

**Efficacy evaluation of plant protection products****PP 1/239 (3) Dose expression for plant protection products****Specific scope**

This Standard defines how the dose of plant protection products should be expressed, and describes different dose expression terms and their interconversion. It also describes the parameters, specific to the crop, site and type of application, which should be recorded so that the applied dose can be determined in a standard way whatever the crop or product, or the equipment used for treatment.

This Standard includes definitions of common terms used in the description of the dose expression of plant protection products (Appendix 1).

One special focus of this Standard is the description of the dose expressions in high growing crops. Information is also given on how to interconvert between the most common dose expression terms in this particular group of crops and on the parameters to be measured and the equations (Appendix 2).

Harmonized procedures on the measurement of individual plant parameters in the field are also illustrated to facilitate consistent approaches (Appendix 3).

National methods for adjusting the recommended dose in country-specific situations are outside of the scope of this Standard.

**Specific approval and amendment**

First approved in 2005–09.

Revision approved in 2012–09.

Revision approved in 2020–09 following discussion in the EPPO *Workshop on harmonized dose expression for the zonal evaluation of plant protection products in high growing crops* (Vienna, 2016-10-18/20).

**Introduction**

An efficacy assessment of plant protection products needs to be based on harmonized guidance providing information on how crop and treatment should be described in the trial report, in order to express the dose in an appropriate way for all plant protection products, independent of the equipment used for application and the model chosen for registration by the different national authorities.

A harmonized dose expression in trial reports and in biological assessment dossiers allows a better exchange of data between countries while enabling countries to maintain specific dose expression terms on their national labels. Therefore, trial reports and biological dossiers should contain all the relevant information allowing (1) an efficacy assessment based on an appropriate dose expression method

for the specific crop and (2) a calculation or interconversion of the applied dose in the trial (see Appendix 2).

With a uniform dose expression model, a consistent and homogenous interpretation of the dose used in the context of generation, presentation and assessment of efficacy trial data is ensured.

The reference product should always be used at the registered dose and the corresponding registered dose expression should be given.

**1. Units**

The units used should always be in the International System of Units 'SI' (previously called the metric system). Generally, the amount of commercial product will be given in kilograms (kg) or litres (L), except in some cases, such as

**Table 1.** Units to be used for the formulated plant protection product and the active substance (quantity per application)

Formulation type (application method) (examples)	Unit for the formulated plant protection product	Unit for the active substance
Liquid formulations – usually sprayed or painted (direct contact), with or without dilution in water (e.g. concentrate, suspension, capsule suspension, emulsion, gel, oil-based liquid, liquid ready-to-use)	L (possibly in mL for very small amounts)	g (or possibly kg for very large amounts)
Solid formulations – usually sprayed after dilution in water or dusted, spread (e.g. granules, powder)	kg (possibly in g for very small amounts)	
Case of other formulations – not sprayed or spread (e.g. vapour-releasing device, aerosol dispensers, smokes, fogs, some baits, tablets)	Number (or range) of ‘devices’ (e.g. dispensers, traps, aerosols, cartridges, tablets, baits) L or kg, if appropriate (possibly mL or g for very small amounts)	
Formulations containing microorganisms (liquid or solid)	In addition to the units mentioned above, colony forming units (cfu) or other appropriate potency units	

the product being used in very small amounts, in which case grams (g) or millilitres (mL) is acceptable (Table 1). The amount of active substance will preferably be given in grams (or kilograms).

## 2. Recommended dose expressions for specific types of treatments

### A) Treatments of soil and other growing/nutrition media

The product (in liquid or solid form) is applied on or in the soil, or to solid or liquid growing media by watering, injection, spraying or spreading. See Table 2.

### B) Treatment of aerial parts of plants

Depending on the direction of application, aerial parts of plants can be treated *horizontally* (downwards, e.g. arable, vegetable or ornamental field crops) or *vertically* (sideward and/or upward, e.g. pome fruit, grapevine).

Independently of the spray direction, the dose should refer to the actual treated area. Also, the applied spray (water) volume (if the product is sprayed) should refer to the actual treated area (same dose expression as for the dose, e.g. spray volume in L per hectare (ha) for a dose per ha ground, spray volume in L per 10 000 m<sup>2</sup> treated Leaf Wall Area (tLWA) for a dose per 10 000 m<sup>2</sup> tLWA).

**Table 2.** Dose expressions for treatments of soil and other growing/nutrition media

Type of treatment (for soil and other growing/nutrition media)	Recommended dose expressions ‘Amount of product per ...’
A1 Soil treatment and treatment of growing media <i>Application on the surface</i>	... <b>area (ha, m<sup>2</sup>) of treated ground</b> <i>e.g. pre-emergence/intercrop applications of herbicides, application against soil insects/soil-borne diseases</i> <i>For treatments not applied on the whole ground area (localized treatments), refer to Section F</i>
A2 Soil treatment and treatment of growing media <i>Application in the soil/growing media</i>	... <b>volume (L, hL or m<sup>3</sup>) of ‘growing media’</b> (e.g. soil, substrate, mushroom beds) ... <b>area (m<sup>2</sup>, ha) of treated soil/growing media</b> (with indication of the depth of incorporation/injection and, if appropriate, duration of sheeting) ... <b>weight (kg or tonne) of ‘growing media’</b> (e.g. soil, substrate, mushroom beds) <i>e.g. disinfection (fumigants etc.), incorporation of microorganisms in the growing media against soil-borne diseases</i>
A3 Treatment via nutrient solutions (recycling or non-recycling systems)	... <b>number of plants (e.g. 100, 1000)</b> (with indication of the number of plants per area) ... <b>area (ha, m<sup>2</sup> etc.) of treated ground</b> (non-recycling system) ... <b>hL (or %) of nutrient solution</b> (with indication of the ground area treated with a given volume) <i>For recycling systems, the duration of the plant protection product in the nutrient solution should be described, as well as the technical design of the irrigation system, the total water capacity of the system and the technology of the nutrient solution distribution</i> <i>For non-recycling systems, the volume of water applied per ha should also be recorded</i> <i>e.g. applications via irrigation (surface, drip or microsprinkler systems), products applied in a nutritive solution</i>
A4 Bait treatments against vertebrates, insects, molluscs etc.	... <b>area of treated ground (ha, m<sup>2</sup>)</b> ... <b>entrance hole (e.g. per burrow) or per treated spot</b> ... <b>m of burrow length</b> ... <b>baiting station</b> <i>When the product is to be mixed with the soil it should be indicated how deep the baits are to be worked into the ground as well as the maximum amount of product per hectare</i> <i>e.g. slug pellets (broadcast application), grain baits/cartridges/tablets against voles</i> <i>For treatments not applied on the whole ground area (localized treatments), refer to Section F</i>

In efficacy trials, it may be necessary to examine doses which are different from those which will be the proposed maximum dose per ha ground area for a specific use. The relevant crop parameters should be reported (see Appendix 3). This is important as the actual applied dose of plant protection product *per hectare of ground area* should always be recorded for risk assessment.

### B1) Horizontally treated crops

In these crops, plant protection products are usually applied from sprayers fitted with a horizontal boom, although other kinds of equipment are sometimes used (spray gun or air-assisted sprayer). The target area is regarded to be two-dimensional, as height of the crop is not the primary factor that determines the dose of the plant protection product and the choice of application equipment (see Table 3).

**Table 3.** Dose expressions for horizontally treated crops

Type of treatment (aerial parts of plants)	Recommended dose expressions 'Amount of product per ...'
B1 Horizontally treated crops	<p><b>...area (ha) of treated ground</b>  <i>e.g. arable crops, field-grown vegetable and ornamental crops, young forest trees, if treated with horizontally guided sprayers</i></p> <p><i>For treatments not applied on the whole ground area (localized treatments, e.g. band application), refer to Section F</i></p> <p><b>...hL of spray volume (hL or %) (with indication of the spray volume per ha)</b>  <i>The maximum amount of product per hectare in practice should be proposed and justified</i></p>

Dose expressions highlighted blue. This dose expression can be used in addition to the recommended one, but should not be used on its own.

### B2) Vertically treated crops: high growing crops

High growing crops are all crops in which foliar applications of plant protection products (other than herbicides) are sprayed vertically (meaning 'from the side') and/or partly upwards, and not towards the ground. Some crops can be sprayed horizontally or vertically, depending, for example, on the training system, on the site of growth (e.g. greenhouse-grown tomatoes are treated vertically and hence are a high growing crop, whereas field-grown tomatoes are treated horizontally and are not), or on crop height/developmental stages. Examples are given in Appendix 1.

In high growing crops various different methods of dose expression have been used in efficacy trials and for efficacy assessment on country level. Numerous crop-, application-, and site-related parameters can be recorded in these crops, which would allow scientific precision at trial level. Therefore, an efficacy assessment of plant protection products

intended for high growing crops needs to be based on harmonized guidance on *recommended dose expressions* and *on site/crop/application specific parameters*, which should be recorded, providing comparability of trials across countries or EPPO zones.

In high growing crops, the dose expression used should take account of crop structure. These types of dose expressions are summarized in Section B2.1. Nevertheless, these expressions coexist with others that do not take into account the two- or three-dimensional nature of the crop; these are summarized in Section B2.2 and should be used in addition to those listed in B2.1 except in specific situations (see Appendix 2, Section 2.1).

#### B2.1 Dose expressions considering crop structure in high growing crops

Recommended:

- ... per 10 000 m<sup>2</sup> of treated Leaf Wall Area (/10 000 m<sup>2</sup> tLWA)
- ... per 10 000 m<sup>3</sup> of treated Tree Row Volume (/10 000 m<sup>3</sup> tTRV)

Not generally recommended (recommended only for historical data):

- ... per ha and per m treated canopy/crown height (/ha/m tCH) or per ha and per m treated Foliage Height (/ha/m tFH)

The recommended dose expressions comprise an adjustment of the dose to crop height, crop area, or crop volume. In principle, any of these dose expressions can be used for trials, biological dossiers and assessments provided that adequate information is given on the experimental plots so that the data can be recalculated (Table 4).

Information on how to measure specific parameters is presented in Appendix 3. Specific crop parameters that should be recorded for trials in high growing crops are presented in Section 3 of Appendix 3. Further information (e.g. formulas, advantages/disadvantages of each of these dose expressions) can be found in Appendix 2.

#### B2.2 Dose expressions not considering crop structure, to be used only in addition to the dose expressions listed above (Section B2.1)

- ... per ha (or m<sup>2</sup>) ground area (/ha)
- ... per hL (/hL or %)

These dose expressions do not consider crop structure. They can only be related to crop parameters and converted to other dose expressions if the treated area (m<sup>2</sup> of tLWA), or the treated volume (m<sup>3</sup> of tTRV), or the treated height (m tCH, m tFH) is recorded, and also if the spray volume is related to the treated area/volume, or height (see Appendix 2).

It is therefore generally recognized that both *dose per ha* and any kind of *concentration* (dose per hL, %, etc.) can be used in addition to recommended ones, but should not be used as the sole measure of dose in trials for efficacy evaluation in high growing crops.

**Table 4.** Dose expressions for vertically treated crops: high growing crops

Type of treatment (aerial parts of plants)	Recommended dose expressions 'Amount of product per ...'
B2 Vertically treated crops: high growing crops	<p><b>B2.1</b></p> <p>...<b>10 000 m<sup>2</sup> of treated Leaf Wall Area (10 000 m<sup>2</sup> tLWA)</b></p> <p>...<b>10 000 m<sup>3</sup> of treated Tree Row Volume (10 000 m<sup>3</sup> tTRV)</b></p> <p><i>e.g. foliar applications of fungicides, insecticides, plant growth regulators to fruit crops, grapevine, high growing vegetables and ornamentals</i></p> <p><i>For treatments not applied on the whole crop area (localized treatments, e.g. applications to the bunch zone in grapevine), refer to Section F</i></p> <p>...<b>ha and per m treated canopy/crown/foilage height (ha/m tCH, ha/m tFH)</b></p> <p><i>This dose expression should be restricted to cases where further information about crop measures is missing (historical data)</i></p> <p><b>B2.2</b></p> <p>...<b>hL of spray volume (%)</b> (with indication of the spray volume)</p> <p><i>In addition to spray volume per ha, other parameters should be recorded to relate the applied dose to the crop structure essential in high growing crops</i></p> <p><i>It can be used if the applied spray volume is expressed per m tCH, per 10 000 m<sup>2</sup> tLWA or per 10 000 m<sup>3</sup> tTRV</i></p> <p>...<b>area (ha) of treated ground</b></p> <p><i>Can be used in high growing crops when treatments are applied downwards to the soil (e.g. very early growth stages, young plantations)</i></p>

Dose expressions highlighted blue. These dose expressions can be used in addition to the recommended ones, but should not be used on its own.

### C) Treatments of seeds and propagation material

See Table 5.

### D) Treatments of non-crop objects

#### D1) Treatments of inert surfaces/non-agricultural areas

Plant protection products are applied to storage surfaces such as walls, litters or wood boxes and also to non-agricultural areas (e.g. railway, permanently non-cultivated land) to control pests (see Table 6).

#### D2) Treatments by fumigating, dusting and fogging

Fumigation is applied to control pests of mushroom beds, glasshouses or storerooms for harvested products. The following application methods may be distinguished: fumigation, i.e. treatment with a gas, dusting, i.e. treatment with tiny solid particles, or fogging, i.e. treatment

**Table 5.** Dose expressions for treatments of seeds and propagation material

Type of treatment (seeds and propagation material)	Recommended dose expressions 'Amount of product per ...'
C1 Seeds	<p>...<b>weight of seeds</b> (e.g. per kg)</p> <p>...<b>number of seeds</b> (e.g. per 100 000 seeds, 10 000 seeds)</p> <p><i>The amount of seeds per area in the trial plot should be recorded to enable conversion to the amount of product per hectare</i></p> <p><i>The maximum amount of seeds per ha should be recorded</i></p>
C2 Tubers, cuttings, bulbs, young plants for propagation (e.g. young trees, shrubs, vines, rootstock, nursery plants, plantlet included in a small block of growing media)	<p>...<b>weight of 'plant propagation material'</b> (e.g. tonne of tubers/bulbs)</p> <p>...<b>number of 'plant propagation material'</b> (e.g. per 100 cuttings, plantlets, young trees or shrubs)</p> <p><i>Both for treatments by dusting or spraying</i></p> <p>...<b>volume (L, hL) of dipping/drenching solution</b> (with indication of the water volume)</p> <p><i>For dip and drench applications, the soaking time should also be recorded, as well as the amount of material dipped in a given volume of mixture e.g. dip application on 'plant material' before planting</i></p> <p><i>The maximum amount of tubers, cuttings and bulbs per ha should be recorded in trials</i></p> <p><i>The maximum amount of product per hectare should be recorded</i></p> <p>...<b>volume of 'plant propagation material'</b></p>

Dose expression highlighted blue. This dose expression can be used in addition to the recommended ones, but should not be used on its own.

**Table 6.** Dose expressions for treatments of non-crop objects

Type of treatment (non-crop objects)	Recommended dose expressions 'Amount of product per ...'
D1 Treatments of inert surfaces/non-agricultural areas	<p>...<b>treated ground area</b> (e.g. ha, m<sup>2</sup> of soil, litter, permeable, impermeable ground surfaces)</p> <p>...<b>treated area, other than soil area</b> (e.g. m<sup>2</sup> of walls, m<sup>2</sup> of inert material)</p>
D2 Treatments by fumigating, dusting and fogging... (other than soil treatments, displayed in section A)	<p>...<b>m<sup>3</sup> of treated volume</b> (e.g. empty greenhouse, empty storerooms)</p> <p><i>For fumigants, duration and concentration-time product (CTP) should be specified</i></p> <p>...<b>weight</b> (e.g. tonne) of inert material</p>

Dose expression highlighted blue. This dose expression can be used in addition to the recommended ones, but should not be used on its own.

with very fine airborne aerosols. These treatments are carried out in the absence of crops/plants/plant products. See Table 6.

## E) Treatments of harvested products

See Table 7.

**Table 7.** Dose expressions for treatments of harvested products

Type of treatment (harvested products)	Recommended dose expressions 'Amount of product per ...'
E1 Post-harvest and 'in-store' applications by dip, drench, dusting, sprayed on a conveyor belt	<p>... <b>hL of water solution</b> (with indication of quantity of 'plant material' treated with a given volume)</p> <p>... <b>weight (e.g. tonne, kg) of 'plant material'</b></p> <p>... <b>volume (m<sup>3</sup>) of 'plant material'</b> (e.g. fruits, tubers, vegetables, cereals)</p> <p><i>e.g. fungicides against storage rots, rodenticides, plant growth regulators for regulation of ripening</i></p> <p><i>For dip and drench applications, the soaking time should also be recorded</i></p> <p><i>For bait treatments, see also Section A, Table 2 (A4)</i></p> <p>... <b>number of plants or plant product</b> (e.g. conveyor belt)</p> <p><i>The duration of the application and the flow of the machinery (e.g. conveyor belt) should be recorded</i></p>
E2 Post-harvest and 'in-store' applications by fumigation, fogging etc.	... <b>volume (m<sup>3</sup>) of 'plant material'</b> (e.g. stored fruits, tubers)
E3 Treatment of cut wood	<p>... <b>hL of water solution</b> (with indication of volume of solution to be applied per m<sup>2</sup> surface area of bark/trunk)</p> <p>... <b>volume (e.g. m<sup>3</sup>) of cut wood</b></p>

Dose expression highlighted blue. This dose expression can be used in addition to the recommended ones, but should not be used on its own.

## F) Localized treatments

### F1 Band or row/inter-row application

In horizontally treated crops the amount of product refers to the ground area. Normally the whole ground area is treated (1 kg/ha means that 1 ha ground is treated), even if the crop does not cover the whole ground area (e.g. early crop developmental stages). However, for some crops which are grown in rows (e.g. strawberries), band application of rows is carried out with specific application equipment (e.g. row crop spray brackets or spray hoods, drop-legs) targeting only the crop, leaving the surface between rows untreated. Another case of this type of treatment is band application

of herbicides in field row crops (e.g. with even distribution nozzles, hooded nozzles) or in orchards and berry plantations (e.g. with herbicide booms).

In trials carried out in high growing crops, the treated crop height/area/volume may also be smaller than the actual height/area/volume of the crop, e.g. spray band height is lower than the actual Foliage Height, e.g. bunch applications in grapevine.

It must be clear how much product is applied to the area of the crop itself and how much is applied to the whole ground or crop area. In any case, the amount of product should refer to the real treated area. See Table 8.

**Table 8.** Localized treatments

Type of treatment (localized treatments: treatments not applied over the whole ground/ crop area)	Recommended dose expressions 'Amount of product per ...'
F1 Band or row/inter-row applications	<p>Localized treatments of ground area or horizontally treated crops</p> <p>... <b>ha of treated band, row/inter-row area on the ground</b> (with indication of maximum % of treated zone over the whole ground area)</p> <p><i>e.g. row application of strawberry rows carried out with specific application equipment (e.g. spray brackets) targeting only the crop rows, leaving the surface between rows untreated; band application of herbicides in high growing crops (only the ground below the crop is treated with herbicide boom etc.); herbicides applied only on the inter-row (e.g. hooded nozzles)</i></p> <p>Localized treatments of high growing crops</p> <p>... <b>10 000 m<sup>2</sup> of treated Leaf Wall Area</b></p> <p>... <b>10 000 m<sup>3</sup> of treated Tree Row Volume</b></p> <p>(... <b>ha and per m treated canopy/ crown/foilage height</b>)</p> <p><i>e.g. bunch applications in grapevine</i></p> <p>... <b>area (ha, m<sup>2</sup>) of treated spots on the ground</b> (with indication of max % of treated area over the whole ground area)</p> <p>... <b>number of plants or 'plant parts'</b></p> <p>e.g. single plants, trunks, stems, wounds)</p> <p>... <b>area (m<sup>2</sup>) of trunk/stem section or surface</b></p> <p><i>e.g. herbicide applications directly to single weeds (spot application on dock); game repellents brushed on lower part of trunks; trunk injections; wound treatments</i></p> <p>... <b>stem diameter (e.g. cm)</b></p> <p><i>Stem diameter at breast height (DBH) of the treated plant (tree) may be recorded, where relevant</i></p>
F2 Spot or single plant applications	

Dose expression highlighted blue. This dose expression can be used in addition to the recommended ones, but should not be used on its own.

### F2 Spot or single plant application

In case of spot application, restricted areas or single plants are treated. See Table 8.

### G) Other cases

#### G1 Mating disruption pheromones and other semiochemical-based techniques

See Table 9.

#### G2 Game and rodent repellents

Repellents are generally applied to the stem or trunk of plants to protect them against debarking by game or rodents, or sometimes to the growing points to prevent biting. For seed treatment, see the relevant section. See Table 9 and also Section F2 (Table 8).

**Table 9.** Other cases

Type of treatment (other cases)	Recommended dose expressions 'Amount of product per ...'
G1 Mating disruption (pheromones) and other semiochemical based techniques	<p>...<b>area (ha) of treated ground</b></p> <p>...<b>volume (e.g. m<sup>3</sup>) for stored products</b></p> <p><i>The maximum dose per ha and per year/cropping cycle should be proposed and justified</i></p> <p><i>Duration of persistence of action and number of pest generations intended to be covered should be indicated</i></p> <p><i>For sprayed products, an appropriate dose expression should be used, depending on the crop (horizontally or vertically sprayed, see Section B)</i></p> <p>...<b>number of 'plants'</b> (e.g. trees, shrubs)</p> <p><i>The maximum dose per ha should be justified and derived from the maximum number of plants intended to be present in practice</i></p>
G2 Game and rodent repellents	<p>...<b>number of plants or plant part (e.g. trunk, stem)</b></p> <p>...<b>area of plant surface (m<sup>2</sup>)</b> (if relevant)</p> <p>...<b>area (ha) of treated ground</b></p> <p><i>The maximum dose per ha should be justified and derived from the maximum number of plants intended to be present in practice</i></p>

Dose expression highlighted blue. This dose expression can be used in addition to the recommended ones, but should not be used on its own.

## Acknowledgements

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## Appendix 1 – Definition of terms



General definitions and terms used within the Standard (Table 10), crop-related terms (Table 11) and application-related terms (Table 12) are included below to support and supplement EPPO Standard PP 1/239.

**Table 10.** General definitions and terms used within the standard

Term	Definition
Dose expression	<p>Dose expression is a mass or volume unit (e.g. kg or L, g or mL) of a plant protection product (or active substance) linked to a certain reference amount.</p> <p>Reference amounts always characterize the size of the application area/the treated volume/the number of treated objects.</p> <p>Depending on the application scope, it can be expressed as area (e.g. ha or m<sup>2</sup>, ground area as well as crop area), volume (L or m<sup>3</sup>, e.g. tTRV) or other (e.g. number/weight of seeds).</p> <p>Example: 1.5 kg per ha ground area (1.5 kg/ha)</p> <p>The dose of the plant protection product is 1.5 kg and the unit is kg. Per ha ground (/ha) is the reference amount, both together (kg/ha) is the dose expression.</p> <p>Example: 1.2 kg per 10 000 m<sup>2</sup> treated Leaf Wall Area (1.2 kg/10 000 m<sup>2</sup> tLWA)</p> <p>The dose of the plant protection product is 1.2 kg and the unit is kg. Per 10 000 m<sup>2</sup> LWA (/10 000 m<sup>2</sup> tLWA) is the reference amount, both together (kg/10 000 m<sup>2</sup> tLWA) is the dose expression.</p>
Dose adjustment	<p>Dose adjustment is the adjustment of the dose to a specific local situation (e.g. growth stage, pest pressure). The term dose adjustment should not be used for efficacy trials.</p> <p>Dose adjustment is the adaption (reduction or increase) of a plant protection product's dose to obtain, e.g.:</p> <p>a sufficient level of plant protection product deposit to achieve an expected efficacy under specific circumstances (canopy size and density, BBCH, application method, controlled organism, climatic factors, etc.)</p> <p>or</p> <p>to ensure a minimum variation in the product's deposit across a wide range of crop structures.</p>



Table 11. Crop-related terms

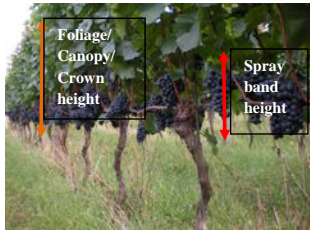
Term	Definition	Unit
Crop shapes and training systems often depend on national or sometimes local practice, therefore the same crop can be identified as, for example, wall forming or globular (e.g. stone fruit). Some crops can be treated horizontally or vertically, depending on the local growth conditions (e.g. greenhouse-grown tomato is treated vertically, whereas field-grown tomato is treated horizontally) or on crop heights or different developmental stages. The definition of different crop types, along with appropriate structure parameters, is provided below.		
<b>High growing crops</b>	Crops in which foliar plant protection product applications (other than herbicides) are sprayed vertically (meaning 'from the side') and/or partly upwards and not towards the ground. <i>e.g. pome fruit and stone fruit ('top fruit'), high growing berry crops (e.g. elder, raspberry, blackberry, currants, gooseberry), grapevine, hop, kiwifruit, citrus fruit, nut fruit, olives, but also some vegetable crops (e.g. tomato, pepper, aubergine, cucumber) and some ornamental crops (e.g. roses, alley trees) in open fields or in greenhouses sprayed in this way constitute a high growing crop</i>	–
<b>Wall forming crops or wall crops</b>	These are terms for high growing crops with a linear ground projected area without significant gaps along the row.	–
		
	Wall crop (vineyard) with a linear ground projected area. Photo G. Kovacs	
<b>Globular crops</b>	<i>e.g. orchards, hop, grapevine, and some greenhouse-grown fruiting vegetables</i> Term for high growing crops with elliptical or round ground projected area, with or without gaps in the row between the single plants resp. canopies.	–
		
	Globular tree plantation. Photo J. Jiménez Ruiz	
	<i>e.g. some citrus, olives, stone fruits, nut fruits, persimmon, pomegranate</i>	
<b>Canopy/Crown Height (CH) or Foliage Height (FH)</b>	Distance from the lowest leaves/fruits to the tree/plant top, excluding the trunk/stem area. The terms Canopy or Crown Height are particularly used for trees. The term Foliage Height is particularly used for fruiting vegetables grown in greenhouses.	m
<b>Crop height</b>	Total height of the aerial part of the plant, including trunk/stem.	m
<b>Canopy/crown/foliage shape (cropping system)</b>	Crop characteristic reflecting the morphology due to the natural plant growth and/or training/pruning system used. Term to differentiate, e.g. between spindle trees, globular tree shape, plants in goblet pruning system, tendone, pergola, etc.	–
<b>Globular diameter</b>	Average distance between the outer leaves of a globular tree/plant, measured at the middle of the canopy/crown/foliage height. Globular diameter = (min. width + max. width)/2	m
<b>Ground area</b>	Ground surface area of the site/plot.	ha (m <sup>2</sup> )
<b>Mid-width of the canopy/crown/foliage (width at the middle of the canopy/crown/foliage height)</b>	Average maximum distance between outer leaves of the foliage, measured at the middle of the canopy/crown/foliage height.	m
<b>Rows per plot</b>	Number of (treated) rows per plot. Double or multiple rows are considered as one as long as they are treated as single rows.	–
<b>Row length per plot</b>	Sum of lengths of all rows within a plot. In the case of double or multiple rows they are considered as single rows.	m

(Continues)

Table 11 (Continued)

Term	Definition	Unit
<b>Spacing between rows or row spacing</b>	In case of single rows: distance from the centre of one row to the next row. In case of double or multiple rows: distance from the middle of one double/multiple row to the middle of the next double/multiple row.	m
<b>Spacing within row</b> (spacing between tree/plants in the row)	Distance from tree/plant to the next tree/plant within a row.	m
<b>Leaf Wall Area (LWA)</b>	The area of the canopy/crown/foilage surface per ha ground area. Calculated using canopy/crown/foilage height and spacing between rows. Formula: <b>LWA per ha ground area (m<sup>2</sup>/ha ground area)</b> = canopy/crown/foilage height (m) × row sides applied (usually 2) × 10 000 m <sup>2</sup> /spacing between rows (m)	m <sup>2</sup> /ha
<b>Tree Row Volume (TRV)</b>	The cubic volume of the rows per ha ground area. Calculated using canopy/crown/foilage height, mid-width of the canopy/crown/foilage and spacing between rows. Formula: <b>TRV per ha ground area (m<sup>3</sup>/ha ground area)</b> = canopy/crown/foilage height (m) × mid-width of the crown (m) × 10 000 m <sup>2</sup> / spacing between rows (m)	m <sup>3</sup> /ha
<b>Globular Tree Row Volume (GTRV)</b>	The cubic volume of globular trees per ha ground area. Calculated using canopy/crown/foilage height, the globular diameter and spacing between rows. Formula: <b>GTRV per ha ground area (m<sup>3</sup>/ha ground area)</b> = canopy/crown/foilage height (m) × globular diameter (m) × 10 000 m <sup>2</sup> /spacing between rows (m)	m <sup>3</sup> /ha

Table 12. Application-related terms

Term	Definition	Unit
<b>Treated row width or spray band width</b>	The width of the horizontally sprayed band, usually indicating the width of the treated rows. <i>Application directed to the ground</i>	m
<b>Treated canopy/crown height (tCH) or treated Foliage Height (tFH) or spray band height</b>	The height of the vertically sprayed band, usually indicating the height of the treated leaf wall/crop. <i>Application directed vertically and/or partly upwards</i>	m
<b>Mid-width of the treated canopy/crown/foilage (width at the middle of the treated canopy/crown/foilage height)</b>	Average maximum distance between the outer leaves of the foliage, measured at the middle of the treated canopy/crown/foilage height.	m
<b>Treated Leaf Wall Area (tLWA)</b>	The area of the leaf wall/crop actually treated with the plant protection product. The tLWA may be smaller than the actual LWA, if calculated from a spray band height lower than the actual canopy/crown/foilage height, e.g. bunch applications in grapevine.  (Photograph B. Fiedler) Basic formula: <b>tLWA per ha ground area (m<sup>2</sup>/ha)</b> = spray band height (m) × row sides applied (usually 2) × 10 000 m <sup>2</sup> /spacing between rows (m) <i>The treated Leaf Wall Area can also be calculated from a row length instead of ha ground area. This calculation should be limited to efficacy trials since it does not allow conversion to the actually applied dose per ha.</i> Formula for trial plots: <b>tLWA per plot (m<sup>2</sup>)</b> = spray band height (m) × row sides applied (usually 2) × total length of all plot rows (m). <i>Both formulas can be used to calculate tLWA for efficacy trials.</i>	m <sup>2</sup> /ha

(Continues)



Table 12 (Continued)

This Standard notes that ‘per treated Leaf Wall Area’ is becoming a common dose expression method for the efficacy assessment of high growing crops, in particular for wall forming crops.

The 2016 EPPO Workshop ‘Harmonized dose expression for the zonal evaluation of plant protection products in high growing crops’ also concluded that ‘Leaf Wall Area (LWA) was an appropriate dose expression for evaluating plant protection products in pome fruit, grapevine and high growing vegetables’.

The tLWA may be smaller than the actual LWA of the crop, if calculated from a spray band height lower than the actual canopy/crown/foilage height, e.g. bunch applications on grapevine (see also Appendix 3, Section F1). It may also be slightly higher, e.g. due to the number of open nozzles on a spray boom.

#### Example

This example shows how the maximum tLWA is determined and how the dose can be adapted to an increasing canopy/crown/foilage.

Maximum dose per ha ground area: 2 kg/ha; the proposed dose is 1.25 kg/10 000 m<sup>2</sup> tLWA:  $(2/1.25) \times 10\,000 = 16\,000\text{ m}^2$  LWA/ha ground area can be treated efficiently with the dose of 2 kg/ha. For further detail refer to Table 12.

If the crop has a lower LWA, e.g. early in the season, accordingly lower doses per ha ground should be applied, e.g. if the crop which requires treatment has only 8000 m<sup>2</sup> tLWA per ha ground area, then only 1 kg of product per ha ground area needs to be applied to achieve a sufficient level of control. The dose per 10 000 m<sup>2</sup> tLWA is a constant value, determined from minimum effective dose trials.

### 1.2. Dose expression ‘per treated Tree Row Volume’

‘Per treated Tree Row Volume’ is currently the only dose expression which considers the third dimension of a high growing crop since it also considers the width of the crop in addition to canopy/crown/foilage height and spacing between rows.

To determine the treated Tree Row Volume (tTRV) per ha ground area, two crop related parameters and one application related parameter need to be recorded:

- Treated canopy/crown/foilage height = spray band height (needs to be measured before each application) (m).
- Mid-width of the treated canopy/crown/foilage (m).
- Spacing between rows (m).

The formula is:

**tTRV per ha ground area (m<sup>3</sup>/ha)** = spray band height (m) × mid-width of the treated canopy/crown/foilage (m) × 10 000 m<sup>2</sup>/spacing between rows (m).

This formula can be used for both farmers’ plots and efficacy trials.

A different formula can be used to calculate the tTRV of trial plots:

**tTRV per plot (m<sup>3</sup>)** = spray band height (m) × mid-width of the treated canopy/crown/foilage (m) × row length per plot (m).

When calculating the tTRV in this way, cropping density at the trial site (spacing between rows) is not considered.

The dose of a plant protection product should always be expressed ‘per 10 000 m<sup>3</sup> treated Tree Row Volume’.

This Standard notes that ‘per treated Tree Row Volume’ is an appropriate dose expression for globular trees.

In the case of globular trees with elliptical ground projected area, the mid-width of the treated canopy/crown across and along the row should be recorded (see Appendix 3). A specific dose expression for globular trees is still under development (‘treated Globular Tree Row Volume’).

### 1.3. Dose expression ‘per ha ground area and per m treated canopy/crown/foilage height’

‘Per ha ground area and per m treated canopy/crown height’ or ‘per ha ground area and per m treated foliage height’ are dose expressions which consider only crop height.

Only one crop parameter needs to be measured:

- Treated canopy/crown/foilage height = spray band height (needs to be measured before each application) (m).

The treated height should be recorded in every efficacy trial and at each application in high growing crops and only this value should be used to calculate the dose (see Appendix 3).

This dose expression can be implemented very easily in efficacy trials, as the relevant crop parameter is usually recorded in trials. However, crop density, i.e. spacing between rows, which may be highly variable in a crop even within a single country,<sup>1</sup> is not considered.

This Standard notes that this dose expression cannot substitute for other dose expressions such as ‘per tLWA’ and ‘per tTRV’, and therefore it should be restricted to cases where complete information about crop parameters is missing (historical data).

## 2. Dose expressions not considering crop structure, to be used only in addition to the dose expressions listed above (see section B2.2)

### 2.1. Dose expression ‘per ha (m<sup>2</sup>) ground area’

‘Dose per ha (m<sup>2</sup>) ground area’ is a dose expression which does not consider crop structure. Therefore, ‘dose per ha’ should not be used in trials and for efficacy evaluation in high growing crops, with two exceptions:

- Exception 1: At very early growth stages in high growing crops treatments may be applied directed downwards to the soil. In this case, the dose can be expressed per unit ground area.
- Exception 2: When the same crop is treated vertically in the greenhouse and horizontally in the field (e.g.

<sup>1</sup>For example, in viticulture spacing between grapevine rows may range from 1.8 up to 3.6 m (based on data from AT and DE), and may be only 1 m in some regions of France.

**Table 13.** Practical information on dose expressions used in high growing crops

Dose expression abbreviation	Dose to be expressed per...	Considers crop structure	Crop/site/application related parameters to be measured in the field	Conversion on trial level possible to:	Further practical information
Recommended dose expressions					
Dose per treated Leaf Wall Area tLWA	... 10 000 m <sup>2</sup> tLWA	Yes	<ul style="list-style-type: none"><li>Treated Canopy/crown/Foliage Height (spray band height)</li><li>Spacing between rows</li><li>Spray volume per 10 000 m<sup>2</sup> tLWA</li></ul>	Dose per ha ground area and per m tCH Dose per ha ground area Dose per hL	<ul style="list-style-type: none"><li>Easy to implement (only 2 parameters need to be measured)</li><li>Currently best approach for wall crops</li><li>Does not consider crop volume</li><li>Considered an appropriate dose expression for pome fruit, grapevine and high growing vegetables, ornamentals</li></ul>
Dose per treated Tree Row Volume tTRV	... 10 000 m <sup>3</sup> tTRV	Yes	<ul style="list-style-type: none"><li>Treated Canopy/crown/Foliage Height (spray band height)</li><li>Spacing between rows</li><li>Mid-width of the treated canopy/crown/foliage</li><li>Spray volume per 10 000 m<sup>3</sup> tTRV</li></ul>	Dose per 10 000 m <sup>2</sup> tLWA Dose per ha ground area and per m tCH Dose per ha ground area Dose per hL	<ul style="list-style-type: none"><li>Currently best approach for crops not forming a wall (e.g. globular trees)</li><li>More difficult to implement compared to tLWA (3 parameters to be measured)</li></ul>
Dose expression not recommended (useful for historical data)					
Dose per ha ground area and per m treated Canopy/Foliage Height ha/m tCH ha/m tFH	... ha/m tCH ... ha/m tFH	Yes (limited)	<ul style="list-style-type: none"><li>Treated Canopy Height (spray band height)</li><li>Spray volume per ha and per m of treated Canopy Height</li></ul>	Dose per ha ground area Dose per hL	<ul style="list-style-type: none"><li>Very easy to implement compared to tLWA and tTRV (one single parameter to be measured)</li><li>Common approach used in the past for high growing tree crops (e.g. pome fruit)</li><li>Does not consider crop area or volume</li><li>Does not consider row spacing</li><li>The use of this dose expression should be restricted to cases where complete information is missing (historical data) since it cannot substitute for other dose</li></ul>

(Continues)

(Continues)

Table 13 (Continued)

Crop/site/ application related					
Dose expression abbreviation	Dose to be expressed per...	Considers crop structure	parameters to be measured in the field	Conversion on trial level possible to:	Further practical information
expressions such as per 10 000 m <sup>2</sup> tLWA or per 10 000 m <sup>2</sup> tTRV. Assumptions can be made when spacing between the rows is not available.					
<b>Dose expressions not considering crop structure, to be used only in addition to dose expressions listed above</b>					
Dose per ha ground area	... ha	No	–	–	<ul style="list-style-type: none"><li>• Without recording of crop parameters no conversion possible</li><li>• Does not consider crop structure (area, volume, row spacing)</li><li>• Can only be related to crop parameters if the treated area (m<sup>2</sup> tLWA) or the treated volume (m<sup>3</sup> of tTRV) or the treated height (m tCH or m tFH) is recorded</li></ul>
Dose per hL (or %)	... hL	–	–	–	<ul style="list-style-type: none"><li>• Without recording of crop parameters and/or spray volume no conversion possible</li><li>• Not related to crop parameters if the spray volumes refer only to the ground area</li><li>• Can only be related to crop parameters if the spray volume is related to a treated area (ha ground area or m<sup>2</sup> tLWA) or to a treated volume (m<sup>3</sup> tTRV) or to a treated height (m tCH or m tFH)</li></ul>

**Table 14.** Overview of average Leaf Wall Area (m<sup>2</sup>) per ha in European apple orchards, and how spacing between rows and Canopy/Foliage Height influence the LWA

Row distance (m)	Canopy or foliage height (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<sup>2</sup> 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.

tomatoes, cucumbers). For the application to the field-grown crop, expression of the dose per ha is appropriate, but is not appropriate for the use in the greenhouse.

## 2.2. Dose expression 'per hL (%)' and 'concentration'

Concentration is usually expressed per hL (100 L) of water and is often written with the % symbol. However, concentration or percent (%) (as well as others such as ‰, ppm) is a dose expression lacking reference to the treated object.

Dose per hL (%) is the oldest expression of dose and is still very commonly used in registration certificates (labels), e.g. for globular crops, vegetables and ornamentals, and for products intended for non-professional users.

If only the spray volume per ha is recorded, the applied dose cannot be related to the crop structure, which is an essential need in high growing crops. It is therefore generally recognized that concentration (dose per hL, %, etc.) is no longer sufficient and should not be used in trials and for efficacy assessment in high growing crops.

For this to be a meaningful dose expression for efficacy trials, it is important that both the concentration *and* the spray volume are provided. To adapt the dose to the treated canopy, concentration rates must always be accompanied by the corresponding water volumes per treated canopy unit, e.g. L spray volume per ha/m tCH, per 10 000 m<sup>2</sup> tLWA, or per 10 000 m<sup>3</sup> tTRV.

For a single trial, the actually applied dose of plant protection product *per unit height/area/volume* can only be calculated if also the spray volume is recorded *per unit height/area/volume*: dose (kg or L per unit height/areal volume) = concentration (%, L/hL) × spray volume (L per unit height/areal volume)

## 3. Dose expression and possible exchanges of dose expressions ('dose conversion') in high growing crops

To convert between different types of dose expressions in a trial, it is necessary to measure or record the following crop structure and application parameters (at each application time):

- Row sides applied.
- Spacing between rows (row spacing).
- Treated canopy/crown/foliage height (spray band height).
- Mid-width of the treated canopy/crown/foliage.
- Applied spray volume (and not just the expected volume or a theoretical volume used as a calculation basis).

The following parameters are not needed to convert between dose expressions, but may be helpful to compare results, for example:

- Spacing within row (spacing between trees/plants in the row).
- Cropping system (single or multiple rows, training system).
- BBCH growth stage at application, and at assessment.
- Application equipment and its setup (nozzle type, size and distribution).<sup>2</sup>
- Application orientation.

Across countries and regions, different cropping systems lead to different LWA within the same crop. Table 14 shows the range of LWA per ha ground in apple orchards at various sites. Therefore, terms such as

<sup>2</sup>For dose conversion only the number of nozzles and distance between them is relevant (for historical data), if at all (to estimate spray band height if it was not clearly indicated in the trial report).

**Table 15.** Example table for inter-dose conversion calculations.

Dose expression in the trial	Example rate	Parameters recorded in the trial (example values)	Conversion possible to:	Conversion formula	Dose calculation
kg (L) product per hL	0.15 kg/hL = 0.15 %	<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li></ul>	Dose per ha ground area	Calculation of dose per ha:  Dose per ha = dose per hL (= %) ×spray volume per ha / 100	Dose per ha = 0.15×1 200/100 = 1.8 kg/ha
% concentration		<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li><li>Spray band height (2.5 m)</li></ul>	Dose per ha ground area and per m treated Canopy Height (tCH)	Calculation of dose per ha and per m tCH:  Dose per ha/m tCH = Dose per hL (= %) × spray volume per ha / 100 / spray band height	Dose per ha/m tCH = 0.15×1 200/100/2.5 = 0.72 kg/ha/m tCH
		<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li><li>Spray band height (2.5 m)</li><li>Spacing between rows (4 m)</li><li>Row sides applied (2)</li></ul>	Dose per 10 000 m <sup>2</sup> treated Leaf Wall Area (tLWA)	1. Calculation of tLWA per ha (m <sup>2</sup> /ha):  tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows  2. Calculation of dose per 10 000 m <sup>2</sup> tLWA:  Dose per 10 000 m <sup>2</sup> tLWA = dose per hL (or %) ×spray volume per ha / 100 × 10 000 / tLWA per ha	tLWA per ha = 2.5×2×10 000/4 = 12 500 m <sup>2</sup> /ha  Dose per 10 000 m <sup>2</sup> tLWA = 0.15×1 200/100×10 000/12 500 = 1.44 kg/10 000 m <sup>2</sup> tLWA
		<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li><li>Spray band height (2.5 m)</li><li>Mid-width of the treated canopy (1.5 m)</li><li>Spacing between rows (4 m)</li></ul>	Dose per 10 000 m <sup>3</sup> treated Tree Row Volume (tTRV)	1. Calculation of tTRV per ha (m <sup>3</sup> /ha):  tTRV per ha = spray band height × mid-width of the treated canopy × 10 000 / spacing between rows  2. Calculation of dose per 10 000 m <sup>3</sup> tTRV:  Dose per 10 000 m <sup>3</sup> tTRV = dose per hL × spray volume / 100 × 10 000 / tTRV per ha	tTRV per ha = 2.5×1.5×10 000/4 = 9 375 m <sup>3</sup> /ha  Dose per 10 000 m <sup>3</sup> tTRV = 0.15×1 200/100×10 000/9 375 = 1.92 kg/10 000 m <sup>3</sup> tTRV
kg (L) product per ha ground area	1.8 kg/ha	<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li></ul>	Dose per hL %	Calculation of dose per hL (or %):  Dose per hL = % = dose per ha / spray volume per ha × 100	Dose per hL = % = 1.8/1 200×100 = 0.15 kg/hL = 0.15 %
		<ul style="list-style-type: none"><li>Spray band height (2.5 m)</li></ul>	Dose per ha ground area and per m treated Canopy Height (tCH)	Calculation of dose per ha and per m tCH:  Dose per ha/m tCH = dose per ha / spray band height	Dose per ha/m tCH = 1.8/2.5 = 0.72 kg/ha/m tCH
		<ul style="list-style-type: none"><li>Spray band height (2.5 m)</li><li>Spacing between rows (4 m)</li><li>Row sides applied (2)</li></ul>	Dose per 10 000 m <sup>2</sup> treated Leaf Wall Area (tLWA)	1. Calculation of tLWA per ha (m <sup>2</sup> /ha):  tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows  2. Calculation of dose per 10 000 m <sup>2</sup> tLWA:  Dose per 10 000 m <sup>2</sup> tLWA = dose per ha × 10 000 / tLWA per ha	tLWA per ha = 2.5×2×10 000/4 = 12 500 m <sup>2</sup> /ha  Dose per 10 000 m <sup>2</sup> tLWA = 1.8×10 000/12 500 = 1.44 kg /10 000 m <sup>2</sup> tLWA
		<ul style="list-style-type: none"><li>Spray band height (2.5 m)</li><li>Mid-width of the treated canopy (1.5 m)</li><li>Spacing between rows (4 m)</li></ul>	Dose per 10 000 m <sup>3</sup> treated Tree Row Volume (tTRV)	1. Calculation of tTRV per ha (m <sup>3</sup> /ha):  tTRV per ha = spray band height × mid-width of the treated canopy × (10 000 / spacing between rows)  2. Calculation of dose per 10 000 m <sup>3</sup> tTRV:  Dose per 10 000 m <sup>3</sup> tTRV = dose per ha × 10 000 / tTRV per ha	tTRV per ha = 2.5×1.5×(10 000/4) = 9 375 m <sup>3</sup> /ha  Dose per 10 000 m <sup>3</sup> tTRV = 1.8×10 000/9 375 = 1.92 kg/10 000 m <sup>3</sup> tTRV
kg (L) product per ha ground area and per m treated Canopy Height	0.72 kg/ha/m tCH	<ul style="list-style-type: none"><li>Spray volume per ha (1 200 L)</li><li>Spray band height (2.5 m)</li></ul>	Dose per hL %	1. Calculation of spray volume per ha and per m tCH:  Spray volume per ha/m tCH = Spray volume per ha / spray band height  2. Calculation of dose per hL (or %):  Dose per hL = % = dose per ha/m tCH / spray volume per ha/m tCH × 100	Spray volume per ha/m tCH = 1 200/2.5 = 480 L/ha/m tCH  Dose per hL = % = 0.72/480×100 = 0.15 kg/hL = 0.15 %
				1. Calculation of dose per ha:  Dose per ha = dose per ha/m tCH × spray band height  2. Calculation of dose per hL (or %):  Dose per hL = % = dose per ha / spray volume per ha × 100	Dose per ha = 0.72×2.5 = 1.8 kg/ha  Dose per hL = % = 1.8/1 200×100 = 0.15 kg/hL = 0.15 %
		<ul style="list-style-type: none"><li>Spray volume per ha and per m tCH (480 L)</li></ul>		Calculation of dose per hL (or %):  Dose per hL = % = dose per ha/m tCH / spray volume per ha/m tCH × 100	Dose per hL = % = 0.72/480×100 = 0.15 kg/hL = 0.15 %
		<ul style="list-style-type: none"><li>Spray band height (2.5 m)</li></ul>	Dose per ha ground area	1. Calculation of dose per ha:  Dose per ha = dose per ha/m tCH × spray band height	Dose per ha = 0.72×2.5 = 1.8 kg/ha

(Continues)



Table 15 (Continued)

Dose expression in the trial	Example rate	Parameters recorded in the trial (example values)	Conversion possible to:	Conversion formula	Dose calculation
<b>kg (L) product per ha ground area and per m treated Canopy Height</b>	0.72 kg/ha/m tCH	<ul style="list-style-type: none"> <li>Spray band height (2.5 m)</li> <li>Spacing between rows (4 m)</li> <li>Row sides applied (2)</li> </ul>	Dose per 10 000 m <sup>2</sup> tLWA	<b>1. Calculation of tLWA per ha (m<sup>2</sup>/ha):</b> tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows  <b>2. Calculation of dose per ha:</b> Dose per ha = dose per ha/m tCH × spray band height  <b>3. Calculation of dose per 10 000 m<sup>2</sup> tLWA:</b> Dose per 10 000 m <sup>2</sup> tLWA = dose per ha × 10 000 / tLWA per ha	tLWA per ha = 2.5×2×10 000/4 = <b>12 500 m<sup>2</sup>/ha</b>  Dose per ha = 0.72×2.5 = <b>1.8 kg/ha</b>  Dose per 10 000 m <sup>2</sup> tLWA = 1.8×10 000/12 500 = <b>1.44 kg/10 000 m<sup>2</sup> tLWA</b>
		<ul style="list-style-type: none"> <li>Spacing between rows (4 m)</li> <li>Row sides applied (2)</li> </ul>		<b>1. Calculation of tLWA per ha and per m tCH:</b> tLWA per ha and per m tCH = spray band height (1 m) × row sides applied × 10 000 / spacing between rows  <b>2. Calculation of dose per 10 000 m<sup>2</sup> tLWA</b> Dose per 10 000 m <sup>2</sup> tLWA = Dose per ha/m tCH / tLWA per ha and per m tCH × 10 000	tLWA per ha and per m tCH = 1×2×10 000/4 = <b>5 000 m<sup>2</sup>/ha/m tCH</b>  Dose per 10 000 m <sup>2</sup> tLWA = 0.72/5 000×10 000 = <b>1.44 kg/10 000 m<sup>2</sup> tLWA</b>
		<ul style="list-style-type: none"> <li>Spray band height (2.5 m)</li> <li>Mid-width of the treated canopy (1.5 m)</li> <li>Spacing between rows (4 m)</li> </ul>	Dose per 10 000 m <sup>3</sup> treated Tree Row Volume (tTRV)	<b>1. Calculation of tTRV per ha (m<sup>3</sup>/ha):</b> tTRV per ha = spray band height × mid-width of the treated canopy × 10 000 / spacing between rows  <b>2. Calculation of dose per ha:</b> Dose per ha = dose per ha/m tCH × spray band height  <b>3. Calculation of dose per 10 000 m<sup>3</sup> tTRV:</b> Dose per 10 000 m <sup>3</sup> tTRV = dose per ha × 10 000 / tTRV per ha	tTRV per ha ground area = 2.5×1.5×10 000/4 = <b>9 375 m<sup>3</sup>/ha</b>  Dose per ha = 0.72×2.5 = <b>1.8 kg/ha</b>  Dose per 10 000 m <sup>3</sup> tTRV = 1.8×10 000/9 375 = <b>1.92 kg/10 000 m<sup>3</sup> tTRV</b>
		<ul style="list-style-type: none"> <li>Mid-width of the treated canopy (1.5 m)</li> <li>Spacing between rows (4 m)</li> </ul>		<b>1. Calculation of tTRV (m<sup>3</sup>) per ha and per m tCH:</b> tTRV per ha and per m tCH = spray band height (1 m) × mid-width of the treated canopy × 10 000 / spacing between rows  <b>2. Calculation of dose per 10 000 m<sup>3</sup> tTRV:</b> Dose per 10 000 m <sup>3</sup> tTRV = Dose per ha/m tCH / tTRV per ha / m tCH × 10 000	tTRV per ha and per m tCH = 1×1.5×10 000/4 = <b>3 750 m<sup>3</sup>/ha/m tCH</b>  Dose per 10 000 m <sup>3</sup> tTRV = 0.72/3 750×10 000 = <b>1.92 kg/10 000 m<sup>3</sup> tTRV</b>
<b>kg (L) product per 10 000 m<sup>2</sup> treated Leaf Wall Area (tLWA)</b>	1.44 kg / 10 000 m <sup>2</sup> tLWA	<ul style="list-style-type: none"> <li>Spray band height (2.5 m)</li> <li>Spacing between rows (4 m)</li> <li>Row sides applied (2)</li> <li>Spray volume per ha (1 200 L)</li> </ul>	Dose per hL %	<b>1. Calculation of tLWA per ha (m<sup>2</sup>/ha):</b> tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows  <b>2. Calculation of dose per hL (or %):</b> Dose per hL = % = dose per 10 000 m <sup>2</sup> tLWA × tLWA per ha / 10 000 / spray volume × 100  <b>Calculation of dose per hL (or %):</b> Dose per hL = % = dose per 10 000 m <sup>2</sup> tLWA / spray volume per 10 000 m <sup>2</sup> tLWA × 100	tLWA per ha = 2.5×2×10 000/4 = <b>12 500 m<sup>2</sup>/ha</b>  Dose per hL = % = 1.44×12 500/10 000/1 200×100 = <b>0.15 kg/hL = 0.15 %</b>
		<ul style="list-style-type: none"> <li>Spray volume per 10 000 m<sup>2</sup> tLWA (960 L)</li> </ul>		Dose per hL = % = 1.44/960×100 = <b>0.15 kg/hL = 0.15 %</b>	Dose per hL = % = 1.44/960×100 = <b>0.15 kg/hL = 0.15 %</b>
		<ul style="list-style-type: none"> <li>Spray band height (2.5 m)</li> <li>Spacing between rows (4 m)</li> <li>Row sides applied (2)</li> </ul>	Dose per ha ground area	<b>1. Calculation of tLWA per ha (m<sup>2</sup>/ha):</b> tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows  <b>2. Calculation of dose per ha:</b> Dose per ha = dose per 10 000 m <sup>2</sup> tLWA × tLWA per ha / 10 000	tLWA per ha = 2.5×2×10 000/4 = <b>12 500 m<sup>2</sup>/ha</b>  Dose per ha = 1.44×12 500/10 000 = <b>1.8 kg/ha</b>

(Continues)

Table 15 (Continued)

Dose expression in the trial	Example rate	Parameters recorded in the trial (example values)	Conversion possible to:	Conversion formula	Dose calculation
kg (L) product per 10 000 m <sup>2</sup> treated Leaf Wall Area (tLWA)	1.44 kg / 10 000 m <sup>2</sup> tLWA	• tLWA per ha ground area (12 500 m <sup>2</sup> )	Dose per ha ground area	Calculation of dose per ha: Dose per ha = dose per 10 000 m <sup>2</sup> tLWA × tLWA per ha / 10 000	Dose per ha = 1.44×12 500/10 000 = 1.8 kg/ha
		• Spray band height (2.5 m) • Spacing between rows (4 m) Row sides applied (2)	Dose per ha ground area and per m treated Canopy Height (tCH)	1. Calculation of tLWA per ha (m <sup>2</sup> /ha): tLWA per ha = spray band height × row sides applied × 10 000 / spacing between rows 2. Calculation of dose per ha and per m tCH: Dose per ha/m tCH = dose per 10 000 m <sup>2</sup> tLWA × tLWA per ha / 10 000 / spray band height Calculation of dose per ha and per m tCH: Dose per ha/m tCH = dose per 10 000 m <sup>2</sup> tLWA × tLWA per ha / 10 000 / spray band height	tLWA per ha = 2.5×12 500/4 = 12 500 m <sup>2</sup> /ha Dose per ha/m tCH = 1.44×12 500/10 000/2.5 = 0.72 kg/ha/m tCH
		• tLWA per ha ground area (12 500 m <sup>2</sup> /ha) • Spray band height (2.5 m)			Dose per ha/m tCH = 1.44×12 500/10 000/2.5 = 0.72 kg/ha/m tCH
		• Mid-width of the treated canopy (1.5 m) • Row sides applied (2)	Dose per 10 000 m <sup>2</sup> treated Tree Row Volume (tTRV)	Calculation of dose per 10 000 m <sup>3</sup> tTRV: Dose per 10 000 m <sup>3</sup> tTRV = dose per 10 000 m <sup>2</sup> tLWA × row sides applied / mid-width of the treated canopy	Dose per 10 000 m <sup>3</sup> tTRV = 1.44×2/1.5 = 1.92 kg/10 000 m <sup>3</sup> tTRV
kg (L) product per 10 000 m <sup>3</sup> treated Tree Row Volume (tTRV)	1.92 kg/ 10 000 m <sup>3</sup> tTRV	• Spray band height (2.5 m) • Spacing between rows (4 m) • Mid-width of the treated canopy (1.5 m) • Spray volume per ha (1 200 L)	Dose per hL %	1. Calculation of treated Tree Row Volume per ha (m <sup>3</sup> /ha): tTRV per ha = spray band height × mid-width of the treated canopy × 10 000 / spacing between rows 2. Calculation of dose per hL (or %): Dose per hL = % = dose per 10 000 m <sup>3</sup> tTRV × tTRV per ha ground area / 10 000 / spray volume per ha × 100 Calculation of dose per hL (or %): Dose per hL = % = dose per 10 000 m <sup>3</sup> tTRV / spray volume per 10 000 m <sup>3</sup> tTRV × 100	tTRV per ha = 2.5×1.5×10 000/4 = 9 375 m <sup>3</sup> /ha Dose per hL = % = 1.92×9 375/10 000/1 200×100 = 0.15 kg/hL = 0.15 % Dose per hL (%) = 1.92/1 280×100 = 0.15 kg/hL = 0.15 %
		• Spray volume per 10 000 m <sup>3</sup> tTRV (1 280 L)			
		• Spray band height (2.5 m) • Spacing between rows (4 m) • Mid-width of the treated canopy (1.5 m)	Dose per ha ground area	1. Calculation of treated Tree Row Volume (m <sup>3</sup> /ha): tTRV per ha = spray band height × mid-width of the treated canopy × 10 000 / spacing between rows 2. Calculation of dose per ha: Dose per ha = dose per 10 000 m <sup>3</sup> tTRV × tTRV per ha ground area / 10 000	tTRV per ha = 2.5×1.5×10 000/4 = 9 375 m <sup>3</sup> /ha Dose per ha = 1.92×9 375/10 000 = 1.8 kg/ha
		• Spray band height (2.5 m) • Spacing between rows (4 m) • Mid-width of the treated canopy (1.5 m)	Dose per ha ground area and per m treated Canopy Height (tCH)	1. Calculation of tTRV per ha (m <sup>3</sup> /ha): tTRV per ha = spray band height × mid-width of the treated canopy × 10 000 / spacing between rows 2. Calculation of dose per ha and per m tCH: Dose per ha/m tCH = dose per 10 000 m <sup>3</sup> tTRV × tTRV per ha / 10 000 / spray band height	tTRV per ha = 2.5×1.5×10 000/4 = 9 375 m <sup>3</sup> /ha Dose per ha/m tCH = 1.92×9 375/10 000/2.5 = 0.72 kg/ha/m tCH
		• Mid-width of the treated canopy (1.5 m) • Row sides applied (2)	Dose per 10 000 m <sup>2</sup> treated Leaf Wall Area (tLWA)	Calculation of dose per 10 000 m <sup>2</sup> tLWA: Dose per 10 000 m <sup>2</sup> tLWA = dose per 10 000 m <sup>3</sup> tTRV × mid-width of the treated canopy / row sides applied	Dose per 10 000 m <sup>2</sup> tLWA = 1.92×1.5/2 = 1.44 kg/10 000 m <sup>2</sup> tLWA

In GEP-trial reports trial conditions, in particular site-specific parameters as well as applied doses and spray volumes must be recorded (EPPO PP 1/181). Providing that all necessary parameters have been recorded, conversion between dose expressions can easily be made. If not all parameters were recorded, conversion of doses is limited.

tCH, treated canopy/crown height = treated foliage height = spray band height; tLWA, treated Leaf Wall Area; tTRV, treated Tree Row Volume. The term canopy substitutes canopy/crown/foliage.

“ha” always refers to the ground area, m<sup>2</sup> to tLWA, m<sup>3</sup> to tTRV.

‘standard orchard’ or ‘standard vineyard’ should not be used.

### Appendix 3 – Standard measurement procedure in efficacy trials

This appendix presents harmonized procedures on the measurement of individual plant parameters in the field to facilitate consistent approaches. Many figures are included as visual guidance.

**Treated area** is the oversprayed plane between working nozzles and targets and is illustrated in Fig. A1. **Treated Leaf Wall Area** and relevant parameters are illustrated in Fig. A2. The basic formula for treated Leaf Wall Area is:

tLWA per ha ground area ( $\text{m}^2/\text{ha}$ ) = spray band height (m)  $\times$  row sides applied  $\times$  10 000 ( $\text{m}^2$ )/spacing between rows (m)

**Treated Leaf Wall Area (trial plots)** and relevant parameters are illustrated in Fig. A3. The formula for trial plots is:

tLWA per plot ( $\text{m}^2$ ) = spray band height (m)  $\times$  row sides applied  $\times$  row length per plot (m)

**Treated Tree Row Volume** and relevant parameters are illustrated in Fig. A4. The basic formula is:

tTRV per ha ground area ( $\text{m}^3/\text{ha}$ ) = spray band height (m)  $\times$  mid-width of the treated canopy (m)  $\times$  10 000  $\text{m}^2$ /spacing between rows (m)

**Treated Tree Row Volume (trial plots)** and relevant parameters are illustrated in Fig. A5. The formula for trial plots is:

tTRV per plot ( $\text{m}^3$ ) = spray band height (m)  $\times$  mid-width of the treated canopy (m)  $\times$  row length per plot (m)

The **important crop parameters** for any trial in high growing crops are:

- Row sides applied (usually 2).
- Spacing between rows (row spacing).
- Treated Canopy/crown/Foliage Height (spray band height).
- Mid-width of the treated canopy/crown/foliage.



Fig. A2 Treated Leaf Wall Area.



Fig. A3 Treated Leaf Wall Area (trial plots).

- Applied spray volume (and not just the expected volume or a theoretical volume used as a calculation basis).

For the conduct and reporting of efficacy evaluation trials, including good experimental practice, reference is made to EPPO PP 1/181.

Further parameters which may be helpful (see also Appendix 2, Section 3):



Fig. A1 Treated area is the oversprayed plane between working nozzles and targets.

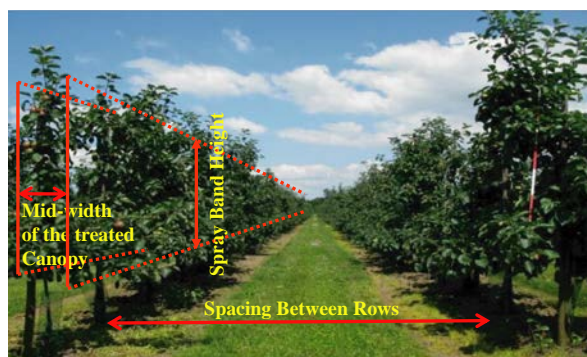


Fig. A4 Treated Tree Row Volume parameters.



Fig. A5 Treated Tree Row Volume (trial plots) parameters.

- Spacing within row (spacing between trees/plants in the row).
- Cropping system (single or multiple rows, training system).
- BBCH growth stage at application and at assessment.
- Application equipment and its setup (nozzle type, size and distribution).
- Application orientation.

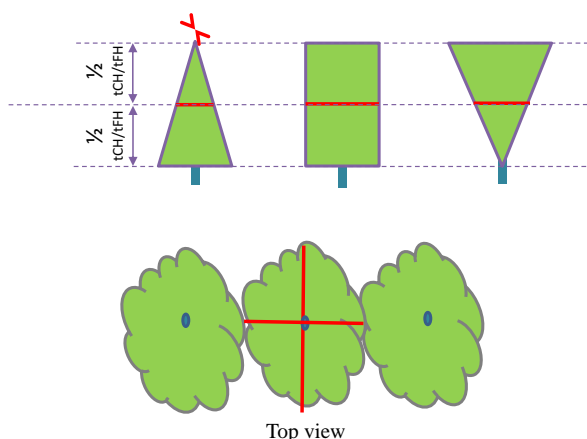


Fig. A6 Measurement of mid-width of the treated canopy/crown/foilage in vertical canopy, V-shape, rectangular and globular shape.

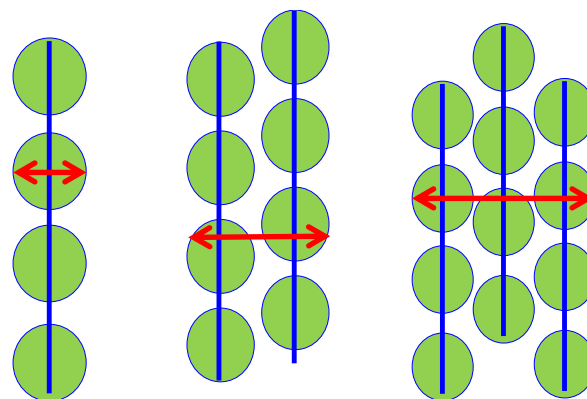


Fig. A7 Measurement of mid-width of the treated canopy/crown/foilage in single, double and multiple rows.

Crop parameters additionally to be given for tLWA/tTRV calculation in trial plots are:

- Row length per plot (sum of length of all rows of a plot).
- Rows per plot.

For the measurement of crop related parameters, it is to be noted that:

- the crop related parameters reported in efficacy trials are mean values calculated based on at least 10 measurements, made on the most representative plants, randomly distributed within the trial site/plot.

**Measurement of mid-width of the treated canopy/crown/foilage** for vertical canopy, V-shaped trees including the middle of the treated canopy/crown/foilage height is illustrated in Fig. A6. The mid-width (diameter) of the treated canopy/crown/foilage should be determined at the middle of the treated canopy/crown/foilage height (tCH/tFH) of the particular plant being measured.

Measurement for globular shaped trees is also illustrated in Fig. A6. The globular diameter should be determined based on the average distance between outer leaves of the globular tree/plant, measured at the middle of the treated canopy/crown/foilage height (tCH/tFH), along and across the row of plants. globular diameter = (min. width + max. width)/2.

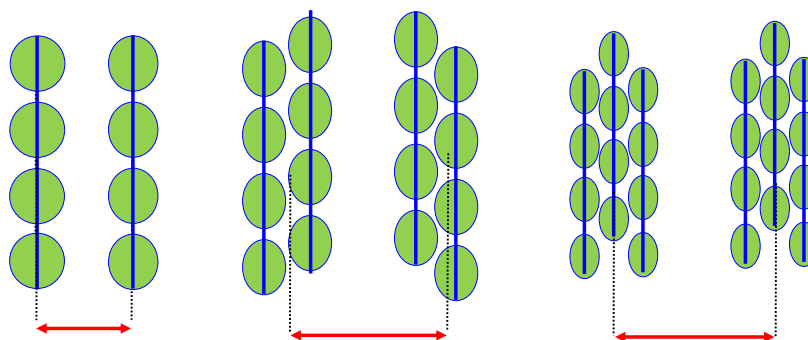
Measurement of the mid-width of the treated canopy/crown/foilage in single, double and multiple rows is illustrated in Fig. A7. Mid-width of the treated canopy/crown/foilage should be taken at middle of the treated canopy/crown/foilage height (tCH/tFH).

Extreme shoots in height and in width which could impact the total Canopy Height should not be taken into account. Parameters to be measured in metres.

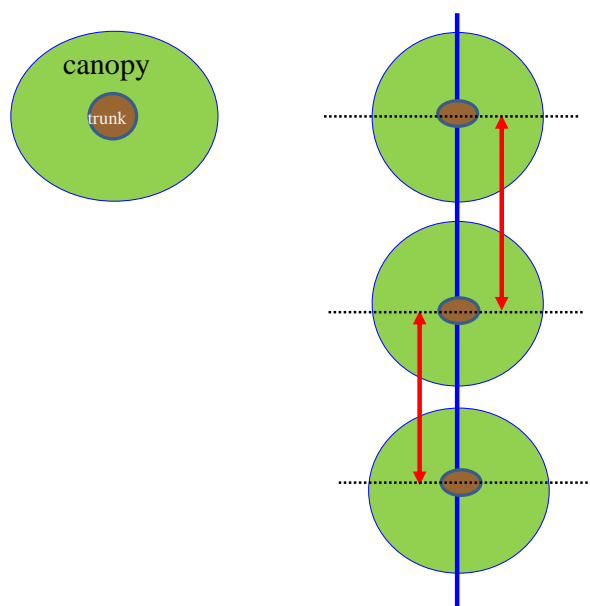
**Measurement of spacing between rows** (row spacing) in single, double and multiple rows is illustrated in Fig. A8. Row spacing is to be measured in meters. **Measurement of spacing within row** is illustrated in Fig. A9.

For band or row application, the **measurement of treated row width** (spray band width) is illustrated in Fig. A10 and the formula is:





**Fig. A8** Measurement of spacing between rows (row spacing).



**Fig. A9** Measurement of spacing within row.

treated row area (ha) = treated row width (m) × 1 ha/  
spacing between rows (m)

Row side application is illustrated in Fig. A11. In all cases row sides applied = 2. The number of row sides



**Fig. A10** Band or row application: measurement of treated row width = spray band width. Photograph: R. Steffek.

applied corresponds to the number of sides of the crop row on which the plant protection product is applied.

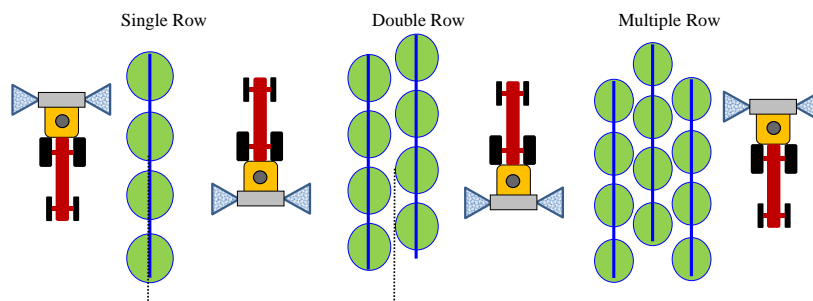
**Measurement of the treated canopy/crown/foilage height (spray band height):** Fig. A12 illustrates the Canopy Height which is actually sprayed. Figure A13 illustrates the measurement of the upper limit, which is the average of the highest treated leaves/branches and depends on the spray height of the equipment used and the height of the target. Figure A14 illustrates the measurement of the lower limit. The height of the untreated trunk should be subtracted. The treated canopy/crown/foilage height (spray band height) is the canopy /crown/foilage height that is actually sprayed (it can be less than the total Canopy Height, e.g. when only a part of the Canopy Height is treated) and this is illustrated in Fig. A15.

#### Measurement of crop parameters:

- in pome fruits, vertical canopy (Fig. A16)
- in stone fruits, V-shape (Fig. A17)
- in stone fruits, globular shape (Fig. A18)
- in grapes, 'trellised' (Fig. A19)
- in grapes, "goblet" (Fig. A20) or "pergola" (Fig. A21).

Only treated canopy/crown/foilage height is relevant. It should reflect the height of the treated area (the trunk is to be disregarded in most cases). An average of the 10 most representative trees of the trial should be recorded.

Examples of recommended and not recommended practices for vertical band spraying in grapevine are shown in Figs A22–A24.



**Fig. A11** Row sides application in single, double and multiple rows.



**Fig. A12** Measurement of the treated canopy/crown/foilage height. The area between the white lines illustrates the Canopy Height which is actually sprayed.



**Fig. A13** Measurement of the treated canopy/crown/foilage height. The red line illustrates the measurement of the upper limit.

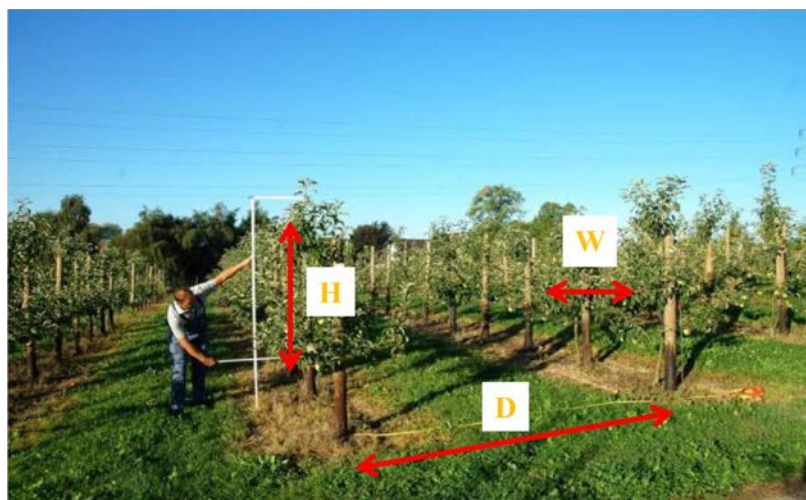




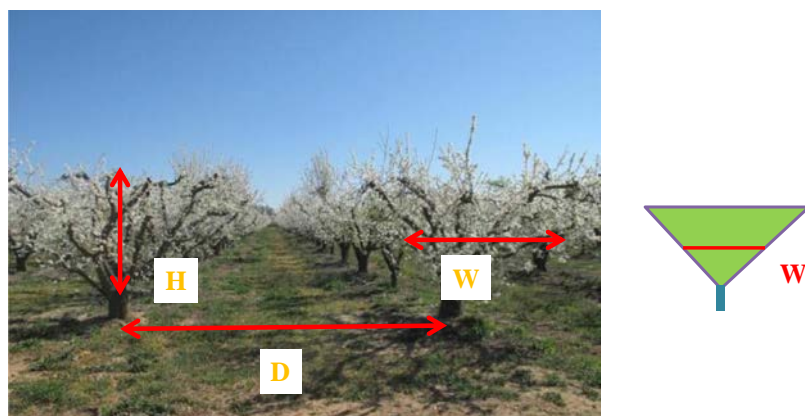
**Fig. A14** Measurement of the treated canopy/crown/foilage height. The dotted red line illustrates the measurement of the lower limit.



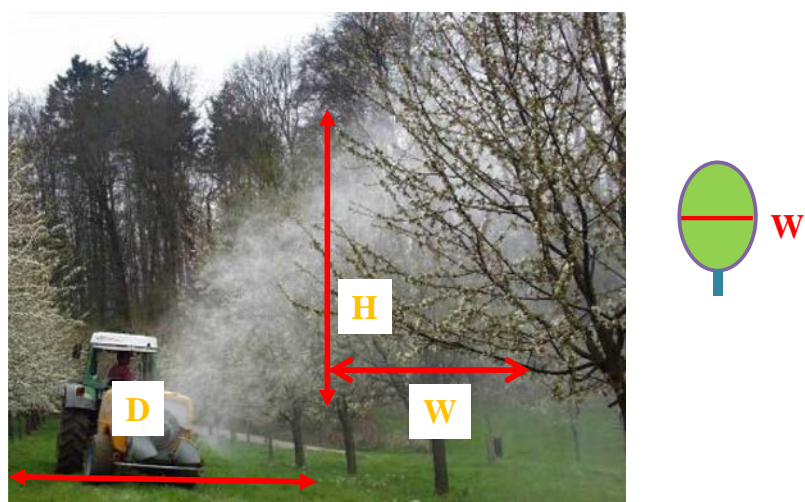
**Fig. A15** Measurement of the treated canopy/crown/foilage height. The red line illustrates the treated height which is actually sprayed.



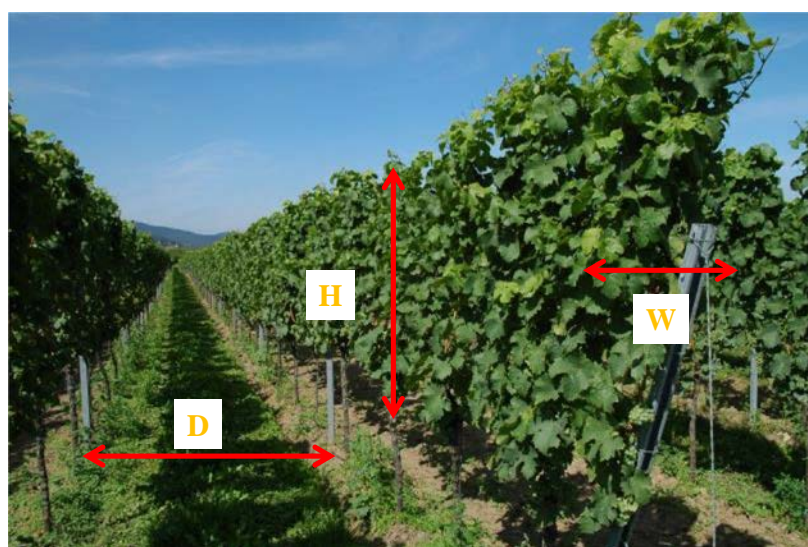
**Fig. A16** Measurement of crop parameters in pome fruits – vertical canopy. H, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: B. Toews.



**Fig. A17** Measurement of crop parameters stone fruits – V-shape. H, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: Agroscope viti 2005/6.

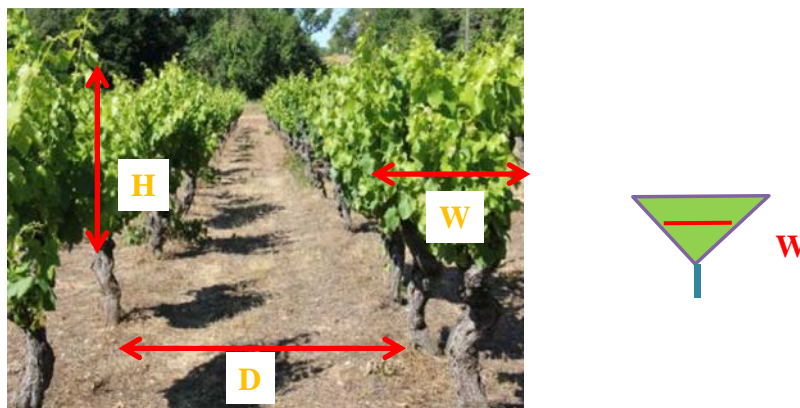


**Fig. A18** Measurement of crop parameter in stone fruits – globular shape. H, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: B. Toews.

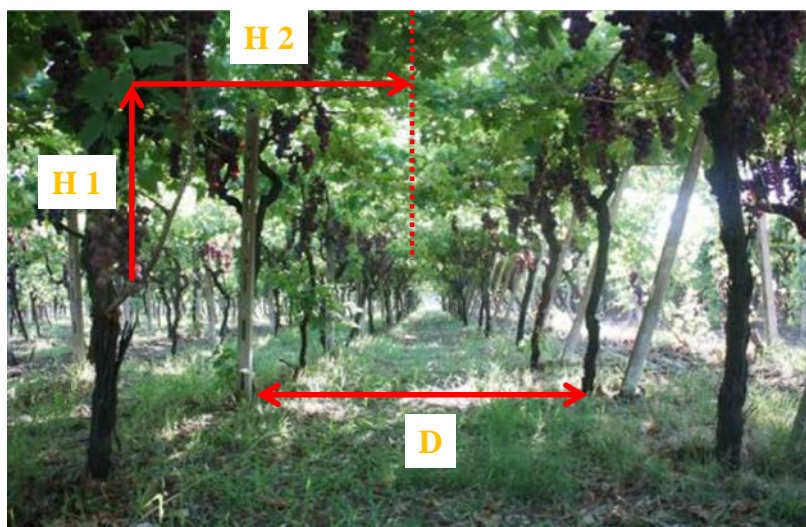


**Fig. A19** Measurement of crop parameters in grapes “trellised”. H, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: B. Toews.





**Fig. A20** Measurement of crop parameters in grapes “goblet”. H, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: Dupont.



**Fig. A21** Measurement of crop parameters in grapes “pergola”. H1 + H2, treated canopy/crown/foilage height (spray band height); D, spacing between rows (row spacing); W, mid-width of the treated canopy/crown/foilage. Photograph: M. Troisi.



**Fig. A22** Good practice for vertical band spraying. An example of grapevine in BBCH 09-11. In this example, the measured spray band height (treated canopy/crown/foilage height) is 50 cm, therefore product calculated based on 50 cm. Product applied on 50 cm – correct (large) distance between nozzle and target area – straight movement.



**Fig. A23** Practice which is *not* recommended for vertical band spraying. An example of grapevine in BBCH 09-11. In this example, the measured spray band height (treated canopy/crown/foilage height) = 20 cm, therefore product calculated based on 20 cm, product applied on 20 cm – small distance between nozzle and target area – curved movement.



**Fig. A24** Practice which is *not* recommended for vertical band spraying. An example of grapevine in BBCH 09-11. In this example, the measured spray band height (treated canopy/crown/foilage height) = 20 cm, therefore product calculated based on 20 cm, but product applied on 50 cm, because of too large distance between nozzle and target area.