to colloids and between 35% and 70% in case of highly adsorbed products.

Run-off mitigation in presence of a burial: 40%.

3.3.2 Technique by means of very low doses (weeding)

It consists in the application of herbicides, each with a reduced dose, as defined in the related authorized labels. It is a practice that can be adopted especially in the soy and sugar beet weeding. It is based on the use of herbicide mixtures, each applied at doses between 1/5 and 1/10 of the ones used in single applications. By adopting such technique, it is obtained a reduction of about 50% of the products used as a whole.
The positive outcome of this practice is basically related to the compliance of the following conditions:

1) performing a careful monitoring of the weed flora;
2) early intervention on weeds in the early stages of development (cotiledonary leaf or 2-3 true leaves);
3) use of mixtures of several products with complementary or synergic action.

Run-off mitigation in presence of the technique by means of very low doses: 50%.

3.3.3 Treatment localization

It consists in the application of the product only along the line, in sections or spots and in any other case where the product is not applied on the whole surface. These techniques do not modify the dose per treated hectare; however, they reduce the treated surface by proportionally mitigating the run-off. The localization along the line in the pre-emergence weeding treatments (width of 20-25 cm) implies a decrease of the dose included between 40% (as in soy with a distance of 45-50 cm between rows) and 70% (as in sown corn with a distance of 75 cm between rows). The degree of the reduction of the treated area shall be defined on a case-by-case basis in agreement with the agronomists. It should be recalled that the mitigation corresponds to the reduction. For instance, a reduction of 25% of the treated surface corresponds to a mitigation of 25%; a reduction of the treated surface of 50% corresponds to a mitigation of 50%, and so on. This technique requires an effective integration between the chemical and mechanical means (weeding among the rows). The run-off reduction related to the reduction of the treated surface is transposed into the run-off analytical data sheets. In the Measurement 3 "Reduction of the dose" they include the options "No reduction", "Reduction of 25%", "Reduction of 50%". They are example values. If the technicians have at disposal specific values, they may use them keeping in mind that reduction of the dose corresponds to the mitigation, obviously in the absence of other measures.

3.4 Combination of mitigation measures

The run-off mitigation proves to be very effective when more mitigation measures are combined; such strategy has the advantage to significantly reduce the less important run-off events and to mitigate the more relevant ones. For example, the mitigation values of the Table 2 according to the vegetated buffer strip of different widths are considered again in the Table 3 and combined with other measures considered to be easily integrated within the ordinary agronomic practice. The importance of this combination is clear as it makes it possible to obtain a significant total mitigation also in case of a vegetated buffer strip with a limited width (3-5 m).

Table 3. Combination of the mitigation measures with the percentage value of the total and single mitigation.

Width of the vegetated *buffer strip* (m)	Mitigation for vegetated *buffer strip* %	Mitigation by means of furrows %	Mitigation by means of low doses %	**Total mitigation** %
0	0	20	50	**60**
3	40	20	50	**76**
5	50	20	50	**80**
10	90	20	50	**96**
20	95	20	50	98

The combination may concern all the mitigation measures, namely:

- burial of the plant protection product (yes/no),
- reduction of the doses (0, 25, 50%),
- furrow (yes/no),
- width of the buffer strip (0, 3, 5, 10, 20 m),
- type of buffer strip (non-vegetated/vegetated),

for a total of (5×2×3×2) = 60 combinations for the non-vegetated strip (1 sheet for plains) and 60 combinations for the vegetated strip (1 sheet for each of the 3 slopes). Overall, there are 4 run-off analytical data sheets, for a total of 240 combinations.

The vegetated buffer strip, possibly combined with furrows, is a very effective measure for run-off mitigation; in order to maximize its effectiveness, the vegetated buffer strip has to be placed, built and kept correctly and has to be well combined with the “good agricultural practices” for the management of the soil. The aim is to avoid soil compaction, to use conservation tillage practices (when possible), to improve the soil porosity and structure and to prevent the formation of the crust.

The tables 4 and 5 show a few example combinations for non-vegetated and vegetated buffer strips (the complete set of combinations can be found in the analytical data sheets).

Table 4. Run-off mitigation with a non-vegetated buffer strip of different width combined with other 3 mitigation measures: percentage value of the single ((Mi (%)) and total (M tot (%)) mitigation. Key: Measurement 1 (Meas. 1): burial of the plant protection product (yes/no); Measurement 2 (Meas. 2): reduction of the dose (R0=no reduction, R25= 25% reduction, R50= 50% reduction); Measurement 3 (Meas. 3): furrow (yes/no); Measurement 4 (Meas. 4): width of the buffer strip (A0= no area, A3= 3 m area, A5= 5 m area).

Meas. 1 Burial	M1 (%)	Meas. 2 Dose red.	M2 (%)	Meas. 3 Furrow	M3 (%)	Meas. 4 Area (width)	M4 (%)	M tot (%)
BURIAL (NO)	0	R0	0	F (NO)	0	A0	0	**0**
BURIAL (NO)	0	R0	0	F (NO)	0	A3	20	**20**
BURIAL (NO)	0	R0	0	F (NO)	0	A5	25	**25**
BURIAL (NO)	0	R0	0	F (YES)	20	A0	0	**20**
BURIAL (NO)	0	R0	0	F (YES)	20	A3	20	**36**
BURIAL (NO)	0	R0	0	F (YES)	20	A5	25	**40**
BURIAL (NO)	0	R25	25	F (NO)	0	A0	0	**25**
BURIAL (NO)	0	R25	25	F (NO)	0	A3	20	**40**
BURIAL (NO)	0	R25	25	F (NO)	0	A5	25	**43**
BURIAL (NO)	0	R25	25	F (YES)	20	A0	0	**40**
BURIAL (NO)	0	R25	25	F (YES)	20	A3	20	**52**
BURIAL (NO)	0	R25	25	F (YES)	20	A5	25	**55**
BURIAL (NO)	0	R50	50	F (NO)	0	A0	0	**50**
BURIAL (NO)	0	R50	50	F (NO)	0	A3	20	**60**
BURIAL (NO)	0	R50	50	F (NO)	0	A5	25	**62**
BURIAL (NO)	0	R50	50	F (YES)	20	A0	0	**60**
BURIAL (NO)	0	R50	50	F (YES)	20	A3	20	**68**
BURIAL (NO)	0	R50	50	F (YES)	20	A5	25	**70**
BURIAL (YES)	40	R0	0	F (NO)	0	A0	0	**40**
BURIAL (YES)	40	R0	0	F (NO)	0	A3	20	**52**
BURIAL (YES)	40	R0	0	F (NO)	0	A5	25	**55**
BURIAL (YES)	40	R0	0	F (YES)	20	A0	0	**52**
BURIAL (YES)	40	R0	0	F (YES	20	A3	20	**61**

BURIAL (YES)	40	R0	0	F (YES)	20	A5	25	**64**
BURIAL (YES)	40	R25	25	F (NO)	0	A0	0	**55**
BURIAL (YES)	40	R25	25	F (NO)	0	A3	20	**64**
BURIAL (YES)	40	R25	25	F (NO)	0	A5	25	**66**
BURIAL (YES)	40	R25	25	F (YES)	20	A0	0	**64**
BURIAL (YES)	40	R25	25	F (YES)	20	A3	20	**71**
BURIAL (YES)	40	R25	25	F (YES)	20	A5	25	**73**
BURIAL (YES)	40	R50	50	F (NO)	0	A0	0	**70**
BURIAL (YES)	40	R50	50	F (NO)	0	A3	20	**76**
BURIAL (YES)	40	R50	50	F (NO)	0	A5	25	**77**
BURIAL (YES)	40	R50	50	F (YES)	20	A0	0	**76**
BURIAL (YES)	40	R50	50	F (YES)	20	A3	20	**80**
BURIAL (YES)	40	R50	50	F (YES)	20	A5	25	**82**

Example

In absence of a buffer strip and other mitigation measures, the mitigation is null (0%, first line). By combining a 5 m buffer strip with the other best mitigation measures, the maximum mitigation is obtained (82%, last line of Table 4). For other combinations there is an intermediate mitigation.
If for the use of a certain herbicide a 50% run-off mitigation is required, the combination “no burial, reduction of the dose of 25%, furrow and 3 m buffer strip” guarantees a mitigation of 52% and makes the herbicide eligible.

Table 5. Run-off mitigation with a vegetated buffer strip of different width combined with other 3 mitigation measures: percentage value of the single ((Mi (%)) and total (M tot (%)) mitigation. Key: Measurement 1 (Meas. 1): burial of the plant protection product (yes/no); Measurement 2 (Meas. 2): reduction of the dose (R0=no reduction, R25= 25% reduction, R50= 50% reduction); Measurement 3 (Meas. 3): furrow (yes/no); Measurement 4 (Meas. 4): width of the buffer strip (A0= no area, A3= 3 m area, A5= 5 m area).

Meas. 1 Burial	M1 (%)	Meas. 2 Dose red.	M2 (%)	Meas. 3 Furrow	M3 (%)	Meas. 4 Area (width)	M4 (%)	**M tot (%)**
BURIAL (NO)	0	R0	0	F (NO)	0	A0	0	**0**
BURIAL (NO)	0	R0	0	F (NO)	0	A3	40	**40**
BURIAL (NO)	0	R0	0	F (NO)	0	A5	50	**50**
BURIAL (NO)	0	R0	0	F (YES)	20	A0	0	**20**
BURIAL (NO)	0	R0	0	F (YES)	20	A3	40	**52**
BURIAL (NO)	0	R0	0	F (YES)	20	A5	50	**60**
BURIAL (NO)	0	R25	25	F (NO)	0	A0	0	**25**
BURIAL (NO)	0	R25	25	F (NO)	0	A3	40	**55**
BURIAL (NO)	0	R25	25	F (NO)	0	A5	50	**62**
BURIAL (NO)	0	R25	25	F (YES)	20	A0	0	**40**
BURIAL (NO)	0	R25	25	F (YES)	20	A3	40	**64**
BURIAL (NO)	0	R25	25	F (YES)	20	A5	50	**70**
BURIAL (NO)	0	R50	50	F (NO)	0	A0	0	**50**
BURIAL (NO)	0	R50	50	F (NO)	0	A3	40	**70**
BURIAL (NO)	0	R50	50	F (NO)	0	A5	50	**75**
BURIAL (NO)	0	R50	50	F (YES)	20	A0	0	**60**
BURIAL (NO)	0	R50	50	F (YES)	20	A3	40	**76**
BURIAL (NO)	0	R50	50	F (YES)	20	A5	50	**80**
BURIAL (YES)	40	R0	0	F (NO)	0	A0	0	**40**
BURIAL (YES)	40	R0	0	F (NO)	0	A3	40	**64**
BURIAL (YES)	40	R0	0	F (NO)	0	A5	50	**70**
BURIAL (YES)	40	R0	0	F (YES)	20	A0	0	**52**
BURIAL (YES)	40	R0	0	F (YES)	20	A3	40	**71**
BURIAL (YES)	40	R0	0	F (YES)	20	A5	50	**76**
BURIAL (YES)	40	R25	25	F (NO)	0	A0	0	**55**
BURIAL (YES)	40	R25	25	F (NO)	0	A3	40	**73**
BURIAL (YES)	40	R25	25	F (NO)	0	A5	50	**77**
BURIAL (YES)	40	R25	25	F (YES)	20	A0	0	**64**
BURIAL	40	R25	25	F (YES)	20	A3	40	**78**

(YES)								
BURIAL (YES)	40	R25	25	F (YES)	20	A5	50	**82**
BURIAL (YES)	40	R50	50	F (NO)	0	A0	0	**70**
BURIAL (YES)	40	R50	50	F (NO)	0	A3	40	**82**
BURIAL (YES)	40	R50	50	F (NO)	0	A5	50	**85**
BURIAL (YES)	40	R50	50	F (YES)	20	A0	0	**76**
BURIAL (YES)	40	R50	50	F (YES)	20	A3	40	**85**
BURIAL (YES)	40	R50	50	F (YES)	20	A5	50	**88**

The vegetated buffer strip is twice as effective as a non-vegetated buffer strip. In fact, the mitigation values have doubled. The vegetated buffer strip combined with the other best mitigation measures can result in a maximum mitigation of 88% (last line) in comparison to the previous 82%. At this point the asymptotic property of the calculation of the total mitigation is evident and it may not exceed 100%.

In addition, it is clear that the various mitigation measures, including the buffer strip, are perfectly interchangeable among them. For instance, a mitigation of 70% can be obtained both with a 5 m buffer strip (BURIAL (NO), R25, F YES, A5 combination) and without a buffer strip (BURIAL (YES), R50, F NO, A0 combination).

4 RUN-OFF MITIGATION MEASURES IN SOILS WITH SLOPE (SLOPE > 2%)

Run-off is more copious and frequent in soils with slope. The run-off and erosion control in soils with slope is a practice where Italy has a long tradition. The specific orographic characteristics of a large part of the Italian territory have in fact led to the development and deployment of several agricultural and hydraulic arrangements. The arrangements regarding the soils with slope represent themselves significant mitigation measures thanks to the sensible placement of ditches, collectors, roads, hedges, areas of terrace cultivation and fences within the plots of land on the edges of the traffic routes.
The most ancient and still widespread arrangement for the soils with slope in Italy is called “rittochino”. According to Giardini (2002) this arrangement provides for *“... the slope to be divided into cultivation units by means of parallel ditches, whose distance is 15-30 meters from each other. The ditches follow a straight line, as close as possible to the maximum slope line. The ditches are often lined with rows of vines. The length of the plots of land is very variable: from few tens of meters for 20-30% slopes to 100-150 meters for 5-10% slopes; it is 60-80 meters on average. In this case the plowing is performed according to “rittochino”, only from the top to the bottom. If the slope is too steep, the agricultural machinery does not perform the tillage by coming back. The water flows downstream both through ditches and tillage furrows; the liquid mass is then finely divided into many rivulets so that the water speed and, therefore, the erosion are reduced. Nonetheless, with steep slopes it is necessary to stop the water downstream by means of main ditches adopted in contour plowing (“girapoggio”) which are not too distant between them”.*
To make the mitigation effective in presence of a downstream watercourse to be protected, it is significant to avoid that the water of the ditches is immediately introduced in the main water system. Instead, it should stay still for a certain number of hours. In this context, the grassing of the canals would be very useful.
Other arrangements that are still quite widespread are “girapoggio” (contour plowing) and “cavalcapoggio” (intermediate form between “girapoggio” and “rittochino”). The “cavalcapoggio” arrangement is still adopted in the Monferrato area, in the Pesaro province and in the Tuscan-Emilian Apennines. It fits to slopes up to 30% and it is characterized by cultivation units with a regular shape bordered by parallel ditches created according to the “cavalcapoggio” arrangement. Each row is usually bordered downstream by a dry stone wall and the distance between the rows is about 8 to 16 m. The contour plowing arrangement (“girapoggio”) is suitable for regular slopes and provides for: *“…cultivation units bordered by ditches whose profile is slightly different (1-2%) from the one of the contour lines. In this way and if the conditions allow it, the ditch twists down around the hill by bordering buffer strips whose width varies according to the slope (generally 4-5 m)”.*

According to the results of some experiments, there is a direct relationship between the slope of the soil and the quantity of herbicide in the run-off water (Vicari and Catizone, 2007; Miao *et al.* 2004, Rossi *et al.* 1994, 2000).
Taking into account the few experiments performed in Italy and the experiences acquired in other countries, the most effective run-off reduction measures are the vegetated buffer strip, the conservative crops and the covering crops.

4.1 Vegetated buffer strip

In the soils with slope the problem of run-off and erosion should be addressed in a more structured way in comparison to flat soils. In flat soils the run-off generally occurs by means of a sheet flow that moves evenly along the soil profile. On the contrary, in soils with slope the run-off flows tend often to concentrate in more or less intense channel flows and, therefore, they regard a limited surface. Under certain conditions, the concentration of the run-off flows may reduce the effectiveness of the vegetated buffer strip. Furthermore, in case of heavy rainfall the run-off flows may cause deep grooves in the soil cause the appearance of soil erosion. Under these conditions the riparian buffer strip close to the watercourse may not fulfill its full role and be less effective than the vegetated buffer strip placed on the edges of the field.

In presence of concentrated run-off flows it is appropriate to use mitigation measures in a series and create a system with vegetated buffer areas of moderate width to protect the talwegs in the field (ex. Figure 2 A) and wider vegetated buffer areas along the sides in order to intercept and redistribute the concentrated flows (Figure 2C). Basically, in soils with slope which have at their bottom water bodies to protect, one cannot speak of a vegetated buffer strip only but of a "system of vegetated buffer areas along the sides" to slow down and intercept at various levels the run-off of the whole hill system.

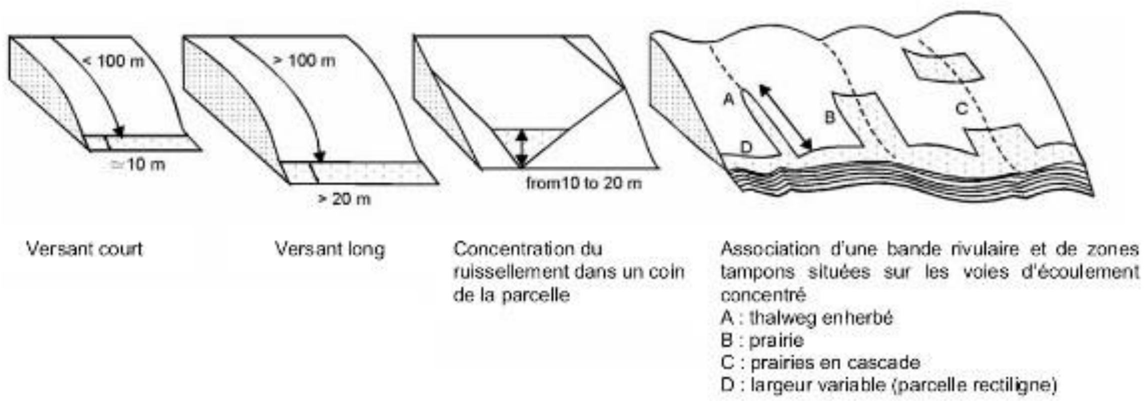

Figure 2. Sizing of the vegetated buffer strips (from CORPEN, 2007).

It should be noted that the vegetated buffer strip is not a headland or a maneuvre area, as the agricultural vehicles continuously passing by can create soil compaction areas that hinder the vegetation growth and become run-off preferential routes.
On slopes, the effectiveness of the vegetated buffer strip is reduced and only the application of mitigation measures in a series can limit effectively the run-off. In this document three slope ranges have been considered. Each of them outlines a different kind of run-off exposition:

- Plains (0-2%) : zero or low run-off;
- Medium slope (2-5%). Medium run-off;
- Steep slope (>5%). High run-off.

This document admits non-vegetated buffer strips only for plains (see SHEET 0. References for run-off mitigation).
By evaluating the available data in literature (Reichenberger, 2007), for a *vegetated* buffer strip with slope (in comparison to a flat area) a 50% mitigation is assumed in case of medium slopes (2-5%) and a 30% mitigation in case of steep slopes (>5%).
This assumption is in line with the recommendations of the FOCUS Document regarding the acceptable mitigation measures at European level for the reduction of run-off contamination.
In fact, in Table 6 are described the run-off reduction values that are acceptable to perform model calculations regarding the exposure of surface water bodies, in scenarios with slopes steeper than 2% and in line with what has been proposed in this document.

Table 6. 90th percentile of the worst-case values for the reduction efficiency regarding the vegetated buffer strips of different width for the different stages of the surface run-off (derived from FOCUS 2007)

Buffer strip width (m)	10-12	18-20
Run-off volume reduction (%)	60	80
Mass reduction of the plant protection product transported in solution (%)	60	80
Mass reduction of the eroded sediments (%)	85	95
Mass reduction of the plant protection product transported in sediments (%)	85	95

The values proposed in this guidance document are in line with the FOCUS values. For instance, for the flat areas in Italy it is proposed a 50% run-off mitigation for a 5 m vegetated buffer strip (Table 4 and 5, line 3). This mitigation is halved (25%) in case of a 2-5% slope (see text above, as well as the Sheet 0 - References for run-off mitigation). This 25% for a 5 m vegetated buffer strip is to be compared with the 60-85% proposed by FOCUS for a 10-12 m buffer strip (Table 6, range of values).

Example of run-off mitigation

Consider a hill system with a 2-5% slope and with a 3 m wide **vegetated buffer strip** (M=20%, half in comparison to flat areas) to protect a **25 m long grassed talweg** (M=70%, hypothetical value in accordance with MAgPIE). The mitigation so far is 76% (end of Step 2: 100-24=76) and if a **riparian buffer strip** (M=20%, hypothetical value) is added, the total mitigation is 80.8%.

Step	**Input %**	**Mitigation %**	**Output %**
1	100	20	80.0
2	80	70	24.0
3	24	20	19.2
$\mathbf{M_{tot}}$		**80.8**	

In the assessment process it is a priority to verify with the agronomists if there is the possibility to forbid the use of the plant protection product in areas with slopes steeper than 2% or 5%.

4.2 Conservative crops

The conservative crops are mainly those where the seedbed is prepared by means of operations different from the traditional tillage. The anti-run-off effect is due to the presence of crop residues on the soil surface and to the higher soil porosity that facilitates the infiltration of water. In case of herbaceous crops the long-term experiment carried out in Italy (Vicari and Catizone, 2007) has underlined a reduction of at least 20% in the loss of herbicides depending on the products used and the intensity of rainfall.

According to the MAgPIE document, a value of 50% is noted. This is not only for slopes but in general. The analytical data sheets do not integrate this mitigation factor; it is up to the agronomist to evaluate on a case-by-case basis using the 20-50% values as a reference.

4.3 Covering crops

The land cover with crops sown within the cash crop (for ex. barley within corn) has shown the effective reduction of the run-off of plant protection products and of the erosion. As it has been said for the flat soils, this is a practice difficult to manage and with a limited use.

In the soils with slope it is much more interesting the sowing of *secondary crops* between the harvesting of a cash crop and the sowing of the next one. This practice is especially important in those periods of the year when there is not any crop on the soil and it is therefore more prone to run-off and erosion. In the case of plant protection products with a high persistence or, also, of nutrients such as nitrogen and phosphorus, in the autumn-winter period the amount of product can be largely reduced. It follows that the mitigation actions are far from being valid only on a seasonal basis. On the contrary, they are relevant all over the year.

The grassing of the space between the rows in tree crops or in vineyards can be seen as a variation of the covering crops and, therefore, as a very useful mitigation measure that is a physical obstruction to erosion and run-off. This has obvious positive effects in terms of reduction of the transportation of sediments, nutrients and plant protection products (Table 7).
The presence of a turf between the rows of orchards and vineyards performs many functions. Among them, the creation of a habitat for beneficial arthropods and the periodical supply of organic matter to the soil by mowing are essential.

Table 7. Percentage value of the mitigation, in comparison to the weeding in open field, for two orchard or vineyard arrangements and two operations regarding the space between rows.

Orchard or vineyard placement	Permanent grassing in the area between rows and weeding on the row (%)	Operations in the space between rows and weeding on the row (%)
Rows according to the maximum slope (“rittochino”)	40	30
Rows according to the contour lines (“cavalcapoggio”, “girapoggio”)	50	40

4.4 Artificial wetlands

The artificial systems that can be defined as wetland, namely small artificial basins for the harvesting of run-off water characterized by a good green cover, can play a role for the purification of water from plant protection products in intensively cultivated areas. Ongoing studies show the high capacity of these systems to retain the active substances used in agriculture before they reach the surface water. Recent results of tests performed in the Po Valley show that a constructed surface flow wetland can mitigate **run-off up to 90%** (Pappalardo *et al.*, 2015). The data is in accordance with MAgPIE values.

4.5 Vegetated ditches

Various studies (Moore et al., 2008) have shown that the vegetated ditches receiving run-off water are able to reduce the concentration of plant protection products as long as they are long enough and properly managed. According to MAgPIE the mitigation is 50%. Specific tests for the conditions of the Po Valley have confirmed the high efficiency of the vegetated ditches (Otto et al., 2016).

5 DRIFT MITIGATION MEASURES

The drift mitigation measures can be:

1. indirect , they reduce the drift exposure of the water body to protect. They are collection systems like buffer strips or vertical barriers (for ex. hedges, anti-hail nets).
2. direct, they reduce the generation of drift. They are mainly technical devices acting on the drop formation and the spraying orientation.

5.1 Indirect drift mitigation measures

5.1.1 Buffer strips

As mentioned in the paragraph 2.3, a buffer strip interposes some space between the source of pollution and the element to protect; therefore, it always reduces element to protect drift risk exposure. In this Guidance document the capacity reduction has been established considering as a starting point the Rautmann FOCUS table, modified and adapted with the following assumptions:

1) crops classified in 4 groups:
   a) cereals and horticultural crops with low height (height lower than 50 cm);
   b) horticultural crops with high height (higher than 50 cm) and ornamental plants;
   c) fruit- bearing trees without leaves and fruit-bearing trees with leaves;
   d) grapevines without leaves and grapevines with leaves;
2) introduction of a minimum width according to the crop type;
3) introduction of a maximum width of 15 m for horticultural crops with high height;
4) always rounding up to the next integer;
5) width calculation for all the 7 ISO22369 drift mitigation classes (0, 25, 50, 75, 90, 95, 99%).

In general, the "cereals", horticultural crops (with high height and low height)" and "ornamental plants" categories include unpruned crops, treated from top to bottom with a conventional spray boom working at a maximum height of 75 cm and lacking of specific direct drift mitigation measures (e.g. anti-drift nozzles, see also paragraph 5.2.2). In the absence of specific instructions for Italy, the maximum width for horticultural crops with high height (> 15 m) has been chosen because it is intermediate between the horticultural crops with low height (> 10 m) and the grapevines without leaves (> 20 m).
Fruit-bearing trees and grapevines have different values because grapes are often grown against wall and are shorter. Consequently, the grape treatment is in general less subject to the drift. It is up to the agronomist (specialist about efficacy) to evaluate intermediate cases. For instance, the values applied to grapes may be applied also to the apple trees grown against wall and with a spacing of 3 m between the rows.
For the sake of prudence, for each width range it has been assigned the mitigation value of the lower bound: for instance, for the grapevines treated with leaves, a *buffer strip* from 10 to 14 m reduces the drift of 50% (50% is the value at 10 m). In addition, since it is about cultivated fields with all the following anomalies, inaccuracies and variabilities, the reductions are not reliable and considered invalid below a minimum width. For this reason, in presence of a hedge in an area of a certain width, it is not assigned to the area itself a mitigation capacity unless it exceeds the minimum width (see Example 5).

Table 8. Drift mitigation capacity (M%) according to the width of the buffer strip for cereals and horticultural crops treated with spray boom and grapes and fruit plants treated with atomizer, in two periods

ISO drift reduction class and range	Mitigation M%	Cereals and horticultural crops with low height[a] L (m)	Horticultural crops with high height[b] L (m)	Fruit bearing trees without leaves[c] L (m)	Fruit bearing trees with leaves[d] L (m)	Grape vines without leaves[c] L (m)	Grape vines with leaves[d] L (m)
A (99-100%)	99	>10	>15	>30	>30	>20	>20
B (95-98%)	95	9-10	14-15	29-30	28-30	19-20	18-20
C (90-94%)	90	8-9	12-14	27-29	25-28	18-19	17-18
D (75-89%)	75	7-8	10-12	25-27	22-25	16-18	14-17
E (50-74%)	50	5-7	7-10	18-25	15-22	13-16	10-14
F (25-49%)	25	3-5	5-7	10-18	8-15	8-13	5-10
G (0-24%)	0	<3	<5	<10	<8	<8	<5

[*] The mitigation value assigned is the lower one of the ISO range
[a] Cereals and horticultural crops with low height <50 cm; weeds control under row of grapes and fruit bearing trees
[b] Horticultural crops with high height >50 cm and ornamental plants
[c] Without leaves
[d] vegetation

The drift mitigation capacity (M%) obtained by applying the buffer strip refers to specific reference conditions for the various crops, as specified in paragraph “5.2.2. Reference conditions for the risk of drift. In the case of weeds control under row of grapes and fruit bearing trees, the values of the category “Cereals and horticultural crops with low height” can be applied.

Consider a plant protection product for grapevines with leaves indicating on the label “it can be used only with mitigation measures able to reduce the drift of 50%”. Table 8 shows that it is possible to obtain a reduction of 50% by means of a buffer strip of 10-14 m (Category E). If a *buffer strip* of at least 14 m is observed, the use is certainly admissible. It is feasible the agronomist can establish more precisely the width of the buffer strip through the knowledge related to the growing system, the phenological phase, the type of sprayer and determine that 11 m are enough. Anyway, it will be impossible to obtain such a mitigation value with a *buffer strip* less than 10 m wide.

In the case of herbicides, for herbaceous and tree crops, it is possible the buffer strip consists of an unweeded crop plot (Paragraph 2.2, type 1). If, for instance, the plot is 3 m wide, it would allow a drift reduction of 25% (Table 8, Class F). In the evaluation process, such measure shall be applied also considering its viability and after consultation among environmental experts and agronomists; in particular, it should be excluded that the treatment can be performed on bare soil. Also for insecticide and fungicide treatments applied to the soil or on herbaceous crops, the buffer strip can be formed by a non-treated crop plot, especially for industrial crops. However, in this case, the environmental experts and the agronomists should carefully evaluate the risk acceptability that this plot may be an infestation or adversity inoculation source for the whole crop.

5.1.2 Artificial hedges and barriers

Especially in case of treatments on tree crops, as well as on herbaceous crops, the drift towards the surface water bodies can be further reduced by inserting in the buffer strip vertical barriers able to intercept the drift (hedges, tree lines, artificial windbreaks).
Inserting vertical barriers within the buffer strip can make it possible to reduce the drift even of 50% already few meters away from the spray dryer and, with optimal

barriers, the reduction can reach 90% and further. A particularly important feature of the barrier (vegetative or artificial) is its optical porosity, due to the fraction of empty spaces through which light can filter. A very thick hedge has therefore a very low porosity (e.g. it has a 5% of empty spaces); a hedge with an average thickness has a 30-40% porosity and, if there is not any hedge, the porosity is considered 100%. The optical porosity influences the ability to intercept the drift and, in the case of vegetative barriers, the best interception is obtained with thick barriers, with an optical porosity lower than 35%.

The same goes for artificial barriers; for instance, with 4 mm square-meshed plastic nets with a porosity of 64% (namely a quite sparse but regular porosity), the interception can be 30%. In general, the hedge carry out various functions, therefore they have to be designed in accordance with the main function required.

If its main function is to be a protective screen against drift, then the focus has to be on a reduced optical porosity (already at the time of the first treatments). Therefore, the precocity of leaves emission at the beginning of spring can be an important factor in the choice of the plant species to use. The height of the plant species in relation to the height of the crops to be treated and the uniformity of development (thickness) from the bottom to the top are also relevant.

If such measure needs to be also effective against the surface run-off, then the botanical composition of the plant species in relation to the shading of the hedge towards the turf below is especially important. With little light the herbaceous vegetation tends to disappear rapidly and this reduces the run-off mitigation, even though the vegetation is almost completely replaced by the leaf litter and the increase of organic matter on the surface. With a less thick leaf coverage, the light filters more easily and therefore the vegetation layer below can remain active. For instance, from this point of view the false acacias should be preferred to plane trees. Nonetheless, with their cespitose habit, false acacias tend to invade the nearby areas and are difficult to contain.

As it has been said, the presence of hedges in the agricultural biotope protects the water courses from the drift. The drift reduction depends on the height of the hedge and on the development stage of the leaves. The drift reduction values recommended at European level (FOCUS) for a hedge at least 1 meter higher than the crop are:

- 25% when the hedge is without leaves;
- 50% when the hedge is in an intermediate development stage;
- 75% when the foliage is completely developed.

In this Guidance document only the 25% (treatment in absence of leaves) and 75% (treatment in presence of leaves) values are adopted.

If a plant protection product is used in more periods, the period of higher use will be chosen. In order to have an anti-drift function, it is necessary that the hedge complies with some conditions:

- it has to be higher of at least 1 m than the treated crops and of at least 4 m if in presence of equipment with a high risk of drift (Class G);
- canopy from the bottom to the top, to be obtained also by allowing the herbaceous species at the bottom to develop;
- full length along the entire side of the plot of land that borders with the water body, without any interruption.

5.1.2.1 Effectiveness of country hedges over time

In the evaluation process it has to be considered that the hedge is a structure with its own life cycle and that country hedges are also subject to a coppicing period (7-8 years) after which they are cut. The mitigation capacity of these barriers is then variable over time: it is zero at the beginning of each period and then it increases up to the maximum level just before the coppicing. An ideal hedge should be formed by two rows to coppice alternatively every 2 years in order to guarantee always the desired value of optical porosity and mitigation.

5.1.2.2 Other functions of hedges

If the hedge is meant to safeguard the animal biodiversity and serve as a breeding and development ground for beneficial arthropods (predators and parasitoids), its design is more complex to achieve. In fact, the choice of the plant species should secure the survival of the beneficial arthropods without fostering a pest outbreak. A hedge performing these functions should be formed by a high number of both tree and shrub species, as well as by a relevant herbaceous layer with a variable height that can secure the transfer of the natural enemies of the phytophagous species from the edge of the field to the field itself and, therefore, start the colonization after the treatments.
The function of shelter for the beneficial arthropods can be anyway carried out also by generic hedges which have not been specifically designed for this purpose and even by hedges with an anti-drift function. In fact, if the hedge is thick enough (at least 1 m) and has enough foliage, just the drift of the plant protection product from the treated arboretum is not sufficient to destroy completely the arthropod populations that can find in the highest or deepest areas of the hedge still favorable conditions for survival.

5.1.3 Anti-hail nets

In the treatments regarding tree crops, drift can be reduced with an anti-hail net applied above the crops and closed along the edge rows of the plot (Figure 3). The net prevents the drop dispersion and allows to reduce the drift by 50-95% according to the kind of atomizer and the operating conditions.

Figure 3. Anti-hail net in an orchard.

5.2 Direct drift mitigation measures

5.2.1 ISO classification of anti-drift devices

A reduction of the buffer strip can be obtained by using technical devices for drift reduction, for instance anti-drift nozzles, adjuvants with an anti-drift function or spray booms with air sleeves, shielding and nozzles at the end of the boom, atomizers with lateral closing devices for the airflow or with tunnel systems. In some European countries it is already available a classification of those devices according to their anti-drift effectiveness compared to the reference conditions (SDRT = Spray Drift Reducing Technologies, ISO 22369-1). If an anti-drift device is present on the sprayer, the width of the buffer strip is reduced in proportion to the effectiveness of the device. The technique-buffer strip width combinations may be included in the label (Table 9).

Table 9. Example of a table setting out the width of the buffer strip that the user has to comply with according to the anti-drift technique adopted during the distribution. In the reference conditions, to Class G, which does not reduce or reduces too little the drift is assigned the mitigation value of 0%; to Class F which reduces the drift of 25-49% is assigned the mitigation value of 25% and so on until Class A, which is assigned the maximum mitigation value (99%).

Distribution technique		Width of the **buffer** strip (m)			
ISO class and reduction range	**Assigned value (M%)**	Cereals and low horticultural crops	High horticultural crops	Fruit plants without leaves[a]	Grapevines without leaves[a]
G (0-24%)	**0**	10.0	15.0	30.0	20.0
F (25-49%)	**25**	7.5	12.0	22.5	15.0
E (50-74%)	**50**	5.0	7.5	15.0	10.0
D (75-89%)	**75**	2.5	3.0	7.5	5.0
C (90-94%)	**90**	1.0	1.5	3.0	2.0
B (95-98%)	**95**	1.0	1.5	3.0	2.0
A (99-100%)	**99**	1.0	1.5	3.0	2.0

a) the maximum values of width in the stage "with leaves" are the same as in the stage "without leaves" (see Table 8)

Table 9 shows two key aspects.

1)**Request for a buffer strip:** given a width of the buffer strip established on the label, a new width (lower) is found by using other mitigation measures (Section 2.2). Consider, for instance, a plant protection product for grapes that provides for a 20 m buffer strip when it is distributed on grapes without leaves by means of a standard technique (Class G, assigned mitigation value: 0%). In accordance to the principle “technique in exchange for space”, if it is used a technique reducing drift by 80% and it falls within Class D that has an assigned mitigation value of 75% (lower value of the ISO range), this value can also be applied to a buffer strip of
20-(20×75/100)= 5 m only.

The principle “technique in exchange for space” is clearly illustrated by the decreasing value of width as the distribution techniques improve.

2) **Minimum practical width**. Regardless of the soundness of the technique and of the mitigation applied, the width of the buffer strip should not be lower than a minimum value (variable according to the crop), because in the field practice measurements lower than 1 m are never recommended. It is interesting to compare Table 8 with Table 9. In Table 9, the minimum width to maintain with the maximum mitigation (M = 99%) can be compared with the minimum width of Table 8; here, a lower value of width is so unreliable that the reduction of the mitigation is considered as invalid (M=0%). In other words, the minimum value in Table 9 sets out "what is the minimum width that should always be maintained", while the minimum value in Table 8 sets out "what is the width from which the mitigation starts".

As said in Section 2.2, this Guidance document shows the necessary mitigation measures to obtain the percentage of exposure reduction included in the label. In principle, such percentage can also be obtained with a buffer strip of limited width if other mitigation measures are also used: The analytical data sheets are therefore based on the values shown in Table 8.

5.2.2 Reference conditions for the risk of drift

Currently, in Italy an official classification of the anti-drift devices is not available yet. Similarly, the reference conditions for the main contexts regarding crops have not been officially defined. Pending a classification method for machines on the basis of the risk of drift (see Section 6.2 - Recommendation 2), it is possible to borrow some criteria already adopted in other European countries which take into account both the technical devices on the machines and their conditions of use.

In order to be able to establish the drift reduction percentages corresponding to the use of the different technical devices, it is necessary first to set the reference conditions for herbaceous and tree crops.
On the basis of the data collected by ENAMA (Ente Nazionale per la Meccanizzazione Agricola - National Agricultural Mechanization Body) at a national level in the framework of the functional control of the sprayers in operation and of what set out in other European countries about the characteristics of the standard equipment, the following reference conditions are set:

1. **Spray boom for herbaceous crops**: conventional spray boom with cone nozzle or conventional slot nozzle, ≤ ISO 04 size, nominal flow rate ≤ 1.6 L/min at 3 bar, working pressure ≤ 3 bar, forward speed 6 km/h, boom height between 50 and 75 cm, no nozzle at the end of the boom.
2. **Air-convection sprayer for vineyards**: machine equipped with an axial fan and radial nozzles placed along the air outlet sections. ISO 01 nozzle size, working pressure 15 bar, forward speed 6 km/h, fan diameter 500 mm, maximum fan flow rate no lower than 20,000 m^3/h (power take-off (PTO) speed regulation 540 rpm, fast drive speed of the fan).
3. **Air-convection sprayer for fruit plants:** machine equipped with an axial fan and radial nozzles placed along the air outlet sections. ISO 03 nozzle size, working pressure 15 bar, forward speed 6 km/h, fan diameter 800 mm, maximum fan flow rate no lower than 40,000 m^3/h (power take-off (PTO) speed regulation 540 rpm, fast drive speed of the fan).

The drift reductions indicated below are therefore always intended to be reductions in comparison to the reference conditions mentioned above.

5.2.3 Anti-drift nozzles

The use of air injection anti-drift nozzles in sprayers is nowadays almost always feasible and it guarantees a relevant reduction of the drift, especially in the sprayers for herbaceous crops. The anti-drift nozzles can also be used on hand nozzles.
The use of anti-drift nozzles, already available on the Italian market at a relatively cheap price, should anyway be complemented by a monitoring of the working pressure because for air injection anti-drift nozzles the use of high pressures (> 8 bar) undermines the anti-drift action.
Bearing in mind the different functionality and maintenance conditions of the machinery in operation nowadays, it can be concluded that on traditional spray booms and spray booms for herbaceous crops the air injection anti-drift nozzles reduce the drift by 50% at least.
The indication of such reduction might be explicitly requested by the companies interested in the authorization of the plant protection products and a phrase or a warning of this kind should be stated on the label: *“the use of air injection anti-drift nozzles is compulsory, with a maximum working pressure of 8 bar”.*

5.2.4 Anti-drift adjuvants

Adjuvant products can also have an anti-drift action related to an increase of the size of the drops supplied by the nozzles. To be identified as anti-drift, an adjuvant should be registered following the guidelines published by the Italian Ministry of Health regarding the marketing and use authorization of adjuvants of plant protection products. In particular, the product should undergo measurement comparative tests on the field and in laboratory to document the reduction action of the drift. Furthermore, it is necessary to indicate on the label the nozzle typology and the working pressure ranges for which the adjuvant performs an anti-drift effect, in comparison to the use of conventional mixture without adjuvants or pure water.

The adjuvants registered with an anti-drift function reduce the drift by 50% at least.
A test result obtained at DISAFA (Dipartimento di Scienze Agrarie, Forestali e Alimentari - Department of Agricultural, Forestry and Food Sciences) of the University of Turin, Italy, is shown by way of example. In this experiment, a vegetable oil-based adjuvant for cupric salts allowed to reduce the drift sensitivity of the supplied drops of more than 50% in comparison to the use of pure water (Figure 4).

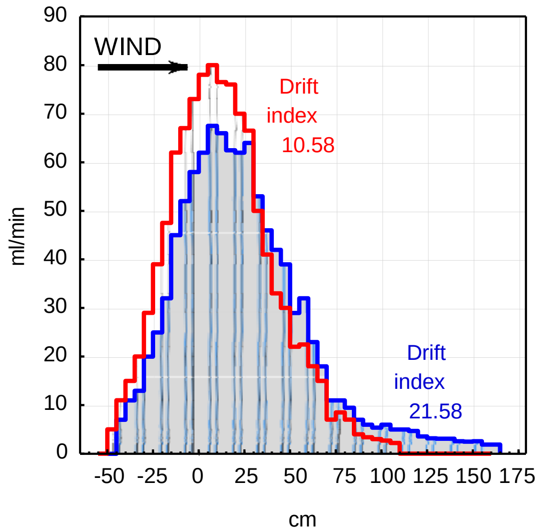

Figure 4. Distribution diagram with pure water (blue line) or with a water + adjuvant mixture at 0.05% (red line). The mixture presents a less distorted diagram and a lower value of the drift index. Results obtained in a wind tunnel, with an air speed of 2.8 m/s for an ISO 03 slot nozzle at a pressure of 3 bar.

5.2.5 Importance of a proper adjustment of the sprayer

The various measures and technical devices to reduce the drift that are described here below are effective only if the sprayer is properly adjusted.
It is essential that the spray booms operate at a height between 50 and 75 cm with respect to the target and that the stability of the boom is ensured.
As far as the sprayers for herbaceous crops are concerned, it is essential to adjust properly the vertical distribution pattern of the liquid and the air, in order to direct the drops only inside the vegetation and minimize the dispersion outwards.

5.2.6 End-of-boom nozzles for sprayers for herbaceous crops

On the spray booms for herbaceous crops the use of slot nozzles characterized by an asymmetric jet and mounted on the end of the boom allows to spread the supply of the phytosanitary mixture only below the boom itself. Thus, the distribution of the liquid is more precise along the edges of the field (Figure 5) and the drift outwards is reduced. The use of nozzles at the end of the boom reduces the drift by 25%.

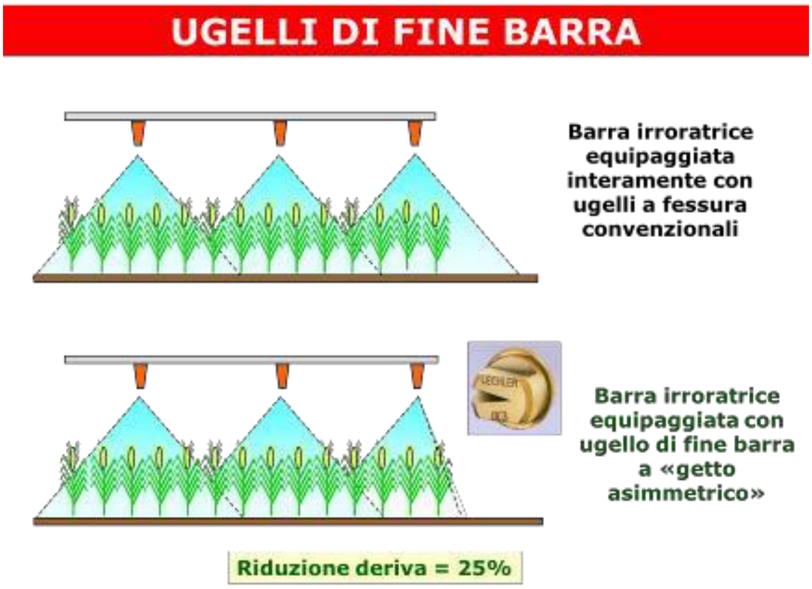

Figure 5 Distribution scheme of the liquid below a spray boom fully equipped with conventional slot nozzles and scheme of a bar equipped with end-of-boom nozzles with asymmetric jet.

5.2.7 Deflector nozzles for spray booms for herbaceous crops

On spray booms, in particular for the applications on bare soil, hydraulic spray nozzles can be used. The drops formed inside the nozzle are directed towards a small deflector placed inside the body of the nozzle itself and then bounce towards the soil (Figure 6). This kind of nozzles, characterized by a wider opening angle of the jet (150°) in comparison to the one of the conventional slot nozzles (110°), should be supplied with moderate working pressures, not higher than 3 bar. They create drops of an approximate size and with a low kinetic energy that are less sensitive to drift compared to the ones supplied by the slot or turbulence conventional nozzles with the same flow rate. The use of deflector nozzles reduces the drift by 50% **at least**.

Figure 6 Scheme of the structure of a deflector nozzle and its related liquid distribution.

5.2.8 Sprayer air sleeve for herbaceous crops

On spray booms equipped with hydraulic spray nozzles, an air flow is conveyed to an inflatable sleeve (Figure 7) and it enables to direct the flow of the drops towards the bottom part. In this way, the quantity of plant protection product directed towards the target is increased and the drift is reduced thanks to the decrease of the stream of drops suspended in the air behind the boom. It has to be specified that the use of the air sleeve with an anti-drift function is effective in presence of wind blowing in the opposite direction to the forward direction of the machinery and, above all, only in presence of crops already developed. On the contrary, the use of the air sleeve on bare soil has to be avoided, as it causes a relevant turbulence around the spray boom and can even cause more drift in comparison to the conventional boom. The use of the air sleeve, in the proper conditions of use, reduces the drift by 75%.

Figure 7 Spray boom with air sleeve.

5.2.9 Localized distribution systems for sprayers for herbaceous crops

For herbaceous crops placed in rows it is possible to use systems treating rows only (Figure 8). They are systems usually mounted on machinery carrying out other cultivation operations (seed drills, weeding machines, etc.). They reduce the drift by 75%.

Figure 8 Seed drill with nozzles for localized treatment along the row.

5.2.10 Localized distribution systems with shielding

In the framework of the equipment used for weeding and similar to the spray booms, it is included also the equipment used for treating under-rows in tree crops. This equipment is characterized by small bars with one or more nozzles. The bars are mounted on articulated arms directing the treatment to the under-row. These devices can be easily equipped with shielding (Figure 9) preventing the dispersion of drops. The use of these localized distribution systems equipped with a shielding placed as close as possible to the soil enables the reduction of the drift by 90%.

Figure 9 Equipment to weed the vineyard under-rows with nozzle shielding systems.

5.2.11 Devices to circumscribe the air flow

In the sprayers for tree crops a determining factor for the creation of drift is the air flow produced by the fan. In particular, during the spraying of the edge rows, the air flow directed towards the outer side of the orchard/vineyard can create a remarkable drift. In order to prevent such drift, it is possible to use mobile bulkheads or shielding that stop the air flow towards the outer side (Figure 10). By using this measure, the drift regarding the outermost three rows is reduced by 50%.

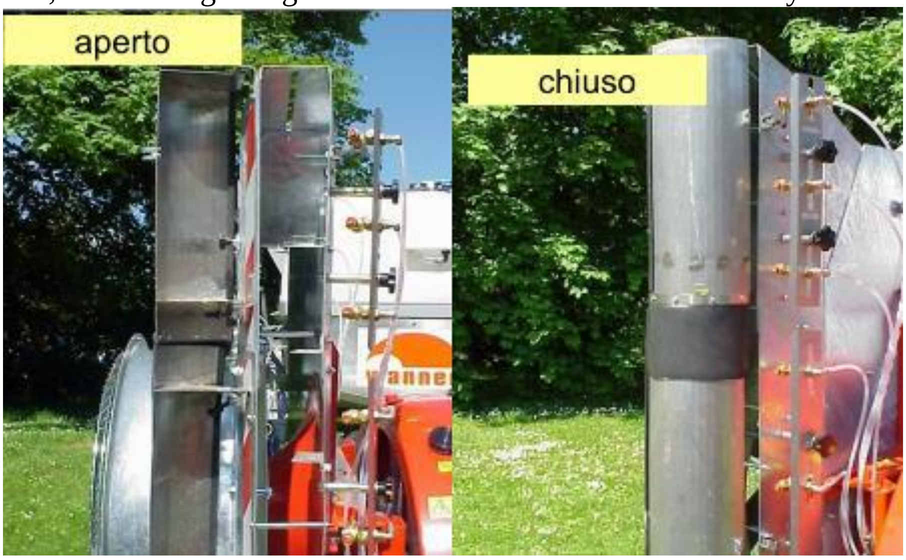

Figure 10 Mobile bulkhead to stop the air flow on a side of the sprayer for tree crops.

5.2.12 Spraying direction of the last row

The spraying of the last row only towards the inner side of the plot is an important mitigation measure that can reduce the drift by 35% at least.

5.2.13 Tunnel sprayers for tree crops

Tunnel sprayers for tree crops are equipped with straddling structures and panels surrounding the row, thus reducing the drop dispersion outside the treated row (Figure 11). The panels can be equipped with systems to collect and use again the gathered liquid. The use of these sprayers enables to reduce the drift by at least 90%.

Figure 11 Single and double tunnel sprayers in a vineyard.

5.3 Combination of mitigation measures

The various machinery devices and the anti-drift measures for the treatment can be combined among them. In Table 10 and Table 11 it is specified the total mitigation that can be obtained. It is then possible to add other mitigation measures (adjuvants, buffer strips, hedges) and calculate a final mitigation.

5.3.1 Spray booms for herbaceous crops

Table 10. Percentage reduction of the drift obtained in spray booms according to the kind of nozzle, flow rate and working pressure, treatment localization, presence of shielding and air sleeves. The reductions are set according to the reference conditions (**first line, traditional spray boom, M%=0,** see also Section 5.3.2) and provided that the operations are performed with a boom height between 50 and 75 cm and at a speed not exceeding 8 km/h.

Nozzle type	Size	Nominal flow rate at 3 bar (L/min)	Working pressure (bar)	Traditional spray boom (M%)	Local. distrib. along the rows (M%)	Local. distrib. with shielding (M%)	Presence of an air sleeve (M%)	Nozzle at the end of the boom (M%)
Conventional cone or flat nozzle	<=ISO 04	<=1.6	<=3	0	75	90	75	**25**
Conventional cone or flat nozzle	>=ISO 05	>2	<=3	50	75	90	75	**25**
Air injection anti-drift nozzle (e.g. TD, AVI, AI) / Deflector nozzle (e.g. TTI)	ISO 01-03	0.4 - 1.2	<=8 / <=3	50	75	90	75	**25**
Air injection anti-drift nozzle (e.g. TD, AVI, AI) / Deflector nozzle (e.g. TTI)	ISO 04-05	1.6 - 2.0	<=8 / <=3	75	75	90	75	**25**
Air injection anti-drift nozzle (e.g. TD, AVI, AI) / Deflector nozzle (e.g. TTI)	>=ISO 06	>2.4	<=8 / <=3	90	75	90	75	**25**

The combination specified in the first line represents the reference conditions with a 0% drift reduction. The anti-drift performance of a traditional spray boom can be immediately improved by using a >=ISO 06 anti-drift nozzle that reduces the drift by 90% or a nozzle at the end of the boom that reduces the drift by an additional 25%.

The use of anti-drift devices is especially interesting when it is combined with a buffer strip. For instance, in cereals a 3 m buffer strip reduces the run-off by 20% (Table 2, line 2) and the drift by 25% (Table 8, line 6); by using a spray boom with devices that reduce the drift by 90% and by applying the recursive calculation described in Section 2.3.1, the total reduction of the drift is 92.5%. It should be noted that such buffer strip might be a non-treated plot of crops, whereas in the remaining part of the field plant protection products indicating on the label “use only with mitigation measures able to reduce the drift by 90%” might be used.

Example 1. Triple combination

Consider a **traditional spray boom for cereals** equipped with conventional nozzles with a size inferior to ISO 04 (M=0%). If **nozzles at the end of the boom** (M=25%) are used and a **4 m buffer strip** (M=25%) (see Table **8**) with a **sparse hedge** is available (M=25%, without leaves), the total mitigation of the drift is **58%**. [SHEET 5.1.2. Combination 21, Total mitigation D]

Step	Input (%)	Mitigation (%)	Output (%)
1	100	25	75
2	75	25	56
3	56	25	42
Total mitigation (%)		58	

To obtain the same percentage of total mitigation without the help of the nozzles at the end of the boom and the hedges, a buffer strip at least 5 m wide should have been taken into account (see Table **8**).
On the contrary, if a buffer strip with a hedge is not going to be included, an ISO 01-03 (M=50%) air injection anti-drift nozzle could be used, also at the end of the boom (M=25%). This nozzle guarantees by itself a mitigation of 62%
[SHEET 5.1.2. Combination 23, Total Mitigation A].

Example 2. Double combination
Consider a **traditional spray boom for herbaceous crops** equipped with **anti-drift nozzles** only, with a size smaller than ISO 03 (mitigation M=50%) and without nozzles at the end of the boom. If an **anti-drift adjuvant** is also used (mitigation M=50%), the total mitigation of the drift is **75%**
[SHEET 5.1.2. Combination 42, Total Mitigation A]

Step	Input (%)	Mitigation (%)	Output (%)
1	100	50	50
2	50	50	25
Total mitigation (%)		75	

This example shows that it is possible to obtain mitigation even without a buffer strip. On the contrary, in the case of cereals, it could have been possible to obtain the same percentage of total mitigation with a buffer strip at least 7 m wide (see Table **8**).

Example 3. Quadruple combination
Consider horticultural crops lower than 50 cm and treated with a spray boom equipped with **conventional** nozzles, whose dimension is <=ISO 04 (M=0%), with **nozzles at the end of the boom** (M=25%) and with an **air sleeve** (M=75%). In presence of a 5 m **buffer** strip (M=50%) with a **thick hedge** (with leaves) (M=75%), the total mitigation is **97.7%.**
[SHEET 5.2.3. Combination 21, Total Mitigation E]

Step	Input (%)	Mitigation (%)	Output (%)
1	100	25	75.0
2	75	75	18.8
3	19	50	9.4
	9	75	2.4
Total mitigation (%)		97.6	

5.3.2 Sprayers for tree crops

Table 11. Percentage reduction of the drift obtained with three typologies of air-convection sprayers for tree crops according to the type of nozzle, flow rate and working pressure. The reductions are set according to the reference conditions and provided that the operations are performed with a working pressure not exceeding 10 bar, with a speed not higher than 8 km/h and with a reduced flow rate of the fan (the fan gear ratio is on a low gear or, if there is not any gearbox, the power take-off (PTO) speed not exceeding 450 rpm).

Nozzle type	Size	Nominal flow rate (L/min) at 10 bar	Working pressure (bar)	Conventional atomizer (M%)	Mounted atomizer (M%)	Tunnel sprayer (M%)
Conventional nozzle	All	All	All	0	0	90
Anti-drift nozzle A	ISO 01-03	0.73 - 2.15	>8	25	25	90
Anti-drift nozzle B	ISO 01-03	0.73 - 2.15	<=8	50	50	95
Anti-drift nozzle C	ISO 04 and above	>2.88	>8	50	50	95
Anti-drift nozzle D	ISO 04 and above	>2.88	<=8	75	75	99

Conventional atomizer: axial fan with deflecting slats, hydraulic spray nozzles radially arranged. Mounted atomizer: axial fan, mounted air conveyor, hydraulic spray nozzles placed along vertical half-bars.

The combination specified in the first line (conventional nozzle) represents the reference conditions with a 0% reduction of the drift.

Example 4. Quadruple combination

Also in traditional atomizers with conventional nozzles with size <=ISO 04 (M=0%), paying attention to **close the air outwards in the last three rows** has a relevant effectiveness (mitigation M=50%). If at the edge of a vineyard a **7 m buffer strip** (M=25%) and then a **thick hedge** (hedge with leaves, M=75%) are present, the total drift is reduced by 90.6% [SHEET 6.4.2. Combination 21, Total Mitigation E]. The use of ISO 04 or above (M=75%) **anti-drift nozzles** increases the reduction to **97.6%.**
[SHEET 6.4.2. Combination 25, Total Mitigation E]

Step	Input (%)	Mitigation (%)	Output (%)
1	100	50	50.0
2	50	25	37.5
3	37.5	75	9.4
4	9.4	75	2.4
Total mitigation (%)		97.6	

Example 5. Triple combination

For tree crops, the technical innovation and the vertical barriers can significantly reduce the drift. If in an orchard (without leaves) at the beginning of the bud burst it is used a **mounted atomizer** equipped with ISO 01-03 **anti-drift** nozzles working at a pressure not exceeding 8 bar (M=50%), with the **air closed outwards in the last three rows** (M=60%) and a **closed anti-hail net** (mitigation M=90%) at the edge of a 3 m (M=0%) **buffer strip**, the total mitigation is **98.0%.**
[SHEET 7.3.1, Combination 28, Total Mitigation A].

Step	Input (%)	Mitigation (%)	Output (%)
1	100	50	50.0
2	50	60	20.0
3	20	90	2.0
4	2	0	2.0
Total mitigation (%)		98.0	

This example shows that it is possible to obtain some mitigation even without a **buffer strip**, because it is absent or it is too narrow to be reliable.

Example 6. Double combination

Anti-drift measures are really effective also with suboptimal equipment, as the closing of air outwards in the last three rows (M=50%) and the treatment of the last row only towards the inner side (M=35%). If both measures are applied, the air outwards is then closed from the third to last row and, in the last row, also the spraying is closed; in this scenario the total mitigation is remarkable **(67.5%)** even in the worst case, namely a traditional atomizer equipped with conventional nozzles.
[SHEET 6.1.1, Combination 31, Total Mitigation A].

Step	Input (%)	Mitigation (%)	Output (%)
1	100	50	50.0
2	50	35	32.5
Total mitigation (%)		67.5	

It is interesting to notice that without such measures it could have been possible to obtain a similar mitigation level (M=75%) only by using a very wide buffer strip, for instance 25-27 m in fruit plants without leaves, 22-25 m in fruit plants with leaves, 16-18 m in grapes without leaves and 14-17 m in grapes with leaves.
[SHEET 6.1.4, Combination 1, Total Mitigation C],
[SHEET 6.2.4, Combination 1, Total Mitigation C],
[SHEET 6.3.4, Combination 1, Total Mitigation C],
[SHEET 6.4.4, Combination 1, Total Mitigation C]

In Table 12 it is included the mitigation percentage that can be obtained with some combinations including the treatment of the last row only inwards. It is interesting to point out that in the treatments with leaves the best combination “nozzles-last row-hedge” reduces the drift by **91.9%.**

Table 12. Combination of three drift mitigation measures: percentage value of the total and single (M%) mitigation.

Measurement 1 Nozzle type	M1 (%)	**Measurement 2** Spraying of the last row	M2 (%)	**Measurement 3** Hedge	M3 (%)	**Total mitigation (%)**
Conventional nozzle	0	No measure adopted	0	None	0	**0.0**
Conventional nozzle	0	No measure adopted	0	Treatm. without leaves	25	**25.0**
Conventional nozzle	0	No measure adopted	0	Treatm. with leaves	75	**75.0**
Conventional nozzle	0	Only inwards	35	None	0	**35.0**
Conventional nozzle	0	Only inwards	35	Treatm. without leaves	25	**51.3**
Conventional nozzle	0	Only inwards	35	Treatm. with leaves	75	**83.8**
Anti-drift nozzle A	25	No measure adopted	0	None	0	**25.0**
Anti-drift nozzle A	25	No measure adopted	0	Treatm. without leaves	25	**43.8**
Anti-drift nozzle A	25	No measure adopted	0	Treatm. with leaves	75	**81.3**
Anti-drift nozzle A	25	Only inwards	35	None	0	**51.3**
Anti-drift nozzle A	25	Only inwards	35	Treatm. without leaves	25	**63.4**
Anti-drift nozzle A	25	Only inwards	35	Treatm. with leaves	75	**87.8**
Anti-drift nozzle B	50	No measure adopted	0	None	0	**50.0**
Anti-drift nozzle B	50	No measure adopted	0	Treatm. without leaves	25	**62.5**
Anti-drift nozzle B	50	No measure adopted	0	Treatm. with leaves	75	**87.5**
Anti-drift nozzle B	50	Only inwards	35	None	0	**67.5**
Anti-drift nozzle B	50	Only inwards	35	Treatm. without leaves	25	**75.6**
Anti-drift nozzle B	50	Only inwards	35	Treatm. with leaves	75	**91.9**

* Conventional nozzle: nozzle of any size, flow rate at 10 bar and working pressure. Anti-drift nozzle A: ISO 01-03 air injection anti-drift nozzle, nominal flow rate 0.73-2.15 L/min at 10 bar, working pressure higher than 8 bar. Anti-drift nozzle B: ISO 01-03 air injection anti-drift nozzle, nominal flow rate 0.73-2.15 L/min at 10 bar, working pressure lower than 8 bar.

Example 7. Double combination

In the wine-growing hilly areas of North Italy it is quite common to find espalier vineyards. These vineyards are treated with traditional atomizers and bordered with discontinuous, not well kept country hedges, that are placed on the outer edge of a track around 3 m wide. The track can be considered as a buffer strip. The treatment of the last row only inwards (M=35%) and the maintenance of the hedge to get the proper thickness (M=75%) allows for a total mitigation of **83.7%.** The contribution of the buffer strip is none (M=0%) because it is too narrow.
[SHEET 6.4.1, Combination 11, Total Mitigation E].

Step	**Input (%)**	**Mitigation (%)**	**Output (%)**
1	100	35	65.0
2	65	75	16.3
Total mitigation (%)		83.7	

It is interesting to point out that without that operational measure, a similar total mitigation (M=75%) could have been obtained by means of a 14-17 m wide buffer strip. It is difficult to implement this solution in wine-growing on hilly areas [SHEET 6.4.4, Combination 1, Total Mitigation C]. In this Guidance document the various mitigation measures are perfectly interchangeable among each other and it is therefore possible to adapt them to the different agronomic situations.

As of today, the experimental data regarding pneumatic sprayers that enable to identify the parameters of use for the reduction of drift in comparison to the reference conditions are not sufficient. Anyway, if the pneumatic sprayer is used in all the rows with jets directed only on the target vegetation and with volumes ≥ 400 l/ha, it is expected to be able to reduce the drift by 30% at least.
On the contrary, the effect deriving from the combination of more drift mitigation measures (e.g. use of anti-drift nozzles or other Spray Drift Reducing Techniques - SDRT, use of anti-drift adjuvants and presence of a hedge on the edge of the field)

requires further in-depth experimental analysis. In the meantime, it is possible to calculate the total mitigation by means of the recursive calculation method (Section 2.5). As said, the total mitigation does not depend on the sequence of the mitigation measures; however, it can be useful to consider the various measures according to their distance from the contamination source; for instance, the reduction of the dose is the first measure, the anti-drift adjuvant the second, the anti-drift nozzle the third, the spraying direction the fourth, the buffer strip the fifth and the hedge or anti-hail net the sixth.

6 RECOMMENDATIONS

6.1 Recommendation 1 (Supplementary interventions for run-off risk mitigation)

When preparing the seedbed, in order to contain the run-off risk, it is in general recommended not to refine excessively the soil, so that the water run-off is slowed down and the infiltration in the soil is eased.

The crop rotation has a considerable influence on the organic matter content of the soil with consequent effects on the structure and aggregates of the soil, on the capacity of water retention and on the increase of the degradation and adsorption of plant protection products.

Soils with a high content of loam (>30%) are frequently subject to run-off as a result of the formation of crusts on the surface of the soil. In these conditions, interventions to increase the soil infiltration capacity are necessary, such as the ones aimed at reducing the soil compaction and at increasing the presence of organic residues in the soil, in addition to the different mechanical operations to break the soil crust.

The subsurface compaction of the soil should be always avoided. For this purpose, low pressure tyres or dual wheels can be used. If possible, avoid driving on wet soils not covered with vegetation and perform subsoiling activities to eliminate the compaction of the subsurface layers.

By working the soil along the contour lines the soil surface obstacles in a better way the water run-off and guarantees both the slowdown of the water flow and the increase of the infiltration in the soil, thus disadvantaging the creation of concentrated run-off flows.

The use of cover crops allows for the impact reduction of the rain on the soil surface, increases the stability of the aggregates and the resistance to the compaction of the soil. It improves the water infiltration and reduces the volume of water running off. The presence of crop residues on the field improves the protection of the soil against the risk of run-off.

The grassing in tree crops (vineyards, orchards, citrus groves, etc.) enables to reduce the surface water flow, to increase the water infiltration in the soil and to retain the sediments transported, thus reducing effectively the run-off and the erosion. Regular mowing and the use of spontaneous vegetation or perennial plant species improve the run-off mitigation and restrict the adverse effects on the crops.

The presence of vegetation along canals and ditches which is regularly mown enables to retain the eroded sediments and to allow for the infiltration and evaporation of the run-off and drain-flow water. In this way, the downstream areas are protected against water and sediments. To maintain the efficiency of these structures, the sediments transported by the water should be periodically removed and the growth of a green cover able to stand submersion conditions should be eased.

Downstream of the ditches and before the confluence in the water courses, it is recommended, where possible, to put in place structures for the dispersion of water, such as artificial barriers formed by wood bundles, trunks, boughs and stones in order to slow down and disperse the water, as well as retain the soil particles transported in it.

6.2 Recommendation 2 (reduction of the drift)

In the framework of the periodical functional monitoring activities regarding the sprayers in operation outlined by the National Action Plan (Italian Ministerial Decree of January 22, 2014, reference to the Italian Legislative Decree 150/2012), it is also necessary to provide the sprayer owner/user with information about the possible amount of drift reduction of the sprayer itself, defined on the basis of what set out in Section 5.3.1 of this Guidance document.

6.3 Recommendation 3 (classification of the sprayers)

Similarly to what has been done by other countries of the European Union, it is necessary to implement a national certification system for sprayers, both for herbaceous and tree crops, in relation to the drift that they produce. In particular, it is necessary to envisage specific research activities to define drift reference curves based on the situation of Italy and referring to the most relevant crops and forms of agriculture present in this same country.

6.4 Recommendation 4 (training and information)

It is necessary to train the users of the plant protection products about the risk mitigation measures and their application, both by means of appropriate training and information notes to make available when purchasing the plant protection products. For this purpose, the Guidelines developed in the framework of the TOPPS-Prowadis Project (they can be downloaded from the Internet website www.topps.unito.it) are a valid reference.
It is also necessary to provide the technicians qualified for the sprayer functional monitoring with proper training, so that they can provide the sprayer user/owner with the indications required in the Recommendation 6.2.

6.5 Recommendation 5 (research activities)

Taking into consideration the increasing importance of the risk mitigation measures regarding the use of plant protection products and the reduced availability of data at a national level, it is necessary to develop research activities to identify mitigation measures that are appropriate to the Italian conditions. Furthermore, it is desirable to develop experimental activities to assess accurately the effectiveness of the single and combined mitigation measures.

6.6 Recommendation 6 (update)

This Guidance document should be periodically updated in order to take into account the new scientific findings and the information deriving from the application of the mitigation measures.

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8 APPENDIX: MANAGEMENT OF THE BUFFER STRIP

Type a: non-treated plot of crops. The anti-drift action is related to its width. Its function of run-off mitigation is due to the retention of the plant protection product performed by the vegetation (if present) and to the soil adsorption, as well as to the infiltration and slowdown of the surface run-off of the water flow. To foster the mitigation it is necessary to maintain the natural roughness of the surface of the soil, therefore avoiding to roll and compact it. It is necessary to increase the organic matter content and, where possible, the presence of plant residues. It will be possible to eliminate the spontaneous vegetation developing in the non-treated plot of crops by means of mechanical interventions.
Also the headland or the edge of the field have an anti-run-off function, related above all to the slowdown and sedimentation of the run-off water and, to a lesser extent, to the infiltration. The grass cutting should be performed some weeks after the treatments and the grass should remain on the soil surface. It is appropriate to eliminate periodically the grooves created by the machinery going past.

Type b: it is the vegetated buffer strip, namely an artificially or naturally grassed area with a thick and continuous turf. If possible, the grass is to be cut some weeks after the treatments and left on the surface of the soil to enrich it with organic matter and to increase its roughness. Avoid the formation of preferential flows by filling the possible small grooves that are created. The presence of cespitose perennial grasses (e.g. *Dactylis* spp., *Festuca* spp., *Lolium perenne*, etc.) should be preferred to dicotyledonous rosette plants. The management of the vegetation is to be performed through mowing. The more the width is reduced, the more the management should be carefully performed. If a hedgerow is also present, this should be simply managed by means of a coppicing cut with a 6-8 year period. If necessary, after the coppicing it is possible to seed the turf again if the shading of the hedge has hindered the growth of the turf itself.

9 GLOSSARY

Feeder canals for irrigation: water bodies whose water is intended only for cultivated fields.

Non-treated buffer strip or **Buffer strip**: see Buffer strip.

Artificial wetlands: artificial wet area.

Bare soil buffer zone: buffer strip.

Crops without leaves: crops with not developed foliage, as at the beginning of the bud burst.

Crops with leaves: crops in full vegetation.

Buffer strip: safety area where the plant protection product cannot be applied. Its aim is to reduce the quantity of product which, as a result of run-off or drift, from the treated area may reach the element to protect.

Vegetated buffer strip: area covered with turf, specifically prepared and managed with an anti-runoff function. It needs to have a uniform and continuous green cover which is permeable and without any furrows;it cannot simply be an area at the edge of the field where the agricultural machinery passes by, as it is usually too compacted to allow the infiltration of water.

Reference sprayer to determine the reduction of drift:

a) **Sprayer for herbaceous crops:** conventional spray boom with cone nozzle or conventional slot nozzle, ≤ISO 04 size, nominal flow rate ≤1.6L/min at 3 bar, working pressure ≤3 bar, forward speed 6 km/h, boom height between 50 and 75 cm, no nozzle at the end of the boom.

b) **For fruit plants**: machine equipped with an axial fan and radial nozzles placed along the air outlet sections. ISO 03 nozzle size, working pressure 15 bar, forward speed 6 km/h, fan diameter 800 mm, maximum fan flow rate not lower than 40,000 m^3/h (power take-off (PTO) speed regulation 540 rpm, fast drive speed of the fan).

c) **For vineyards**: machine equipped with an axial fan and radial nozzles placed along the air outlet sections. ISO 01 nozzle size, working pressure 15 bar, forward speed 6 km/h, fan diameter 500 mm, maximum fan flow rate not lower than 20,000 m^3/h (power take-off (PTO) speed regulation 540 rpm, fast drive speed of the fan).

Shallow water bodies: water bodies where the level of the bottom is at least 1 m higher than the treated crop.

Ditches, drains and other artificial hydraulic structures in cultivated fields for excess meteoric water to be collected and conducted. They do not have their own water and it is present only temporarily.

Vegetated buffer strip.

Vegetated ditches.