Bulletin OEPP/EPPO Bulletin (2012) **42** (3), 409–415 ISSN 0250-8052. DOI: 10.1111/epp.12000

European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

PP 1/239(2)

Efficacy evaluation of plant protection products
Evaluation biologique des produits phytosanitaires

Dose expression for plant protection products

Specific scope

This standard defines how the dose of plant protection products is expressed and describes the parameters, specific to the site and type of application, which should be recorded so that the dose can be determined in a standard way whatever the crop or product, or the equipment used for treatment. Included in the standard is a description of dose expression methods in three-dimensional crops (aerial parts of plants in commercial orchards (e.g. pome fruit, stone fruit), hop gardens and vineyards, small fruit and cane fruit crops (e.g. blueberries, gooseberries, raspberries), taller, isolated fruit trees and other high-growing crops such as fruiting vegetables both in the open field and under protected cultivation) and methods for converting between different dose expression terms.

Specific approval and amendment

First approved in 2005–09.
Revision approved in 2012–09.

Introduction

The aim of this standard is to provide information on how crop and treatment should be described in the trial report so that dose can be expressed in a standard way for all plant protection products, whatever the equipment used for application and the model chosen for registration by the different national authorities. For the simplest cases, a harmonized expression of dose is proposed.

One very commonly used expression of dose in three-dimensional crops is concentration of the formulated product in the spray volume (e.g. dose per hL or %). However, a dose expressed in this way may give highly variable deposits of active substance, mainly due to crop structure, to application (spraying) technique and to the volume of water used. This is particularly true for high-growing crops of variable size in various planting systems (e.g. orchards). As such, it is recognised that this expression is no longer sufficient.

At the present time, great efforts are being made to obtain optimum efficacy from the applied product and to avoid unnecessary emission of products into the environment and residues in feed and food. The best way to achieve this is to adapt the dose rate to the area where the treatment is needed (e.g. crop canopy) and its structure.

Scientific studies examining the deposit of products on the targeted crop area have led to the development of various models in use in some countries, (Rueegg *et al.*, 2001, 2012) and trials carried out for the biological dossier in these countries are based on these models. To allow better exchange of data between countries, to avoid unnecessary repetition of trials and to prevent residue problems between countries, dose expression should be harmonized in trial reports. This can be achieved if the reports contain all relevant information allowing calculation of the applied dose whatever the model chosen by the registration authority. The same consideration applies to residue trials.

This need for a harmonized approach has even more importance following the implementation of the EC Regulation 1107/2009 (EC, 2009), which is based on zonal assessments and authorizations of plant protection products. As such, both regulators and industry require a common

simplified approach to dose expression in order to facilitate the authorisation of products and Mutual Recognition between EU Member States. In doing so, the requirements of growers that are familiar with their own dose expression terms, should still be taken account of, and as such, imposing one scheme may risk practical difficulties. This standard notes that 'per treated leaf wall area unit' (LWA) is becoming a common dose expression method in 3 dimensional crops. However, this Standard also provides a method to convert between the main country dose expression methods (see Appendix 1). This approach therefore both encourages a common dose expression method to be used in trials for generating data and when conducing assessments, whilst allowing the retention of country specific dose expression terms on National labels. It should be emphasised that this approach will only be successful if all relevant parameters of crop structure are recorded, to allow the appropriate dose expression conversions to be made. As additional information, the dose of active substance per hectare of ground area should be calculated and reported.

Units

The units used should always be in the metric system. Generally the amount of commercial product will be given in kg or L, except in some cases, such as product used in very small amounts, where g or mL are acceptable. The amount of active substance will be given in g or in mg. Spray volume should be reported.

The description of the treatment will be given in relation to: a length and width in m; an area in m^2, 100 m^2 or ha; a volume in L, 100 L or m^3; a weight in kg, 100 kg or metric ton; an item (e.g. burrow) depending on the trial situation.

Concentration of microbial pest control agent (MPCA) in a microbial pest control product (MPCP) is measured in terms of g kg^{-1} or g L^{-1} of the MPCP and in cfu (colony forming units) or other appropriate potency units. The content of MPCA in Technical Grade MPCP should be provided in the same terms.

Band or spot application

Normally the amount of product in field crops is expressed as kg or L ha^{-1}. That means that whole field area is treated (1 kg ha^{-1} means that 1 ha ground is treated). However, for some crops which are grown in rows (e.g. strawberries), it must be clear how much product is applied to the area of the crop itself and how much is applied to the whole field ground area. In this case the amount of product should refer to the real treated area. So dose expression 'per ha' means per ha row (band) covered by the crop. For example, when a 1 ha field is covered by crops (e.g. 50% cover by strawberries) the amount of product on the whole field of 1 ha is 0.5 kg ha^{-1}, but 1 kg ha^{-1} on the strawberries' rows.

Types of treatments

Soil treatments

The product is applied on or in the soil by watering, injection, spraying or spreading in liquid or solid form. If the product is applied as bait, the number of baits per kg of formulated product should be given additionally to allow calculation of the number of baits per unit of soil area. The dose for a broadcast treatment should be given in kg or L per unit of soil area. The treatment is sometimes restricted to sowing of seedling rows, plant rows or to individual plants or to a fraction of the inter-rows. The dose for a row treatment may be given in kg or L per row m. In all cases, the inter-row width should be given, as well as the width of the treated area. For band application, the dose may also be expressed in kg or L per unit of treated area, and the bandwidth should be recorded. The dose for a single plant treatment should be given in g or mL per plant number.

Treatment of aerial parts of plants

Field crops

These are considered to include agricultural crops, as well as many horticultural crops grown for the fresh market or vegetables grown for industry. In these crops, plant protection products are usually applied from sprayers fitted with a horizontal boom, though other kinds of equipment are sometimes used (spray gun or air-assisted sprayer). The target is two-dimensional, and height of the crop is not the primary factor that determines the choice of application equipment. The dose is given in kg or L of formulated product per unit of ground area. However, for some crops (generally crops with substantially increasing leaf area e.g. tobacco and some horticultural crops), dose and application may be adapted to the growth stage and the leaf area of the crop.

Commercial orchards, hops and vineyards

In orchards, hop gardens and vineyards, the spray is directed at 3-dimensional targets. Many types of high-performance air-assisted sprayers have been developed for this group of crops and work in different countries continues to improve the quality of application, helping the grower to apply a small dose with high efficacy and with low emission to the environment. Different modes of dose expression have been adopted, based on 'standard orchard', 'leaf-wall area', 'tree-row volume' or 'tree-area density', and used on the labels of plant protection products. It is generally recognised that concentration is no longer sufficient. Greater technical knowledge is now expected from growers, who are being trained in the use of the new modes of dose expression. Several methods are available in parallel, and any can be used provided that adequate information is given on the experimental plots, so that the data can be recalculated.

To allow the three-dimensional nature of the crop to be considered, it is possible to express the dose in kg or L per m^3 of Tree Row Volume, or in kg or L per ha of Leaf Wall Area, or in kg or L ha^{-1} and per m tree height, or in kg or L per 100 m of plant row. An estimation of leaf canopy density by means of pictographs could be useful (e.g. for apple orchards (Chemicals Regulation Directorate, 2006).

To interconvert between these systems for a specific crop, it is necessary to measure crop structure parameters as follows:

- Cropping system (single or multiple rows);
- Distance between rows and between plants in the row;
- Treated foliage height and mid-width of the crown;
- BBCH growth stage at application.

The actual applied spray volume (and not just the expected volume) should be recorded and given in the trial report, as well as information on the application equipment. For more details see Appendix 1 Conversion of doses in three-dimensional crops.

Small fruit and cane fruit crops

As for commercial orchards and vineyards, the target of the spray is three-dimensional and the same dose expression can be used: in kg or L per ha of Leaf Wall Area, in kg or L per m^3 of Tree Row Volume, or in kg or L of formulated products per ha. All crop structure parameters should be recorded and reported as well as the spray volume actually applied.

Taller ornamental or fruit trees

The trees should be measured as for commercial orchards. For the treatment of isolated tall trees the outer surface of the tree canopy to be treated should be measured if possible or estimated. All crop structure parameters should be recorded and reported as well as the spray volume actually applied.

High-growing crops

For crops such as cucumber or tomato, in the field or under protection, spray is also directed at a three-dimensional target and the dose may be expressed in kg or L of formulated products per ha of LWA. All crop structure parameters should be recorded and reported as well as the spray volume actually applied.

At very early growth stages, treatments may be directed at the soil and then the dose can be given only in kg or L of formulated products per ha ground area. For such cases, dose could also be expressed as 'treated area', thus it is valid both for 10 000 m^2 ground area and 10 000 m^2 leaf wall area.

Treatment of seeds and propagating material

Seeds

For seeds sold by specific number per unit, such as sugarbeet, maize and sunflower, dose should be given in g or kg or mL or L per unit. The unit should be specified. For seeds sold by weight, such as wheat, dose should be given in kg or L per 100 kg of seed. For seeds with a small thousand-seed weight that can vary significantly (e.g. leeks and crucifers), it is acceptable to express the dose in g or mL per number of seeds, even if the seeds are sold by weight. As the efficiency of seed treatment can vary greatly according to the equipment used and the characteristics of the seeds, the amount of active substance actually present on the seeds should be verified. This will allow definition of the target dose in relation to the efficacy results. The maximum amount of seeds and maximum amount of product per hectare should be recorded.

Tubers, cuttings and bulbs

For products applied by dusting or spraying, dose should be given in g or kg or mL or L per weight (or per number where relevant) of material to be treated. For products applied by dipping, dose should be given in kg or L per 100 L of water volume and the dipping time should be stated as well as the amount of material dipped in a given volume of mixture. The maximum amount of tubers, cuttings or bulbs and maximum amount of product per hectare should be recorded.

Treatment of harvested products

Harvested products may be treated by dusting, dipping, watering, fogging, spraying or fumigation. For products applied by dusting, dose should be given in kg per tonne or kg per m^3 of material to be treated. For products applied by dipping, dose should be given in kg or L per 100 L of water volume and the dipping time should be stated, as well as, the amount of material dipped in a given volume of mixture. For products applied by watering, dose should be given in kg or L per 100 L and the volume of water per weight of plant product should be stated. For products applied by spraying, dose should be given in kg or L per weight of plant product. For products applied by fumigation, see section '*Treatments by fumigation, smoking and fogging*'.

Treatment of special crops

Some crops such as Christmas trees, or nursery beds of young trees or ornamentals, can vary greatly in size, shape, crop structure and substrate and are generally treated 'until run-off'. If possible the LWA system may be used for trials in these crops. In exceptional cases the dose should be given in kg or L per 100 L of spray volume. The spray volume actually applied and crop parameters should always be reported.

Treatments in forestry

Herbicides are applied as for other crops, but insecticides and fungicides are applied in forestry uses as aerial, foliar,

band or spot treatments. Doses applied for all products can be expressed as kg or L ha^{-1}, and the volume of water used should be reported. The rate may be adjusted to account for the variable characteristics in tree habit, such as height.

Dose expression is also dependent on the proposed use. Treatments applied to cut wood (e.g. to control scolytid bark beetles) are expressed as a concentration (e.g. kg hL^{-1}), indicating the volume of solution to be applied per m^2 of bark area (i.e. log length × mid circumference for single logs) or in amount of product per cubic metre. For dip treatments of plantlets (e.g. against weevils, *Hylobius abietis*) the amount of product in the dipping solution is expressed as a percentage. Wound paint treatments and repellents are usually applied directly to the plants. Wound paints usually refer to application of product over a specified area, whereas for repellents the dose is expressed as a concentration or in kg or L per plant or in kg or L per m^2 of plant (i.e. tree) surface.

Treatments with special application techniques

Treatment of growing media
The dose for the treatment of growing media (e.g. soil, compost, cocopeat) should be given in kg or L per unit of volume of substrate (L, 100 L or m^3). The density of the growing medium should be indicated.

Treatment via nutrient solutions or by irrigation for products applied in a recycling nutritive solution
For products applied in a recycling nutritive solution (e.g. for forcing of chicory, growing tomatoes, berries), dose of formulated products should be given in kg or L per 100 L of nutrient solution. The number or weight of plants should be indicated, as appropriate.

The proportion of the volume containing the plant protection product in the entire volume of nutrient solution should be known and the possibility to exchange the nutrient solution should be granted by the design of the system. Concentration gradients of plant protection product should be excluded as much as possible by the design of the system (e.g. by dripping irrigation).

The following should be described:

- The concentration of the plant protection product in the nutrient solution and its duration;
- The technical design of the irrigation system; the total water capacity of the system and the technology of the nutrient solution distribution.

Treatment via nutrient solutions or by irrigation for products applied in a non-recycling nutrient solution
For a non-recycling nutrient solution or for irrigation (drop or sprinkler systems), dose of formulated products should be given in kg or L per number of treated plants or per unit of treated area. The volume of water applied per ha should be recorded.

Treatments applied to plants or plant products moving on a transport chain
Harvested products such as potatoes, carrots or cereals may be treated in this way. Dose of formulated products should be given in kg or L per weight or per number of plant or plant product. The flow of the transport chain may be recorded.

Treatment of inert surfaces
Plant protection products are applied to surfaces such as walls, litters or wood boxes to control pests. Dose of formulated products should be given in kg or L per unit of area to be treated.

Insecticide or molluscicide baits on or in the soil
Dose should be given in kg of formulated product per unit of ground area. The number of baits should be recorded per unit of ground area. It may also be useful to record the dose in g of active substance per ha.

Insecticide baits in the crop
Dose should be given in kg or litres of formulated product or number of baits per hectare of ground area and kg or litres of formulated product per treated spot. It may also be useful to record the dose in g of active substance per ha.

Pheromones
The number of pheromone dispensers should be recorded per unit of ground area. In stored product protection, the dosage is expressed in number of traps or dispensers per m^3.

Game and rodent repellents
Repellents are generally applied to the base of plants to protect them against debarking by game or rodents, or sometimes to the growing points. Dose of formulated product should be expressed in kg or L per number of plants or per plant surface. For seed treatment, see the relevant section.

Treatments by fumigation, smoking and fogging
Fumigation is applied to control pests of mushroom beds, glasshouses or store rooms for harvested products. The following application methods may be distinguished: fumigation, i.e. treatment with a gas; smoking, i.e. treatment with airborne particulates or gases generated by thermal combustion (e.g. nicotine) or fogging, i.e. very fine airborne aerosols. The dose of the formulated product is given as presented in Table 1.

Trunk/stem injections
Dose should be given in kg or litres of formulated product per plant. Stem diameter at breast height (DBH) of the treated plant should be recorded to give an idea of the amount of product given per plant.

Table 1 Expression of dose for products applied by fumigation, smoking or fogging

Particulates and aerosols applied to crops	g or mL or cartridges per m^2
Gases (e.g. nicotine) applied to crops	g or mL or cartridges per m^3 or m^2
Fogs and smokes applied as space treatments to empty structures	g or mL or cartridges per m^3
Fogs and smokes applied to commodities	g or mL or cartridges per m^3
Fumigants applied to commodities	kg or L or tablets or other specified units per m^3 or tonne duration and CTP (concentration-time product) should be specified
Soil fumigants	kg or L ha^{-1} depth of incorporation/injection and duration of sheeting should be specified where appropriate

Treatments against vertebrates

Cartridges or tablets generating toxic gas can be used to control some burrowing mammals e.g. voles (*Arvicola* spp., *Microtus* spp.) or other field rodents. In this case, the dose is the number of cartridges or tablets per soil area or per m burrow length or per entrance hole or per baiting station. This kind of product can also be used for the treatment of stored seeds, and the dose is then the number of cartridges or tablets per metric ton of treated product.

Against synanthropic rodents (*Mus musculus, Rattus norvegicus, Rattus rattus*), rodenticides and rodenticidal preparations are used as ready-to-use or prepared baits, or as dusts. Various special systems are used for the placing and timing of baits and dusts. See EPPO Standards PP 1/97 and PP 1/114.

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Appendix 1

Conversion of doses in 3-dimensional crops

Introduction

Different countries have different means of expressing the dose of plant protection products applied to three-dimensional crops and in particular orchards. Growers are generally conversant with the expression used in their country and the imposition of any dose unfamiliar to them is unlikely to be understood. Moreover, such misunderstanding has the likelihood to result in incorrect doses being applied and an associated risk to the environment or human health.

Given this, it is generally considered that doses should be expressed in a format that is readily understood by users. To facilitate mutual recognition of plant protection product authorizations, some means of converting between expressed approved doses is necessary. This can be done either directly from the experimental data, providing that all the relevant parameters of the structure that have been treated in the efficacy trials have been assessed, or from the doses expressed on the approved label in one country assuming this relates to a known standard structure and where relevant to a specific growth stage. Standard PP 1/239 *Dose expression for plant protection products* outlines the parameters that should be recorded in the efficacy trials to allow different expressions of dose to be made if required.

Having all necessary data of the crop structure it is possible to convert particular dose expressions into other expressions – e.g. from concentration (%) to kg (L) per ha to kg (L) per ha and m crown height to kg (L) per 10 000 m^2 leaf wall area or tree row volume (see Fig. 1).

It needs to be emphasised that this Appendix deals only with the conversion of expressed approved doses. An essential pre-requisite to dose conversion is that the existing units of dose expression should have been approved by the relevant national pesticide regulatory authority based on the trials data previously submitted.

It should also be emphasized that dose adjustment is a separate process by which the dose applied is reduced or increased in accordance with canopy size, density and climatic factors to obtain minimum variation in deposit across a wide range of crop structures.

National dose expressions and standard structures

The following section outlines the most commonly used forms of dose expressions and also, where available, information on standard structures to which those doses are relevant. A pictograph explaining the relationship between LWA and Ground Area in pome fruit is provided in Fig. 2.

It should be noted that converting between different dose expressions provides an estimation of the intended dose in a different expression. More accurate interpolation may be obtained using an appropriate dose calculator, such as that

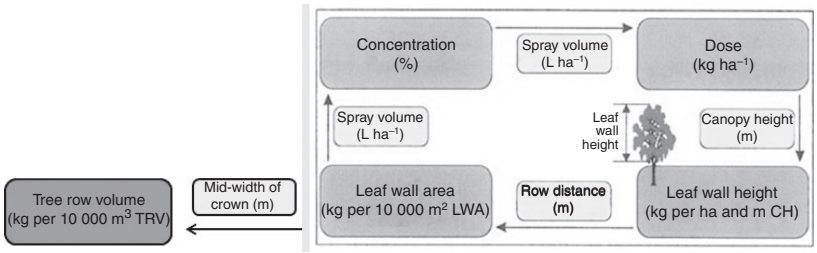

Fig. 1 Conversion of different dose models for high crops. The parameters needed to convert the different dose models are row distance, canopy height, mid-width of the crown, the applied water volume and the application rate, expressed in kg (or L) per hectare. Source: Frießleben *et al.*, 2007. Amended by H. Höhn and A. Naef, ACW, Switzerland

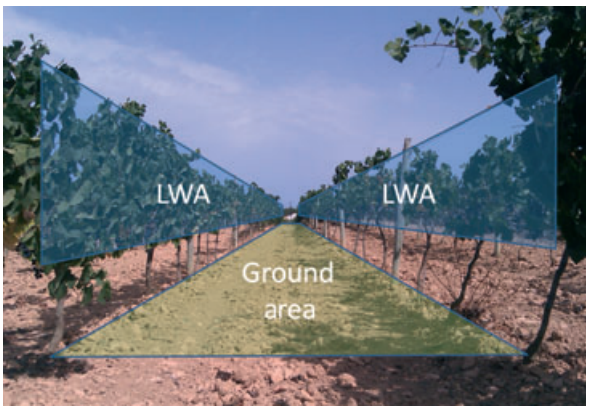

Fig. 2 Pictograph to explain the relationship between LWA and Ground Area in pome fruit (provided by R Sunley).

developed by P. Walklate. http://www.pjwrc.co.uk/Dose-TranslationDemo.aspx

Dose expression 'Method 1': Dose per ha ground

In 'Method 1' orchard structure is considered as a single row at 3.5 m row spacing, with a canopy height of 3 m and (unless a growth stage is specified) a full canopy density (Crop Adjustment Factor (CAF value of 1) from http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/G/g403.pdf).

Dose expression 'Method 2': Dose per ha leaf wall area (LWA)

In 'Method 2' orchard structure is considered as a single row with 3.5 m between rows and a crop canopy height of 3 m.

Dose expression 'Method 3': Dose per ha ground for every m canopy height

For a constant deposit per unit area of canopy this expression requires a row spacing factor which is currently unavailable. In the absence of information to the contrary is assumed at this stage that the standard row spacing is 3.5 m.

Dose expression 'Method 4': Dose/10 000 m^3 Tree Row Volume (TRV)

In 'Method 4', orchard structure is considered as a single row with 3.5 m between rows, a crop canopy height of 3 m and a standard mid-width of crown of 1.2 m.

Dose Conversion (example apple)

Given these main methods of dose expression in use it is possible to establish some general principles for converting between expressions:

'Method 1' Dose per ha ground = 'Method 2' dose per ha LWA × conversion factor (see Table 2).

Table 2 Derivation of leaf wall area conversion factors

	Canopy or foliage height (m)						
Row distance (m)	1.5	2.0	2.5	3.0	3.5	4.0	4.5
2.5	12 000	16 000	20 000	24 000	n.a.	n.a.	n.a.
3.0	10 000	13 333	16 666	20 000	23 333	n.a.	n.a.
3.5	8 571	11 428	14 286	17 143	20 000	22 857	n.a.
4.0	7 500	10 000	12 500	15 000	17 500	20 000	22 500
4.5	6 666	8 888	11 111	13 333	15 555	17 777	20 000
5.0	6 000	8 000	10 000	12 000	14 000	16 000	18 000

Green: the most common typical row distances, foliage heights and LWA.
Yellow: common, but less frequent.
Grey: exceptions.
Source: Bayer CropScience, 2007.
Leaf wall areas expressed in m^2 leaf per ha ground area for the example of apple orchards.
The conversion factor is calculated by dividing the leaf wall area by 10 000. Values may vary for other crops.

Assuming the 'Method 2' dose is expressed for full canopy density trees (or at a specific BBCH growth stage).

Explanation: For a 'Method 1' standard orchard = 3.5 m row distance, and 3 m high.

There are 1.7 ha LWA per ha ground.

'Method 1' Dose per ha ground = 'Method 3' dose per ha ground per m canopy height × 3(m).

Assuming the 'Method 3' dose is expressed for full canopy density trees (or at a specific GS) on comparable row spacing:

Explanation: 'Method 1' standard orchard has a canopy height 3 m.

'Method 2' dose per ha LWA × conversion factor = 'Method 3' dose per ha ground per m canopy height × 3(m).

Explanation: by default, Dose per ha LWA = dose per ha ground per m canopy height.

'Method 2' dose per ha LWA × 2/m mid-width of the crown = 'Method 4' dose/10000 m^3 TRV.

Explanation: 'Method 2' dose can be used to calculate 'Method 4' dose. The formula takes into account the treatments from 2 sides and the dose reduction proportional to the mid-width of the crown. 'Method 2' dose can also be used to bridge from 'Method 4' dose to 'Method 1' and to 'Method 3' doses.