Measurement protocol to determine drift reduction of nozzles for downward-directed and upward/sideways-directed spraying

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Dutch Ministry of Infrastructure and Water Management
in consultation with
Bestuurlijk Overleg Open Teelt (BOOT) [Administrative Coordination on Open Cultivation]

Article 1 General

1. The degree of drift reduction delivered by a certain type and size of the nozzle and the nozzle's classification into Drift-Reducing Nozzle classes is determined using the test method specified in Articles 2 through 9 or a similar test method.
2. Droplet size measurements are used to identify the droplet size characteristics DV10, DV50 (VMD), DV90 and V100 of the nozzles.
3. Nozzles' drift reduction is determined based on the droplet size characteristic of V100.
4. The test referred to in the first paragraph is conducted by an independent expert institute.
5. If the test is not conducted by an independent expert institute, the accuracy of the measurements performed as part of this measurement protocol must be validated by an independent expert institute and the report thereof must be appended to the written report specified in Article 9.

Article 2 Spray

For the test, tap water is used as spraying liquid.

Article 3 Test nozzles, reference nozzle and drift reduction class threshold nozzles

1. In order to determine the drift reduction of a nozzle from a certain manufacturer, of a certain type, and of a certain size, use is made of:
   a. test nozzles
   b. a reference nozzle, in this case a fine/medium-category threshold nozzle according to the British Crop Protection Council (BCPC) classification system (Lurmark 31-030-F110) adopted on April 7 and 8, 1997 for the testing of nozzles intended for downward-directed spraying.
   c. a reference nozzle (Albuz ATR80 Lilac) and four drift reduction class threshold nozzles, to test nozzles intended for upward/sideways-directed spraying.
2. The drift reduction class threshold nozzles specified in the first paragraph, under c, are intended for the following drift reduction class:
   a. 50%, TeeJet DG 80-02
   b. 75%, Albuz AVI 80-015
   c. 90%, Lechler ID 90-01
   d. 95%, Albuz TVI 80-025
3. The versions of the test nozzles, reference nozzle, and drift reduction class threshold nozzles specified in the first paragraph, under c, that were used to perform the measurements are selected based on the procedure described in Article 4.

Article 4 Nozzle selection

1. The test nozzles specified in Article 3, first paragraph, under a, and the reference nozzle and drift reduction class threshold nozzles as specified in Article 3, first paragraph, under c, are selected based on the procedure described in the second, third, fourth, and fifth paragraph.
2. A random batch of ten unused and undamaged nozzles is used for each nozzle of a certain type and size, for the reference nozzle, and for each drift reduction class threshold nozzle.
3. The nozzles' flow rate is measured in terms of litres per minute.
4. The flow rate is measured:
   a. at a spray pressure of 3 bar for test nozzles intended for downward-directed spraying, and
   b. at a spray pressure of 7 bar for test nozzles, the reference nozzle, and drift reduction class threshold nozzles intended for upward/sideways-directed spraying.
5. The median of the flow rates for the test nozzles, reference nozzle, and drift reduction class threshold nozzles is calculated.
6. The three nozzles with a flow rate that is the closest to the median are used as the test nozzles specified in Article 3, first paragraph, under c, and as the reference nozzle and drift reduction class threshold nozzles specified in Article 3, first paragraph, under c.
7. For nozzles used for downward-directed spraying, measurements on a patternator with a gutter width of no more than 10 cm must show that the transversal distribution of the spray of the composite spectrum produced by the combination of nozzle, spray pressure, nozzle distance, and nozzle height is evenly spread, whereby the coefficient of variation must not exceed 10%.

Article 5 Droplet size measuring preconditions

1. Droplet size measurements with test nozzles, reference nozzles, and drift reduction class threshold nozzles are conducted based on the test method detailed in Article 6.
2. During the measuring, the pressure range specified by the nozzle manufacturer is used, whereby measurements are taken within this pressure range in steps of no more than 1 bar each.
3. For droplet size measurements on non-hydraulic nozzles, such as nozzles that mix air and liquid and disc atomisers, the manufacturer's nozzle settings are maintained.
4. A spray pressure of 3 bar is used for droplet size measurements on the reference nozzle for downward-directed spraying.
5. A spray pressure of 7 bar is used for droplet size measurements on the reference nozzle for upward/sideways-directed spraying.
6. The following spray pressures are used for droplet size measurements on the drift reduction class threshold nozzles for upward/sideways-directed spraying.
   a. 7 bar for TeeJet DG 8002
   b. 7 bar for Albuz AVI 80015
   c. 5 bar for Lechler ID 90-01
   d. 7 bar for Albuz TVI 80025
7. The droplet size measurements on the reference nozzles specified in Article 3, first paragraph, under b and c, and on the drift reduction class threshold nozzles specified in Article 3, first paragraph, under c, are conducted immediately after the droplet size measurements on the test nozzles.
8. Droplet size measurements on the test nozzles, reference nozzles, and drift reduction class threshold nozzles are conducted using the same measuring equipment and measurement settings, and in the same environmental conditions.
9. The droplet size measurements are conducted at an ambient temperature of 20°C (± 1°C) and 70% (± 5%) relative humidity and a water temperature of 20°C (± 1°C), whereby the difference between ambient temperature and water temperature must not exceed 5°C.

Article 6 Droplet size measuring

1. Droplet size measurements on the test nozzles, reference nozzles, and drift reduction class threshold nozzles are conducted at the same height at a distance of between 0.3m and 0.5m below the nozzle aperture.
2. A minimum measurement height of 0.5 m above the ground is maintained during the measuring.
3. The nozzles spray vertically in a downward direction.
4. The measuring is done in such a way that a representative part of the spray cone is sampled.
5. The droplets are measured in the spray cone.
6. The spray cone is scanned along a minimum of five lanes.
7. The measuring pattern has been arranged in a way that is ensured that the lanes are spread evenly across the full width of the cone and run parallel to the main axis of the elliptic cross-section of the spray cone.
8. The middle line runs through the centre of the spray cone.
9. The lanes are evenly spread over the full horizontal cross-section of the cone.
10. When scanning one lane at a time, there will be lane changes outside the spray cone.
11. The horizontal scanning speed does not exceed 5% of the average vertical droplet speed at measuring height.
12. The requirement from the eleventh article will be met in any case if 10,000 droplets per nozzle have been measured.
13. The nozzles specified in Article 3, third paragraph, are each measured three times.
14. In case of dual fan nozzles, both spray cones from the test nozzles must be measured individually, as specified in the first through the thirteenth paragraph, whereby the spray cone is sprayed vertically in a downward direction.
15. For the classification of nozzles intended for downward-directed spraying into the Drift-Reducing Nozzle classes of 50%, 75%, 90%, and 95%, droplet speeds are also measured for the reference nozzle and the test nozzles.
16. These droplet speeds specified in the fifteenth paragraph are measured along the central axis under the nozzle at distances of 3 cm, 6 cm, 9 cm, 12 cm, 15 cm, 20 cm, 25 cm, and 30 cm.

Article 7 Identifying droplet size characteristics

1. The results of the droplet size measurements are presented as droplet size characteristics DV10, DV50 (VMD), DV90, and V100.
2. The average of the results of the measurements conducted on the three test nozzles, reference nozzles, and drift reduction class threshold nozzles is calculated for each droplet size characteristic and is used as the value of the respective droplet size characteristics.
3. If the spread between droplet size measurements for calculation of the DV10 and the DV50 is over 5%, additional measurements have to be performed.

Article 8 Classification into Drift-Reducing Nozzle classes

1. For the classification of nozzles for downward-directed spraying into the Drift-Reducing Nozzle class (DRN class; in Dutch DRD-klasse) of 75%, 90%, and 95%, the drift reduction of nozzles is calculated based on the results of the droplet size and droplet speed measurements on the test nozzles and the reference nozzle using the IDEFICS drift model or a similar model.
2. A nozzle of a certain make, type, and size intended for downward-directed spraying and used for field spraying is classified into Drift-Reducing Nozzle class:
    a. 50% if the V100 of the test nozzle at a certain spray pressure is at least 50% lower than the V100 of the reference nozzle tested;
    b. 75%, 90% or 95% if the calculation using the IDEFICS or similar drift model based on droplet size and droplet speed measured shows that at least 75%, 90%, or 95% drift position reduction is achieved at a certain spray pressure compared to the reference nozzle used. The nozzle is classified into the Drift-Reducing Nozzle class for that spray pressure with the associated threshold value of 50%, 75%, 90%, of 95%.
3. A nozzle of a certain type and size, intended for use for upward/sideways-directed spraying, of which the volume percentage of V100 at a certain spray pressure:
    a. lies between the V100 of the 50% threshold nozzle and the V100 of the 75% threshold value, is classified into the 50% Drift-Reducing Nozzle class;
    b. lies between the V100 of the 75% threshold nozzle and the V100 of the 90% threshold value, is classified into the 75% Drift-Reducing Nozzle class;
    c. lies between the V100 of the 90% threshold nozzle and the V100 of the 95% threshold value, is classified into the 90% Drift-Reducing Nozzle class;
    d. is smaller than the V100 of the 95% threshold value, is classified into the 95% Drift-Reducing Nozzle class.

Article 9 Written report

The written report must in any case contain the following information:

1. *Test nozzle details:*
    a. a designation of the brand name, type, and size of the nozzles on which measurements were performed;
    b. a photo of the test nozzle;
2. *Details of the procedure:*
    a. name of and contact at the independent expert institute that conducted the test;
    b. location where and date when the measurements on test nozzles, reference nozzles, and drift reduction class threshold nozzles were conducted;
    c. brief description of the method and performance of the test and specification of the measurement protocol version used;
    d. specification of the measuring tools used and their settings (lenses / focal point distance, laser capacity, diameter range, use of Probe Volume Correction);
    e. specification of the measurement settings and conditions in which the measurements were performed (temperature of the spray liquid, ambient temperature, relative humidity);
    f. spray pressure range used in steps of no more than 1 bar;
    g. settings used in measurements on the test nozzles;
    h. brief description of the (model) calculation method;
    i. If applicable, a description of deviations from the measurement protocol and their impact on the process of establishing the level of drift reduction.
3. *Measurement results*

a. details of the flow rate of the nozzles measured in relation to the selection of the test nozzles, reference nozzles, and drift reduction class threshold nozzles;
b. the coefficient of variation of the transversal distribution on the patternator of the test nozzles at the associated pressure, nozzle distance, and nozzle height measured on the spray board;
c. details showing that the horizontal scanning speed while measuring the test nozzles and reference nozzle did not exceed 5% of the average vertical droplet speed at measuring height;
d. an overview of the average speed of the droplets in the spray cone at the measured height;
e. an overview of the number of droplets measured as specified in Article 6, twelfth paragraph
f. results of the droplet size characteristics of the test nozzles, reference nozzle, and drift reduction class threshold nozzles determined using this measurement protocol
g. results of (model) calculations and classification of test nozzles into Drift-Reducing Nozzle classes with corresponding pressure (and other limitations such as nozzle height, nozzle distance)

4. *Conclusion*

Article 10 Period of validity of Drift-Reducing Nozzle classification

1. After five years, the test method specified in the second through to the tenth paragraph is used to show, based on the droplet size characteristics of DV10, DV50 (VMD), DV90, and V100, that the nozzles have not been modified.
2. To determine the droplet size characteristics of the nozzles, droplet size measurements are conducted as specified in Article 6, first through to fourteenth paragraph.
3. Article 1, fourth and fifth paragraph, Article 2, and Article 5, ninth paragraph, apply accordingly.
4. The measurements are conducted on:
    a. three nozzles that were used in the previous test;
    b. three nozzles from the most recently produced batch, which are selected as per the method specified in Article 4.
5. Contrary to Article 6, thirteenth paragraph, droplet size measurements with the nozzles specified in the fourth paragraph are conducted only once.
6. If the nozzles in question for downward-directed spraying have a Drift-Reducing Nozzle classification within a range of spray pressures that includes 3 bar, the droplet size spectrum must be determined at a pressure of 3 bar or, if 3 bar is not in the range, the droplet size spectrum must be determined at a pressure from the range that is as close as possible to 3 bar.
7. If the nozzles in question for upward/sideways-directed spraying have a Drift-Reducing Nozzle classification within a range of spray pressures that includes 7 bar, the droplet size spectrum must be determined at a pressure of 7 bar or, if 7 bar is not in the range, the droplet size spectrum must be determined at a pressure from the range that is as close as possible to 7 bar.
8. The results of the droplet size measurements are presented as droplet size characteristics DV10, DV50 (VMD), DV90, and V100.
9. If the maximum spread between the old and new measurements for the VMD exceeds ± 5%, the drift reduction of the nozzle and its classification into a Drift-Reducing Nozzle class must be determined using the test method described in Articles 2 through 9.
10. The results are recorded in a written report that will at least include the results of the old and new nozzles and the statistical testing as specified in the ninth paragraph.
11. If, within five years after determining the nozzles' drift reduction performance, there are changes in the production process of the nozzles that affect the nozzles' drift-reducing characteristics, the drift reduction of the nozzle and its classification into Drift-Reducing Nozzle classes must be tested again based on the test method specified in Articles 2 through 9.

Explanatory notes

General

The 'Measurement protocol to determine drift reduction of nozzles for downward-directed and upward/sideways-directed spraying' provides a test method to determine the level of drift reduction provided of nozzles and classify these nozzles into various Drift-Reducing Nozzle classes (DRN classes). The measurement protocol is intended for both nozzles used for downward-directed spraying (including flat fan nozzles) and nozzles used for upward/sideways-directed spraying. This measurement protocol adheres to the ISO standards, with additions that are specific to the Netherlands. The measurement protocol was developed for implementation of the Dutch Activities Decree on Environmental Management (Activiteitenbesluit milieubeheer).

Drift-reducing nozzles are used to apply crop protection products in the form of droplets. As crop protection products are applied, droplets may drift and end up in surface water. Smaller droplets are more susceptible to drift than larger droplets. Therefore, drift-reducing nozzles are, contrary to other nozzles, designed to produce significantly fewer droplets smaller than 100 μm within a certain pressure range, so as to reduce drift of the crop protection products that are being applied. These nozzles are, therefore, less susceptible to drift than other nozzles. Drift-reducing nozzles are tested by determining the volume percentage of droplets produced by these nozzles at a certain pressure.
The level of drift reduction is determined based on the volume percentage of droplets with a diameter smaller than 100 μm, the V100. The V100 of the nozzles that are to be tested is compared to the V100 of a previously classified reference nozzle. Nozzles are classified into four Drift-Reducing Nozzle classes: 50%, 75%, 90%, and 95%.

Explanatory notes to each article

Article 1

The test method to confirm nozzles' drift reduction performance and classify nozzles into Drift-Reducing Nozzle classes is detailed in Articles 2 through 9. It is, however, possible to use another, equivalent test method. This can also be an existing test method from another country. For the classification of nozzles for downward-directed spraying, a classification by the German Julius Kühn-Institut (JKI) and based on wind tunnel measurements conducted in compliance with ISO 22856, will always be accepted. Nozzles to be used for downward-directed spraying that have a 2-star and 3-star rating based on LERAP (UK) can be classified as 50% drift-reducing nozzles for the Dutch situation.

Article 3 Test nozzles, reference nozzle and drift reduction class threshold nozzles

For each type of nozzle, the test is conducted on test nozzles, a reference nozzle, and, for the classification of nozzles for upward/sideways-directed spraying, also on drift reduction class threshold nozzles.
The reference nozzle is used in the test as a benchmark for the volume percentage of the droplets with a diameter smaller than 100 μm (V100). The reference nozzle is an official standard nozzle. Different reference nozzles are used in testing nozzles for downward-directed spraying or for upward/sideways-directed spraying.
For the testing of nozzles used for field spraying or other downward-directed spraying techniques, the reference nozzle used is the threshold nozzle between the categories of fine and medium, as per the classification by the British Crop Protection Council (BCPC) (31-030-F110 at 3 bar). The BCPC threshold nozzle will soon, upon publication of ISO25358, be replaced by the threshold nozzle in the categories Fine and Medium of ISO25358 (TeeJet TP11003-SS at 3 bar). The reference nozzles can be procured from BCPC and ISO (ISO.Ref.Set@TeeJet.com).
For upward/sideways-directed nozzles as used in fruit cultivation, the reference nozzle is the Albuz ATR Lilac at a spray pressure of 7 bar. This reference nozzle has so far only been used in the Netherlands. This is primarily because a nozzle classification for nozzles for fruit cultivation based on nozzle characteristics is not (yet) used internationally, where nozzles are classified only based on field measurements.

Besides the reference nozzle, four established drift reduction class threshold nozzles (50%, 75%, 90%, and 95%) are also used to classify nozzles for upward/sideways-directed spraying into drift reduction categories.

Three test nozzles and three reference nozzles for upward/sideways-directed spraying are used in the measurements. The number of each of the drift reduction class threshold nozzles used is also three. These three nozzles are selected based on the procedure specified in Article 4.

Article 4 Nozzle selection
The test nozzles, reference nozzle for upward/sideways spraying, and the drift reduction class threshold nozzles are selected from a group of 10 new damage-free nozzles. The 10 nozzles are taken from a random batch of the nozzles in question. The nozzles are selected by measuring the flow rate of the 10 nozzles, following which the average flow rate is calculated. The 3 nozzles with a flow rate that is closest to the average are used as the test nozzle, reference nozzle, or drift reduction class threshold nozzle.

To guarantee that drift-reducing nozzles are fit for purpose when used on a spray boom with downward-directed spraying in practice, additional requirements are set in the seventh paragraph. For nozzles used for field spraying and other downward-directed spraying techniques, a transversal distribution measurement on the patternator is required (as per ISO 16122-2) to be able to show that the combination of nozzle, spray pressure, nozzle distance, and nozzle height specified by the manufacturer delivers adequate transversal distribution of the spray. The transversal distribution measurement must be conducted for the nozzle distance and nozzle height at which the nozzle will be used in practice. This means that the transversal distribution of nozzles with a top angle of 110^0-130^0 will be tested at a nozzle distance of 50 cm and a nozzle height of 50 cm and of nozzles with a top angle of 80^0-90^0 at a nozzle distance of 25 cm and a nozzle height of 30 cm. For applications for classification into Drift-Reducing Nozzle classes with a different nozzle height, the transversal distribution must also be measured.
This must confirm that the transversal distribution of the spray of the composite spectrum of the combination of nozzle, spray pressure, nozzle distance, and nozzle height on the spray board is evenly spread, whereby the coefficient of variation must not exceed 10% (based on ISO 16122-2). The transversal distribution measurement must be conducted on a patternator with a gutter width of no more than 10 cm across a width of at least 100 cm. The spray board is used to measure the transversal distribution of nozzles that are positioned next to each other as much as possible, so that there is no more effect on the deposition on the 100 cm on which the coefficient of variation is calculated.

Article 5 Droplet size measuring preconditions
The second paragraph stipulates that the pressure range of the test nozzles for which the manufacturer has submitted an application is used for the measurement and that measurements are conducted within the pressure range in steps of no more than 1 bar.

Besides spray pressure, other settings may also have a bearing on nozzles' drift reduction performance. Besides hydraulic nozzles, special nozzles such as nozzles that mix air and liquid and disc atomisers may also be used as low-drift nozzles. With these special nozzles, not only the pressure range details are important to consider, as the manufacturer-provided data on the settings of these nozzles is also important. For nozzles that mix air and liquid, for example, both the liquid pressure and the pressure of compressed air to the nozzle must be specified. For disc atomisers, the disc's rotational speed is also essential information alongside the liquid pressure. The third paragraph stipulates that these settings, which must be provided by the manufacturer, must be adhered to during the measurements.
The pressure to use when measuring the droplet size spectrum of the reference nozzle and the drift reduction class threshold nozzles is specified in the fourth through to the sixth paragraph.

In order to be able to draw a comparison between the droplet size characteristics of the test nozzles, of the reference nozzle, and of the drift reduction class threshold nozzles, so as to be able to correctly determine the level of drift reduction, it is key that droplet size measurements on the

reference nozzle and the drift reduction class threshold nozzles be conducted immediately following the droplet size measurements on the test nozzles.
Aside from that, the droplet size characteristics of the test nozzles, reference nozzle, and drift reduction class threshold nozzles must be measured using the same measuring equipment, the same measurement settings, and in the same conditions. Conditions such as ambient temperature and relative humidity must be the same as much as possible. This is necessary for comparison purposes. Droplet size measurements should preferably be conducted at an ambient temperature of 20°C and 70% relative humidity and a water temperature of 20°C, whereby the difference between ambient temperature and water temperature must not exceed 5°C (ISO 25358).

Article 6 Droplet size measuring
Article 6 details how to measure droplet size characteristics. The method described is based on a Phase Doppler Anemometry (PDA) system. In order to accurately identify the characteristics, a method must be used that enables detection of both droplet size and droplet speed within the spray cone. The PDA is a suitable method for that.
The droplet size spectrum of the test nozzles, reference nozzle, and drift reduction class threshold nozzles is measured. The nozzles have to spray vertically in a downward direction. Nozzles that, in practice, are used for upward/sideways-directed spraying are also tested in a downward-directed spraying set-up. The effect of upward/sideways-directed spraying is incorporated into the validation of the nozzle classification system for these nozzles.
The nozzles' droplet size spectrum must be measured in a horizontal plane at 30 cm to 50 cm below the nozzle (see Figure 1) and the measurements must be conducted at least 50 cm above the ground surface. This goes both for nozzles with a top angle of 80^0-90^0 and for nozzles with a top angle of 110^0-130^0. The height at which the droplet size spectrum is determined depends on the nozzle height that will be used in practice.
The droplet size spectrum must be measured at the same height for all the nozzles that are compared in the test. Given that the PDA system can only be used to measure the spectrum in a very small area (of around $1mm^3$), it is important to average the measurements over the full spray cone. The easiest way to do this is to attach the nozzle to a traverse system that moves slowly through the space. This way, the spray cone is scanned in a horizontal plane below the nozzle (see Figure 2).

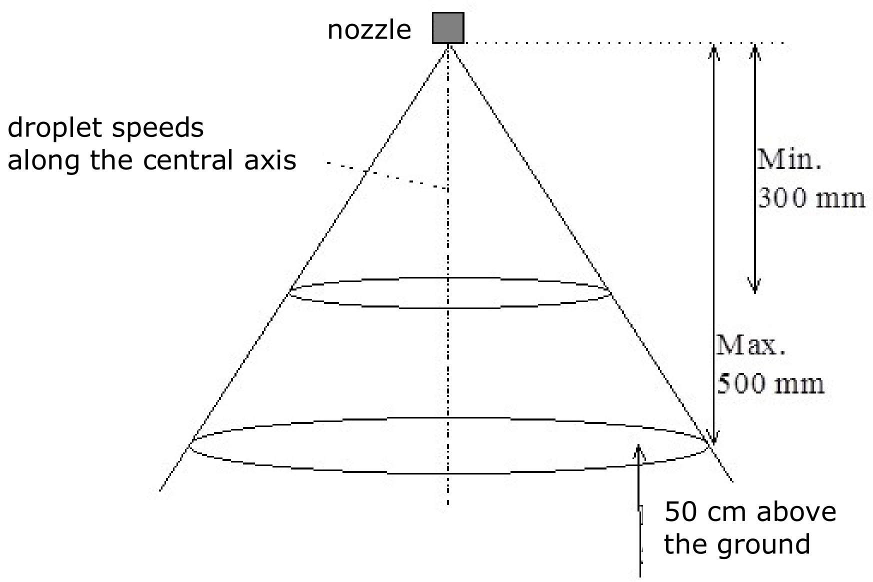

Figure 1 Droplet size measurements with a nozzle in a horizontal plane at 30cm to 50cm below the nozzle. The measuring plane must be at least 50cm above the ground.

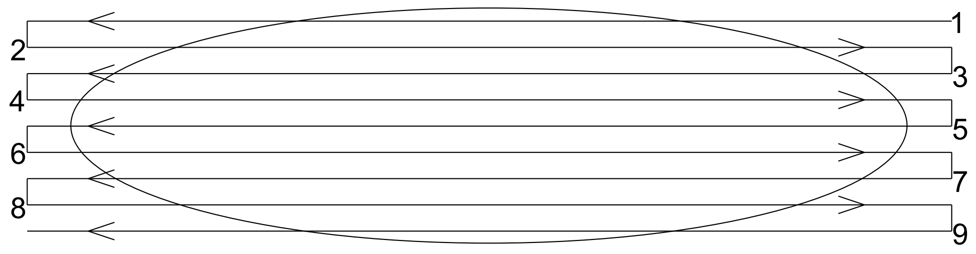

Figure 2 Pattern of lanes in the scan in a horizontal plane below the nozzle. The lateral connecting lanes between two lanes must be outside the spray cone. The total number of lanes must be uneven, with the centre lane running along the centre of the spray cone.

The scan is performed in at least five lanes. The spraying pattern is arranged in a way that ensures that the lanes are spread evenly across the full width of the spray cone and run parallel to the main axis of the elliptic cross-section of the spray cone. The total number of lanes must be uneven, so that the middle lane can run along the centre of the spraying pattern.
The lanes must be long enough to cover the whole spray cone. When scanning one lane at a time, lane changes must be outside the spray cone. This depends on the top angle of the cone and the distance between the measuring plane and the nozzle. The scanning speed (i.e. the speed at which the nozzle moves through the space) must not be too high, so as to prevent irregularities in the spray cone shape and droplet speeds. This is why the measurement protocol requires a scanning speed that differs no more than 5% from the droplet speed.

The number of droplets to measure per test nozzle must be at least 10,000 to achieve an accurate spectral distribution. If this number is not attained, the scanning speed must be reduced or the number of lanes must be increased and the corresponding lane distance reduced. As a matter of fact, most spectrum measurements currently contain between 50,000 to 100,000 droplets.

The measuring range of the PDA system can be modified by installing other front lenses. In general, it is not advisable to use many different ranges, seeing as that could lead to systematic differences. If possible, use only one range.

Before it is possible to determine characteristic spectral quantities of the droplet distribution measured, a statistical correction of the droplet distribution can be performed on account of the difference in sensitivity to different droplet sizes (a so-called probe volume correction). This must be specified in the written report along with the measurement settings.

The droplet size characteristics of the test nozzles, reference nozzle, and drift reduction class threshold nozzles selected as per the procedure specified in Article 4 are measured three times for each selected nozzle. For nozzles with multiple spray cones, such as dual fan nozzles, the measurements are conducted three times for each spray cone.
In the case of dual fan nozzles, the spray is ejected from the nozzle to form two spray cones, generally one in an inclined forward direction and one in an inclined backward direction. Both spray cones must be measured as specified, whereby the nozzle sprays vertically in a downward direction. The measurements on both nozzles are conducted individually by tilting the nozzle in such a way that one spray cone can be measured first and then the other, after tilting the nozzle in the other direction. So as not to interrupt the measurement, it is advised to divert or intercept the spray of the spray cone that is not being measured.

When measuring, droplet speed is also a key factor. Given that small droplets decelerate quicker in the air than larger droplets, droplets in a spray cone always travel at different speeds, depending on the droplet diameter. This local speed distribution depends on the pressure and, therefore, on the starting speed just below the nozzle. The average droplet speed at measuring height is used to make the comparison with the scanning speed. To enter the nozzle details in the IDEFICS drift model (Holterman *et al*., 1997) for classification into drift reduction classes of nozzles used for downward-directed spraying, both droplet size data and droplet speeds along the central axis are needed. Droplet speeds are then measured at 3 cm, 6 cm, 9 cm, 12 cm, 15 cm, 20 cm, 25 cm, and 30 cm below the nozzle. These droplet speeds are converted into an average speed as a function of the droplet size class, from which the entrainment and flow rate of the droplets from the spray nozzle can be calculated.

Droplet size characteristics do not necessarily have to be measured by an independent expert institute, as measurement results may also be provided by, for example, the nozzle supplier. In such cases, the institute must confirm based on the calculated droplet size characteristic values whether the measurements were conducted correctly. The values of these characteristics can be used to make a comparison to other measurement results with the same combination of nozzle and spray pressure.

Article 7 Identifying droplet size characteristics
In line with ISO 25358, the results of the droplet size measurements are presented as droplet size characteristics DV10, DV50 (VMD), DV90, and as the V100. The characteristics of the nozzles are determined based on the droplet size characteristics.
This concerns the following droplet size characteristics:
DV10: droplet diameter whereby 10% of the volume sprayed from the nozzle is made up of droplets with a diameter smaller than this diameter value;
DV50 (VMD): droplet diameter whereby 50% of the volume sprayed from the nozzle is made up of droplets with a diameter smaller than this diameter value;
DV90: droplet diameter whereby 90% of the volume sprayed from the nozzle is made up of droplets with a diameter smaller than this diameter value;
V100: the volume percentage of droplets with a diameter smaller than 100 µm.
The nozzles are classified based on the V100. The other droplet size characteristics DV10, DV50 (VMD), DV90 are needed to check and confirm whether the nozzle produces a good spray spectrum at the spray pressure in question to verify the measurements performed (no major differences between measurements) and to check/compare against the results from other (international) tests.

After measuring the droplet size, the corresponding droplet size spectra are added up and averaged. The values of the various droplet size characteristics equal the average of the results of the three measurements.
With dual fan nozzles, the average of the forward-directed and backward-directed nozzles is calculated, with a weighting based on the flow rate of the forward and backward spray cone.

Article 8 Classification into Drift-Reducing Nozzle classes
Downward-directed
After the values of the droplet size characteristics have been calculated, the V100 volume percentage of the test nozzles can be compared to the V100 volume percentage of the reference nozzle. When the V100 volume percentage of nozzles used for downward-directed spraying is at least 50% lower than the V100 volume percentage of the reference nozzle, the test nozzle can be classified as 50% drift reducing at the spray pressure specified.

In order to classify nozzles for downward-directed spraying into drift reduction classes above 50%, calculations must be performed using IDEFICS (Holterman *et al*., 1997) or a similar drift model. IDEFICS is used to calculate the drift (as a percentage of the spray volume ejected) for the nozzles measured. Based on the results of the drift calculations using IDEFICS, the test nozzles are classified into drift reduction classes as per the method designed by Porskamp *et al*. (1999).

Since IDEFICS can only be used for single spray cones, separate simulations are performed in IDEFICS for the forward-directed and backward-directed spray cones of dual fan nozzles.
The model calculations are made based on the following input parameters, unless the manufacturer specifies otherwise:

- distance between nozzles on the spraying boom:
  - 25 cm for nozzles with a top angle of 80^0-90^0 or
  - 50 cm for nozzles with a top angle of 110^0-130^0;
- spraying direction of the nozzles, i.e. vertically downward, forward and backward tilted at an angle depending on the nozzle type;
- location of last nozzle 50 cm in the crop*;
- a crop height of 50 cm;
- nozzle height of 50 cm above the crop;
- driving speed of 1.67 m/s (6 km/h);
- driving direction parallel to the crop edge;
- wind direction perpendicular to the crop edge, outward from the crop;
- wind speed of 3 m/s (at a height of 2 metres);
- relative humidity of 60%;
- air temperature of 15°C;
- stability of the atmosphere: neutral (no thermals).

* *The starting situation is a potato crop with the last ridge at 75cm from the edge of the ditch, the nozzle at 12.5 cm from the centre of the last ridge and crop development up to the edge. In calculations using IDEFICS, a sloping crop edge is corrected by rounding the distance from the last nozzle to the crop edge to 50 cm (see Figure 3). For simulations with the reference nozzle, the spray cone is set in a vertical downward direction with a nozzle height of 50 cm (the standard height).*

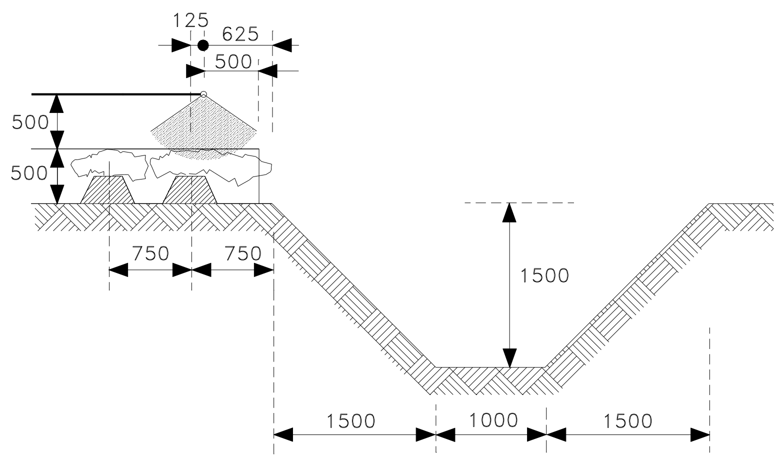

Figure 3 *Overview of the situation for the model calculations for a potato crop (dimensions in mm).*

The simulations with the test nozzles are conducted individually, following which the average of the results is calculated. For dual fan nozzles, simulations of the forward-tilted and backward-tilted spray cones are conducted individually, following which the average of the results is calculated, with a weighting based on the flow rate of the forward and backward spray cone. Although actual dual fan nozzles produce a forward and a backward spray cone at the same time, averaging is still permitted because the drift results are recorded as a percentage of the dosage ejected. All simulations (both of the test nozzles and of the reference nozzle) are repeated five times and performed for 30,000 droplets per nozzle, for 14 nozzles distributed along the spraying boom. The results of the model calculations return the drift position values along consecutive strips of 25 cm, calculated from the crop edge. These results are processed to the average depositions on the strip 2.125 m - 3.125 m from the last nozzle. This is the strip along which the water surface of the ditch is located in the selected starting position for potatoes and corn (Huijsmans *et al*., 1997).

For nozzles used for downward-directed spraying, drift reduction is calculated as per the method devised by Porskamp *et al*. (1999) in relation to the reference nozzle. The drift reductions calculated for the various combinations of nozzle and spraying pressure are stated as a percentage in relation to a reference nozzle. The drift reductions are subsequently classified in the following

Drift-Reducing Nozzle classes in accordance with ISO 22369: 50%, 75%, 90%, and 95%. The reference spectrum is measured on the same days and in similar conditions as the droplet size measurements on the test nozzles.

Some level of statistical spread is to be expected in both the average droplet size spectrum (which impacts on the drift calculated) and in the results of the drift calculations themselves. If, with droplet size measurements, the difference of the DV10 and the DV50 (VMD) between measurements is more than 5% from the average, the measurements will have to be repeated (as stipulated in ISO 25358). If a difference of over 5% is returned by calculations of the drift deposition at the evaluation distance, the simulation will have to be repeated with larger droplet volumes per nozzle. Tests conducted so far have shown that the coefficient of variation is under 3%.
When classifying nozzle/spraying pressure combinations into Drift-Reducing Nozzle classes, statistical spread is not taken into account. Analogous to the classification into classes in Germany (Ganzelmeier and Rautmann, 2000) and the UK (Gilbert, 2000) and the assessment of the results of field tests (ISO 22369, 2006), absolute values of 50%, 75%, 90%, and 95% are used to determine the limits of the Drift-Reducing Nozzle classes.

Upward/sideways-directed
Nozzles used for upward/sideways-directed spraying, such as in fruit cultivation, are classified into the drift reduction classes 50%, 75%, 90%, and 95% (in line with ISO 22369). These nozzles are classified based on the nozzle classification system specified in (Zande *et al*., 2007; Zande *et al*.,2008). Based on measurements performed in the field, threshold nozzles have been selected for the 50%, 75%, 90%, and 95% drift reduction classes that have proven in practice that they can deliver the specified level of drift reduction (Stallinga *et al*., 2011). The threshold nozzles for classification into drift reduction classes for fruit cultivation (sideways/upwards spraying techniques) are the following nozzles and at the spraying pressure specified:

Drift reduction class	Nozzle	Pressure (bar)
reference nozzle	Albuz ATR Lilac	7
50%	TeeJet DG 80-02	7
75%	Albuz AVI 80-015	7
90%	Lechler ID 90-01	5
95%	Albuz TVI 80-025	7

Based on the results of the droplet size measurements, nozzles are classified by volume fraction of droplets smaller than 100 µm. The volume fraction of droplets smaller than 100 µm (V100) is used as a measure of potential drift reduction. The test nozzles' V100 is compared to the V100 of the reference nozzle (Albuz ATR Lilac) and the various drift reduction class threshold nozzles.
A combination of nozzle and spray pressure that is to be classified can be classified in a Drift-Reducing Nozzle class if, based on the average (3 nozzles, measurement repeated 3 times) measured volume fraction, there are droplets smaller than 100 µm (V100) between two threshold nozzles. If the V100 is smaller than the V100 of the reference nozzle or of the drift reduction class threshold nozzle, the nozzle is classified into that Drift-Reducing Nozzle class. The standard error of mean (SEM) of the V100 can be determined and is a measure of the accuracy of this value. The standard error turns out to always be very small (for example 0.02-0.08). The V100 measured for the test nozzle is always lower than the difference of the V100 of the threshold nozzle (standard error). This makes the classification into a class robust.

A nozzle/spray pressure combination:
- is classified into the 50% Drift-Reducing Nozzle class if the average measured V100 of the test nozzles is between the average measured V100 of the 50% threshold nozzle (TeeJet DG 80-02 at 7 bar) and of the 75% threshold nozzle (Albuz AVI 80-015 at 7 bar);
- is classified into the 75% Drift-Reducing Nozzle class if the average measured V100 of the test nozzles is between the average measured V100 of the 75% threshold nozzle (Albuz AVI 80-015 at 7 bar) and of the 90% threshold nozzle (Lechler ID 90-01 at 5 bar);

- is classified into the 90% Drift-Reducing Nozzle class if the average measured V100 of the test nozzles is between the average measured V100 of the 90% threshold nozzle (Lechler ID 90-01 at 5 bar) and of the 95% threshold nozzle (Albuz TVI 80-025 at 7 bar);
- is classified into the 95% Drift-Reducing Nozzle class if the average measured V100 of the test nozzles is lower than the average measured V100 of the 95% threshold nozzle (Albuz TVI 80-025 at 7 bar).

Article 10 Period of validity of Drift-Reducing Nozzle classification
Given that nozzles are continuously being developed further, nozzle specifications are subject to change, which may mean that nozzles no longer deliver the intended level of drift reduction. Replacement of a (worn) mould may also affect the specifications and cause a nozzle to no longer comply with drift reduction requirements. This is why Article 10 states that the nozzles in question must be subjected to a limited number of renewed droplet size measurements five years after the drift test to confirm they still comply with the requirements. The three previously tested nozzles and three nozzles from the most recently produced batch of the nozzle in question must then be subjected to single droplet size measurements.
Paragraph six and seven stipulate at which liquid pressure the droplet size measurements must be carried out for downward-directed spraying nozzles and for upward/sideways-directed spraying nozzles. The Drift-Reducing Nozzle classification for downward-directed spraying nozzles that mix air and liquid, is valid for a fixed combination of liquid pressure and air pressure. The droplet size spectrum of these nozzles must be determined at a liquid pressure of 3 bar, or, if 3 bar is not in the range of the Drift-Reducing Nozzle classification, the droplet size spectrum must be determined with a liquid pressure from the range that is as close as possible to 3 bar, and with an air pressure associated with that fluid pressure.
Given that the results produced by the measuring equipment may have changed over the years (due to hardware and software changes), the droplet size spectrum must also be determined again for the old nozzles for the sake of comparability. This means that the nozzles of which the drift reduction performance has been established for classification into a Drift-Reducing Nozzle class must be retained for at least 5 years.
If the results are insufficiently comparable to the test conducted five years previously, the full test must be repeated for the nozzle in question as specified in Articles 2 through 9.
In the event of any changes to the production process that affect nozzles' drift reduction properties during the five-year term before renewed testing, such as due to mould replacement, the test described in Articles 2 through 9 must be conducted in full again.

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