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*Dutch summary:*
*De geschatte driftreductie op 4.5 tot 5.5 m van de Dominiak Streamliner boomgaardspuit is 99.2 % ten opzichte van een referentie boomgaardspuit. De metingen zijn uitgevoerd in 2022 bij bespuitingen van een appelboomgaard in het volblad stadium (BBCH 75-91).*

*De drift van de Dominiak Streamliner boomgaardspuit is gemeten in combinatie met Teejet AI 80-02 VS spuitdoppen bij 2 bar, 270 RPM PTO, versnellingsbak van de ventilator in stand 1, de buitenste bomenrij eenzijdig bespoten (alleen naar binnenkant perceel) en met de buitenste 6 spuitgangen de luchtondersteuning volgens een vast randrijprotocol. De geschatte driftreductie van de Dominiak Streamliner boomgaardspuit in vergelijking met een referentiespuit is gelijk aan 99,2% op de evaluatiestrook op 4,5-5,5 m van de buitenste bomenrij. Het 95%-betrouwbaarheidsinterval ligt daarbij tussen 98,9% en 99,4%.*

Key words: orchard sprayer, spray drift, nozzle type, air assistance, spray drift reduction



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Picture on front page: Jean-Marie Michielsen (P1050493.JPG)

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# 1. Introduction

Reducing the emission of crop protection products in fruit production plays an important role in the implementation of Sustainable Crop Protection (EZ, 2013), the Activities Decree on Environmental Management (Min I&W, 2022) and the authorization of crop protection products (Ctgb, 2021). For all individual orchard plots, the application of crop protection agents must be carried out with at least 75% drift-reducing techniques (DRT75). Here, the above-mentioned Activities Decree states that for fruit production systems, the crop-free zone for a DRT75 (TCT, 2022a) should be at least 4.5 m. If a 3 m crop-free zone is used, crop protection agents must be implemented with a minimum 90% drift-reducing technique (DRT90).

The emission of plant protection products in fruit cultivation is relatively large compared to other agricultural sectors. This is partly caused by the upward and horizontal spray direction and the often powerful air support in fruit cultivation sprayers. Consequently, a lot of spray liquid is sprayed through the foliage of the tree rows. To reduce emission, various technical and cultivation measures are possible. Technical measures can include the use of suitable nozzle types, shielding and air support. A cultivation measure is, for example, the creation of a windbreak (wind hedge), or the creation of a larger cultivation-free buffer zone which increases the distance between the sprayed crop and the surface water. Experiments have shown that spraying with fine spray nozzles can result in significant drift to the air (Michielsen et al., 2007, Zande et al., 2014). This emission may be relevant for environmental impact at larger distances from plots, or have consequences for nearby residents and buildings (Gezondheidsraad, 2014). In this report, only drift deposition at short distances is evaluated for deposition on surface water for classification in a drift reduction class.

The Dominiak Streamliner orchard sprayer allows the user to set the opening of the air support valves for both sides of the sprayer independently. In the experiments, an edge row protocol was used, where air support is limited to the outside of the plot. Furthermore, a low fan speed was employed by adjusting the PTO RPM and fan gearbox, one-sided spraying was applied to the outer tree row and 95% drift-reducing nozzles were used (Teejet AI 80-02 VS at 2 bar; TCT, 2022b).

This study compares the Dominiak Streamliner orchard sprayer with a conventional cross flow fan sprayer with respect to downwind drift deposition on the ground while spraying an apple orchard at the full-leaf stage (after May 1st). The drift measurements comply with the established requirements from the authorization of plant protection products (Ctgb, 2021), the Activities Decree on Environmental Management (Min I&W, 2022) and international agreements regarding the recognition of drift measurements (ISO22866, 2005; ISO22369, 2006). This report describes the drift measurements and their analysis Chapter 2 discusses the experimental setup, followed by the results and discussion and conclusion in Chapters 3 and 4, respectively.

# 2. Materials and methods

## 2.1 Settings and specifications of candidate sprayers

In field trials, executed in 2022, drift has been measured for the Dominiak Streamliner orchard sprayer. The sprayer that has been measured is a crossflow fan sprayer with adjustable air valves (figure 2.1). The Dominiak Streamliner model has 2 fans and an air crossflow box with valves controlling the air going out of the box on both sides independently. The sprayer terminal in the tractor (figure 2.4) controls the fan speed, which is given in table 2.1.

During each measurement a spraying application was executed in the outer 9 paths of the orchard (see Section 2.4). In paths 7-9  a standard air setting was used. The outer six paths employed a predefined protocol for the air settings, limiting the amount of air being blown towards the outside of the orchard. The outer tree row is being sprayed only from the outside inwards, so in path 1 and 2 the candidate sprayer only sprayed on one side, no air is applied on the side that is not spraying (table 2.1). For spraying, a 95 % drift reducing nozzle was used (figure 2.3, Teejet AI 80-02 VS nozzle at 2 bar; TCT, 2022b).

***Table2.1*** *Air and liquid settings used while measuring the Dominiak orchard sprayer. The lower air setting is always applied to the outside of the orchard, in the case of one-sided spraying, the spraying is also done towards the inside of the field. Air valve setting 0 indicates the valve being closed, 100 means completely open. The field was sprayed inside out, starting with path 9 successively to path 1.*

| Path (workflow) | Tree row | Air valve setting left-right | Terminal indication | spraying |
|---|---|---|---|---|
| 1 (9) | 1 | 0–100 | 100-0 | One-sided |
| 2 (8) | 1 – 2 | 100–0 | 0-100 | One-sided |
| 3 (7) | 2 – 3 | 6–100 | 94-0 | |
| 4 (6) | 3 – 4 | 100-6 | 0-94 | |
| 5 (5) | 4 – 5 | 6-100 | 94-0 | |
| 6 (4) | 5 – 6 | 100-6 | 0-94 | |
| 7 (3) | 6 – 7 | 100-100 | 0-0 | |
| 8 (2) | 7 – 8 | 100-100 | 0-0 | |
| 9 (1) | 8 – 9 | 100-100 | 0-0 | |

The spray drift deposits for the Dominiak orchard sprayer is compared to those for the reference crossflow fan orchard sprayer with Albuz ATR Lilac nozzles (reference technology; TCT, 2017, figure 2.6).


***Figure 2.1*** *The Dominiak Streamliner orchard sprayer.*

***Table2.2*** *Nozzle height [cm] relative to the ground on the Dominiak Streamliner orchard sprayer, left and right are identical. Only the nozzle positions on the straight part of the tower were used during the measurements*

| Nozzle no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | 49 | 75 | 101 | 127 | 153 | 179 | 205 | 231 |

During the measurements, spraying was executed with the 8 nozzles (Table 2.2) that were on the straight part of the tower, the nozzle positions on the arched part of the tower were not used. The spray height was consistent with the tops of the fruit trees. The settings are elaborated in table 2.4.


***Figure 2.2*** *The gearbox setting for the Dominiak Streamliner sprayer's fan is set to 1.*


***Figure 2.3*** *The Teejet AI 80-02 VS nozzle (DRD95, TCT, 2022).*


**Figure 2.4** *In the cab of the tractor are two terminals, the left one controls the setting of the air valves and the right one controls spraying.*

**Figure 2.5** *The air valve of the Dominiak Streamliner orchard sprayer, the size of the opening can be adjusted left and right independently using the terminal in the tractor cab.*

## 2.2 Characteristics reference sprayer

The reference cross flow sprayer (Munckhof, Horst) is an axial fan sprayer equipped with a cross flow airbox on the fan (Figure 2.6). Table 2.3 shows the positions of the nozzle holders of the cross-flow sprayer above ground surface.

***Table 2.3*** *The positions of the nozzle holders [cm] of the reference sprayer above ground surface.*

| Nozze no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| left | 50 | 68 | 84 | 99 | 120 | 153 | 180 | 215 | 250 | 285 |
| right | 48 | 66 | 81 | 99 | 121 | 153 | 181 | 216 | 251 | 286 |

Spraying with the reference machine was done with 2 x 8 open nozzles, with the lower (approx. 50 cm) and upper nozzle (at approx. 285 cm) closed. The upper spraying nozzle was at a height of 2.50 m in accordance with the tops of the fruit trees. The settings are given in table 2.4.

***Figure 2.6*** *Reference sprayer.*

## 2.3 Summary spray techniques used

Table 2.4 summarises the spraying techniques used during the drift measurements.

***Table 2.4*** *Settings for the Dominiak Streamliner orchard sprayer during the field trials.*

| Spuit | reference | Dominiak Streamliner |
|---|---|---|
| PTO rpm | 540 | 270 |
| Fan gearbox setting | High | Low (1) |
| Nozzle | Albuz | Teejet |
| | ATR Lilac | AI 80-02 VS |
| nozzle principle | hollow cone | Venturi |
| pressure [bar] | 7 | 2 |
| no. Of nozzles | 2x8 | 2x8 |
| application rate [l/min] | 0.42 | 0,65 |
| driving speed [km/h] | 6.9 | 6,1 |
| spraying volume [l/ha] | 215 | 350 |

## 2.4 Description of measurements

### 2.4.1 Measurements

The experiments were conducted in 2022, on October 6th (4x) and October 19th (4x). They were carried out at the experimental orchard of WPR at Randwijk, on plot East. This plot is planted with the apple variety Elstar. The fruit trees were planted with 3.0 m spacing between rows and 1.1 m spacing within each row. The trees were about 2.50 m high and at the full-leaf stage (BBCH 75-91). All measurements were done in accordance with the drift measurement protocols from the TCT (TCT, 2017) and ISO22866.

The orchard had a length of 55 m, drift deposition measurements were done on the grass plot adjacent to the orchard. The measurement setup consisted of two measuring strips perpendicular to the last row of the orchard (duplicate measurements) such that the distance between the two strips was approximately 2 m. In figure 2.7, a schematic representation of the measurement setup is shown. Figure 2.8 shows the experimental field with the measurement setup on either side (top) and the last eight tree rows when drift deposition was measured. After each application, the drift collectors were collected, packed and stored individually so the deposition per strip could be determined.

Collectors (Technofil TF 290; 10x100 cm, 10x50 cm) were placed at the following positions to measure drift deposition to the ground (Figure 2.9):

At 1.5 meters, parallel to the outer tree row, a collector of 1 meter length.
At 3 - 15 meters, continuous collectors of 0.5 meters (perpendicular to the tree row).
At 20 and 25 meters a collector of 1 meter (perpendicular to the tree row).

The distance was measured from the centre of the outer tree row.

Before and during spraying, the sprayer setting and the prevailing wind were checked and recorded. According to the measurement protocol (TCT, 2017), the wind speed should be between 1 and 5 m/s and the wind direction should not deviate more than 30° from perpendicular. Only when these conditions were met spraying was started. At the end, meteorological data was averaged (Section 2.6). If the average wind direction and or wind speed during the passage interval did not met the criteria of the protocol, the measurements were rejected.

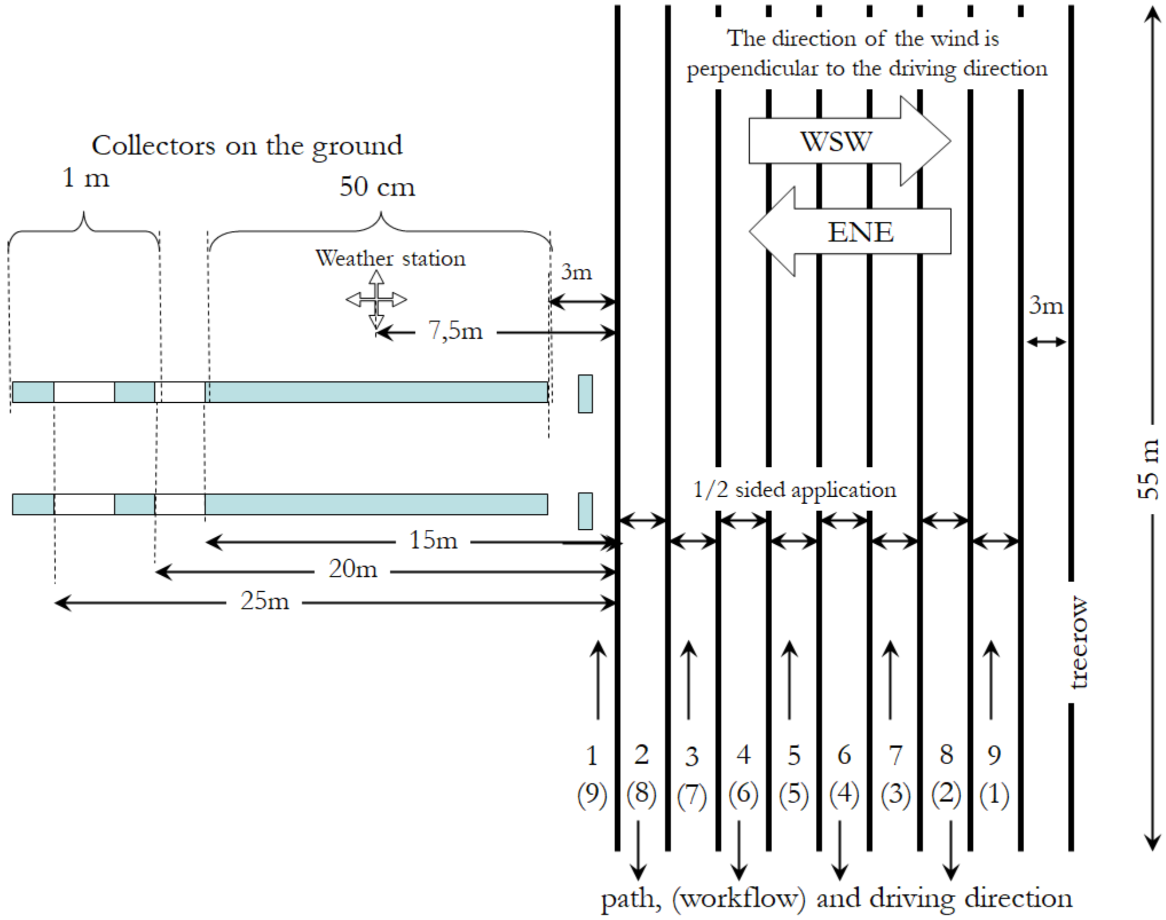



***Figure 2.7*** *Schematic representation of experimental field and measurement setup.*

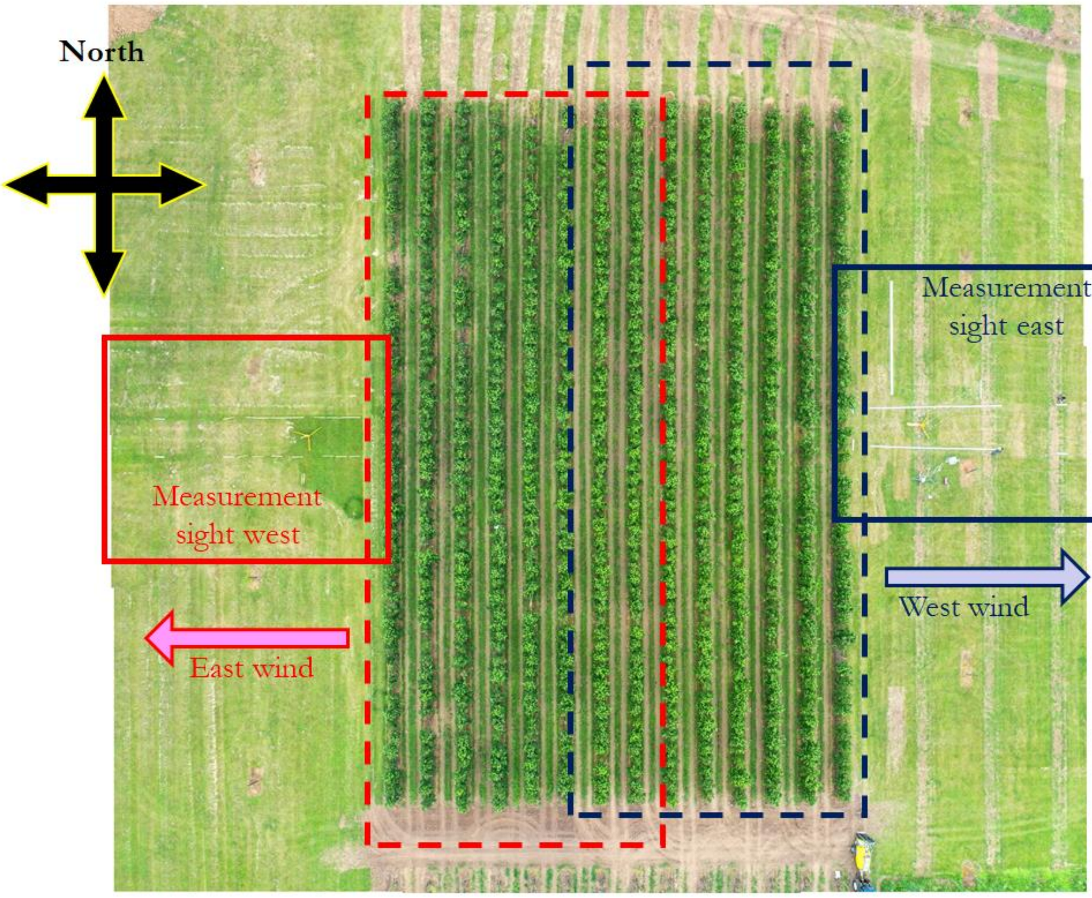



***Figure 2.8*** *Top view of experimental field (above) and of the tree rows and measurement setup.*

## 2.4.2 Analyses

Spraying was done with water to which Acid Yellow 250 (AY250, DC Finechemicals, CAS number 93859-32-6, 2-5 g/l) and a non-ionic effluent (Agral Gold, 0.075 ml/l) had been added. After spraying, the drift collectors were collected and coded for further analysis of the amount of AY250. Samples of the tank liquid were taken from a spraying nozzle each measuring day to measure the AY250 concentration of the sprayed liquid. In the laboratory, the collectors were rinsed with demineralized water such that the AY250 was in solution. From this solution, the concentration of AY250 was measured using a fluorometer (Perkin Elmer FL 8500; $\lambda_{ex}$=450 nm; $\lambda_{em}$=500 nm). Blank collectors and demineralized water were analysed to determine the background fluorescence. The concentration of AY250 in the tank samples was also determined fluorometrically.

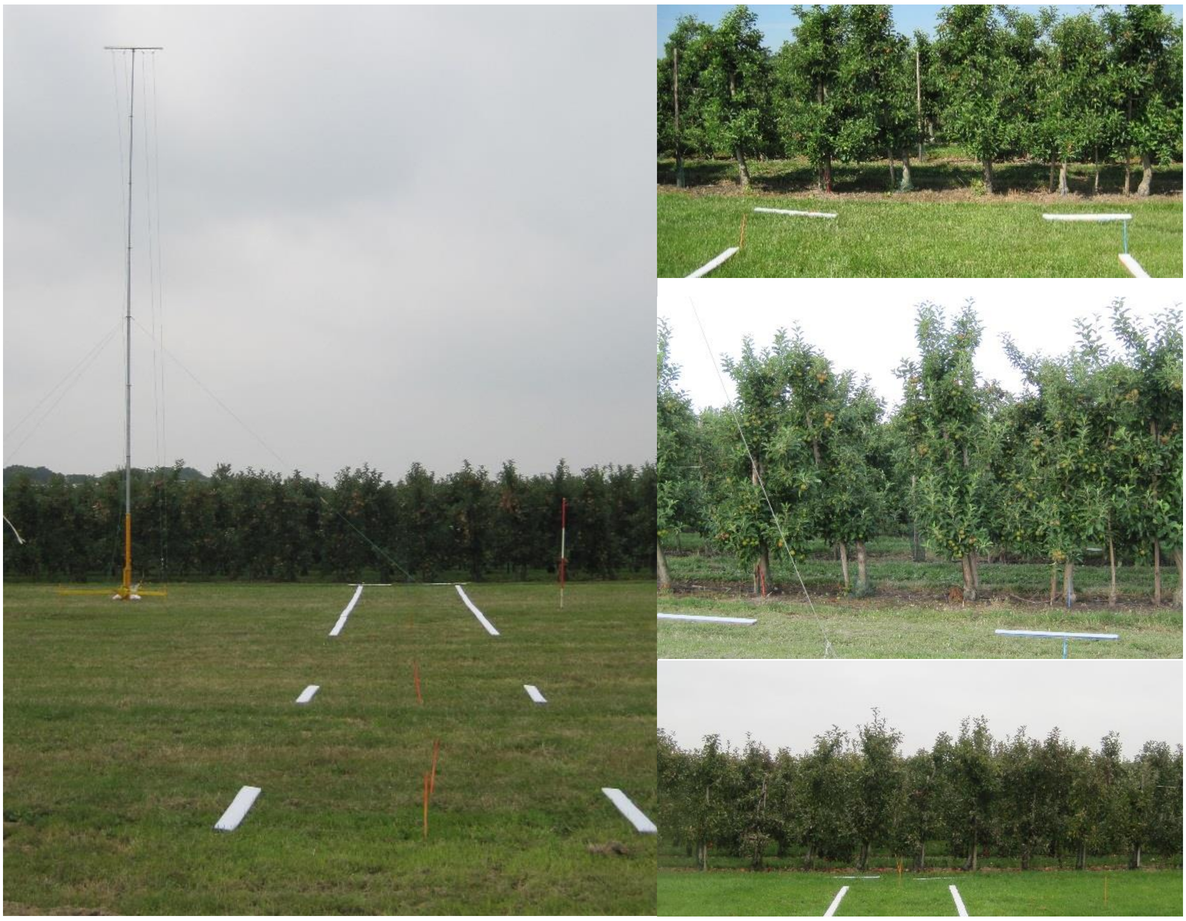


***Figure 2.9*** *The drift measurement setup (left); collectors on the ground up to 25 m from outer tree row; impression of leaf mass of apple trees and collectors close to outer tree row at two measurement sites (right).*

## 2.5 Method for estimating the drift reduction rate

For the comparison of the drift deposition of the Dominiak Streamliner orchard sprayer with the reference machine, the drift values (% of spray volume) were estimated for the evaluation strip corresponding to the position of the ditch and the water surface within it. The cultivation-free zone is defined in the Environmental Management Activities Decree (Min I&W, 2022) as the distance between the ditch insertion and the outermost crop row (for fruit cultivation 3 m in Figure 2.10). The evaluation strip is then the area between 4.5 and 5.5 meters from the centre of the outermost row of trees.

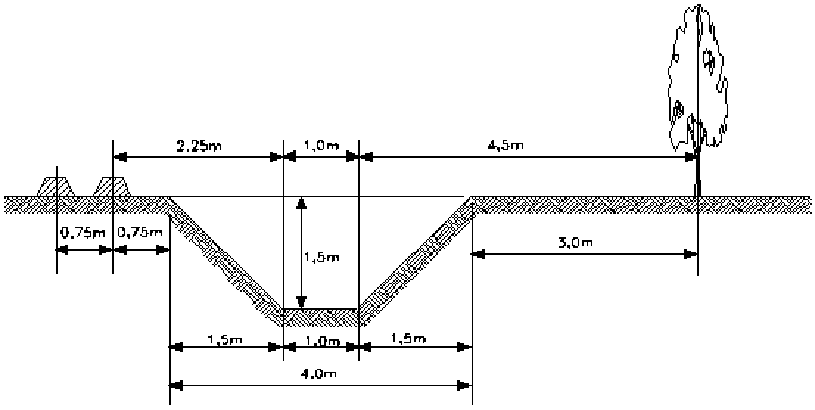



***Figure 2.10*** *Schematic representation of the location of the ditch, slope and water surface in relation to the last crop row in potatoes (left) and the outer tree row in fruit crops (right) (Huijsmans et al., 1997).*

### 2.5.1 General description of the estimation method

The aim is to compare the percentage drift deposition of a Test machine ($T$) in a certain distance interval relative to the sprayed orchard with the percentage drift deposition of a Reference machine ($R$). It is assumed that the percentage deposition decreases monotonously with the distance ($x$) from the orchard. Moreover, drift deposition at an infinite distance is zero. Deposition data for Test machines are generally well described by a single exponential curve, while a double exponential curve is required to obtain a satisfactory fit for Reference machines. Therefore, define the single $P_T(x)$ and double $P_R(x)$ exponential curves for drift deposition as

$$P_T(x) = \beta \exp(-\delta\, x)$$

$$P_R(x) = \beta_1 \exp(-\delta_1\, x) + \beta_2 \exp(-\delta_2\, x)$$

These functions are monotonously decreasing and zero at infinity when both $\beta$ and $\delta$ are positive. The percentage deposition of a machine $M$ in the distance interval $(x_a, x_b)$ is then given by the integral

$$I_M = \int_a^b P_M(x)\, dx$$

The integrals for $P_T(x)$ and $P_R(x)$ are given by

$$I_T = \beta\, [\exp(-\delta\, x_a) - \exp(-\delta\, x_b)]/\delta$$

$$I_R = \beta_1\, [\exp(-\delta_1\, x_a) - \exp(-\delta_1\, x_b)]/\delta_1 + \beta_2\, [\exp(-\delta_2\, x_a) - \exp(-\delta_2\, x_b)]/\delta_2$$

The reduction percentage $X$ of machine $T$ relative to machine $R$ in the interval $(x_a, x_b)$ is then given by

$$X = 100 - 100\, I_T / I_R$$

The percentage deposition of a crop protection product cannot be measured directly. Instead, artificial collectors are placed at different distances from the last row of an orchard. The orchard is then sprayed with water to which a fluorescent liquid has been added. The collectors are flushed with demineralized water and subsequently the fluorescence of the filtrate is measured. The measured fluorescences are then employed to estimate the parameters of the distance functions $P(x)$ for the Test and Reference machine. The estimated parameters can then be used to estimate the reduction percentage $X$ including an associated 95% confidence interval.

An experiment in which a Test machine is compared with a Reference machine is conducted as follows. First two rows of cloth are laid out at different perpendicular distances from the orchard. De orchard is then sprayed by one of the machines and the cloths are collected. Secondly, two rows of new cloths are placed in the same position and the orchard is sprayed by the other machine. The position of the cloths are thus identical for the two machines but weather conditions, e.g. wind speed and direction, can be somewhat different. The parameters of the exponential curve, $P_T(x)$ for the Test machine and $P_R(x)$ for the Reference machine, are estimated separately for each row. A reduction percentage is then estimated for each row. In this way several experiments with duplicated rows are performed, usually on different days but sometimes on the same day. The separate estimates of the reduction percentage are combined into one single estimate, including a 95% confidence interval, by conducting a so-called meta-analysis.

### 2.5.2 Detailed description of the estimation method

Define the following symbols

| | |
|---|---|
| $F_{demi}$ | Fluorescence of demineralized water |
| $F_{cloth}$ | Fluorescence of a clean cloth, assumed to be constant |
| $x_i$ | Distance of the $i$-th cloth with respect to the last row of the orchard (m) |
| $A_i$ | Size of the $i$-th cloth (m2) |
| $Y_i$ | Fluorescence of the $i$-th cloth |
| $D_i$ | Dilution factor which is used to obtain measurement $Y_i$ |
| $F_i$ | Fluorescence of the sprayed liquid on the $i$-th cloth |
| $P_i$ | Percentage deposition of the sprayed liquid on the $i$-th cloth (%) |

Note that the fluorescence is expressed in an arbitrary unit as measured by the fluorimeter.

The fluorescence ($Y_i$) of the $i$-th cloth is the sum of the fluorescence of the sprayed liquid ($F_i$), of the cloth itself ($F_{cloth}$), and of the demineralized water which is used to flush the cloth ($F_{demi}$), i.e. $Y_i = (F_i + F_{cloth} + F_{demi})$. In some cases, especially for cloths at a short distance with large depositions, the fluorescence is too large to be measured by the fluorimeter. The demineralized water is then diluted with a factor $D_i$. This will dilute both $F_i$ and $F_{cloth}$ but not $F_{demi}$. So in general

$$Y_i = (F_i/D_i + F_{cloth}/D_i + F_{demi})$$

The primary interest is in the fluorescence $F_i$ of the sprayed liquid which is given by

$$F_i = D_i\,(Y_i - F_{demi}) - F_{cloth}$$

Note that, due to measurement errors, $F_i$ can become negative when calculated directly from the observed fluorescence values $Y_i$, $F_{demi}$ and $F_{cloth}$. This is clearly undesirable and therefore a modelling approach is used. To obtain the percentage drift deposition $P_i$, the fluorescence $F_i$ is corrected for a calibration constant $K$, a water flush volume $V$, the concentration of the fluorescent liquid in the spraying tank $C$ and the area $A_i$ of the cloth. The deposition of the liquid on the cloth per unit area of the cloth then equals $(F_i\,K\,V)/(C\,A_i)$. Finally, a correction is required for the field release $Q$ of the liquid. The percentage deposition $P_i$ is then given by

$$P_i = F_i\,\frac{(K\,V)/(C\,\mathrm{A_i})}{(Q/100)} \times 100\%$$

Combining these equations it follows that the relationship between the measured fluorescence $Y_i$ and the percentage deposition $P_i$ is given by

$$Y_i = (Z_i/D_i)\,P_i + F_{cloth}/D_i + F_{demi} \qquad \text{with} \qquad Z_i = (Q\,C\,A_i)/(10000\,K\,V)$$

Assuming a single exponential curve $P_T(x)$ for the percentage $P_i$, it follows that

$$Y_i = (Z_i/D_i)\,\beta\,\exp\,(-\delta\,x_i) + F_{cloth}/D_i + F_{demi}$$

or, equivalently, with cloth corrected fluorescence measurements $Y_i^*$

$$Y_i^* = Y_i - F_{cloth}/D_i = (Z_i/D_i)\,\beta\,\exp\,(-\delta\,x_i) + F_{demi}$$

Similar equations can be derived for the double exponential curve $P_R(x)$ for $P_i$.

The cloth corrected fluorescence measurements $Y_i^*$, together with repeated fluorescence measurements of demineralized water in the same measurement series, are employed to estimate the parameters $\beta$, $\delta$ and $F_{demi}$ of the curve. Because the variance of the measurements $Y_i^*$ increases with the mean, gamma distributed errors rather than normal errors are assumed. The estimated $\beta$ and $\delta$ parameters, and their standard errors, for both the Test and Reference machine are then used to calculate the reduction percentage for each row along with a 95% confidence interval. This interval is obtained by application of the so-called delta method on the logit scale; the interval on the logit scale is then back-transformed to the percentage scale.

### 2.5.3 Meta-analyse

The estimated reduction factors $X$ for each duplicated row in multiple experiments, and their associated standard errors, are subjected to a meta-analysis in order to obtain a single estimate of the reduction factor of a Test machine. In the meta-analysis individual estimates are weighted by their standard errors such that more precise individual estimates have a larger weight than less precise estimates. The meta-analysis is performed on the logit scale because normality is better guaranteed on the logit scale than on the percentage scale, especially when reduction percentages are close to 100%. In the meta-analysis two variance components are distinguished: variance between experiments and variance between duplicated rows within the same experiments. The estimated constant of the meta-model and the accompanying 95% confidence interval are back-transformed to the percentage scale to give the final result of the statistical analysis.

### 2.5.4 Remarks

1. The statistical method employs the untransformed cloth corrected fluorescence measurements. The background fluorescence $F_{demi}$ is a parameter in the statistical model.
2. In the calculation of the cloth corrected fluorescence $Y_i^*$, it is assumed that the fluorescence $F_{cloth}$ of a cloth is known. However, $F_{cloth}$ is also measured and is thus subjected to measurement error. Since $F_{cloth}$ is small, smaller than 500, relative to measured fluorescence $Y_i$, which is generally larger than 8000, measurement error in $F_{cloth}$ can be ignored.
3. For experiments conducted on the first and second day $F_{cloth}$ is set to 125 and 100 respectively. The precise value of $F_{cloth}$ only has a minor effect on the final result.
4. Cloths of the two rows of a Test machine in the same experiment are measured in the same fluorescence series. Cloths of the two rows of the Reference machine also form a single measurement series, however, this series can be measured on another day. In each series the calibration factor $K$ is determined; this value can vary somewhat from day to day. The calibration factor is assumed to be constant for a series. In the same series usually four measurements of demineralized water are conducted.
5. For some fluorescence measurements an additional dilution factor $D_i$ is employed. Such measurements are not comparable to un-diluted measurements. Therefore, in a graphical display with the fitted exponential curves diluted measurements are depicted by $D_i\,(F_i - M) + M$ in which $M$ is the mean of the demineralized water measurements in the same series.
6. The exponential curves are fitted by noting that for fixed values of the $\delta$'s, the model is linear in the $\beta$'s and in the $F_{demi}$ parameter. This implies that, given fixed $\delta$ values, the linear parameters can be estimated by a generalized linear model with the gamma distribution and the identical link function. Employing this predicate, a grid search only for the $\delta$ parameters is required. For the single exponential model the grid search is performed by the one-dimensional optimization function *optimize*() in *R*. For the double exponential model the "*L-BFGS-B*" method in the *R* function *optim*() is employed. In both cases initial intervals are obtained by a simple equidistant grid search between $\delta$=0.001 and $\delta$=5.

7. The exponential curves are only monotonously decreasing when the $\beta$ and $\delta$ parameters are positive. For $\delta$ this is ensured by estimating $\delta^*$, defined by $\delta = \exp(\delta^*)$, rather than $\delta$. In some cases the best estimate for $\delta^*$ is minus infinity, implying a zero estimate of $\delta$, resulting in problems for the estimation algorithm. Therefore a lower limit for $\delta^*$ is imposed such that the estimate of $\delta$ is larger than or equal to 0.001. This lower limit results in a curve which slowly reaches the asymptote for large distances.
8. Negative estimates of $\beta$ are set to zero. This results in a constant curve for the single exponential model and a single exponential model for the double exponential model.
9. In some cases a reduction factor of 100% is obtained, for example when a constant model is fitted for a Test machine. A logit transformed estimate of the reduction percentage, required for the meta-analysis, is then not available. Therefore, reduction percentages larger than 99.9% are bounded to 99.9% and the associated variance is calculated by assuming that the lower 95% confidence limit equals 99.5%.
10. The meta-analysis is calculated by the *rma.mv*() function in the *R* package *metafor* employing "*random = ~ 1 | experiment/row)*"
11. The meta-analysis reveals that it is generally appropriate to distinguish between the variance between and within experiments. The estimated correlation between the logit transformed reduction in the same experiment equals 0.45.

Appendix 1 shows graphs for all experiments showing the measured values and fit curves of the statistical model.

In Appendix 3, the fit curves for each repetition are converted to drift deposition, plotted against the distance from the orchard. This is therefore the estimated drift deposition of the reference and test machine separately from each other.

## 2.6 Weather conditions

During spraying, weather conditions were recorded by measuring temperature (Pt100 at 0.5 m and 4 m height), humidity (% RH with a Rhotronic at 1.5 m height), wind direction (0° = perpendicular to the rows of trees) at 10 m height and wind speed (cup anemometers at 0.5, 2, 3, 4 and 10 m height) at 5-second time intervals. The weather station was located 7.5 m from the outer tree line (Figure 2.7). At each passage of the sprayer the data logger time was recorded. Measured weather data were averaged afterwards for the passage interval defined as the time interval 10 seconds before to 10 seconds after the logged passage time. Appendix II shows the results of the measurements of the weather conditions.

The experiments were conducted in 2022 on October 6th (4x) and October 19th (4x). The average overall data is shown in table 2.5.

***Table 2.5*** *Average weather conditions (at passage intervals) for the different objects during the drift measurements.*

| technique | n-repetitions | temperature [⁰C] at | | % RH | wind direction | windspeed [m/s] at | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 m | 4 m | | 0° = perpendicular | 0.5 m | 2 m | 3 m | 4 m | 10 m |
| Reference | 8 | 15.9 | 14.7 | 54 | 3 | 1.2 | 2.0 | 2.7 | 3.1 | 5.0 |
| Streamliner | 8 | 15.5 | 14.3 | 57 | 1 | 1.0 | 1.9 | 2.6 | 3.0 | 4.7 |
| | **average** | **15.7** | **14.5** | **55** | **2** | **1.1** | **1.9** | **2.6** | **3.1** | **4.9** |

# 3 Results

The measured drift reduction on the evaluation strip (4.5-5.5 m) during spraying in the full-leaf situation (BBCH 75-91) is shown in Figure 3.1, the numbers are in Appendix 1.

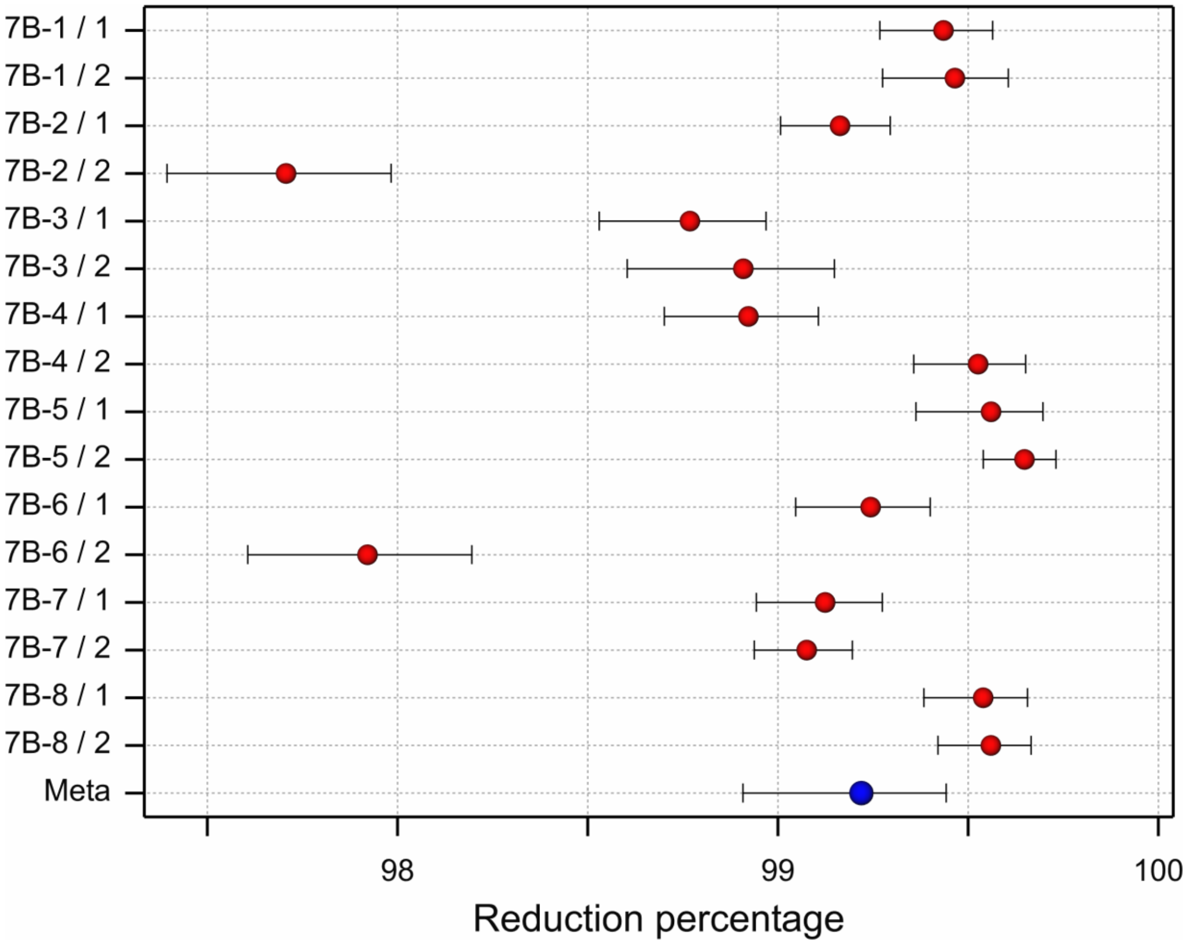



***Figure 3.1*** *The drift reduction on the evaluation strip of the different repetitions of the experiments, 2 values per experiment. The experiment rows are coded as: object no - repetition / measurement strip. For each experiment, the estimated reduction including a 95% confidence interval is given. The meta-analysis gives an estimated (mean) drift reduction of 99.2%.*

The Dominiak Streamliner cross flow fan sprayer, Teejet AI 80-02 VS nozzles at 2 bar, 270 rpm PTO rpm, air support gearbox in position 1, the outer tree row sprayed unilaterally (plot inward only) and with the outer 6 passes of application the air support following a fixed edge driving protocol, has been compared to a reference machine. On average, the drift reduction is 99.2% (confidence interval 98.9-99.4). The Test and Reference machine are significantly different at a significance level of 5%.

# 4 Discussion and conclusion

The estimated drift reduction at a distance between 4.5 and 5.5 m of the Dominiak orchard sprayer is 99.2 % compared to a reference sprayer. Measurements have been executed in 2022 by spraying an apple orchard at the full-leaf stage (BBCH 75-91).

The Dominiak Streamliner orchard sprayer was measured in combination with Teejet AI 80-02 VS nozzles at 2 bar, 270 rpm PTO rpm, air support gearbox position 1, the outer tree row sprayed unilaterally (plot inward only) and with the outer 6 passes of application the air support following a fixed edge row protocol. The estimated drift reduction of the Dominiak Streamliner orchard sprayer compared to a reference machine is equal to 99.2% on the evaluation strip 4.5-5.5 m from the outer tree row. The 95% confidence interval thereby ranges from 98.9% to 99.4%.

In the results, a spreading of the estimated reductions can be observed, both between the measurements as well as between the measurement strips in one measurement. The cause of the observed differences cannot be directly declared, however, there is always variation between measurements, which could be due to weather circumstances, tree development, variation by sprayer performance etc; common variations to cope with in agricultural (or biological) research. These variations underpin the necessity to have enough repetitions of measurements (test protocol points at 8-10 repetitions of the measurements) to give robust results.

# Literature


Ctgb, 2021. Evaluation Manual for the Authorisation of Plant protection products and Biocides according to Regulation (EC) No 1107/2009 NL part Plant protection products Chapter 6 Fate and behaviour in the environment: behaviour in surface water and sediment version 2.6; August 2021. http://www.ctgb.nl/

EZ, 2013. Gezonde Groei, Duurzame Oogst. Tweede nota duurzame gewasbescherming, periode 2013 tot 2023. Ministerie van Economische Zaken, Den Haag. 2013. 46p.

Gezondheidsraad, 2014. Gewasbescherming en omwonenden. Gezondheidsraad, publicatienr. 2014/02, Den Haag. 2014. 194p.

Huijsmans, J.F.M., H.A.J. Porskamp & J.C. van de Zande, 1997. Drift(beperking) bij de toediening van gewasbeschermingsmiddelen. Evaluatie van de drift van spuitvloeistof bij bespuitingen in de fruitteelt, de volveldsteelten en de boomteelt (stand van zaken december 1996). IMAG-DLO Report 97-04, IMAG, Wageningen, 38 pp.

ISO 22866, 2005. Equipment for crop protection – Methods for the field measurement of spray drift. International Standardisation Organisation, Geneva. 2005.

ISO-22369, 2006. Crop protection equipment – Drift classification of spraying equipment. Part 1. Classes. International Organization for Standardization, Geneva.

Michielsen, J.M.G.P., Wenneker, M., Zande, JC van de & Heijne, B., 2007. Contribution of individual row sprayings to airborne drift spraying an apple orchard. In: E. Gil, F. Solanelles, S. Planas, J.R. Rossell & L. Val (eds). 8th Workshop on Spray Apllication Techniques in Fruit Growing June 2005 Barcelona, Book of Abstracts, Universitat Politècnica de Catalunya, Generalitat de Catalunya, Universitat de Lleida, Barcelona, 2007. p.37-46

MinI&W (Ministry of Infrastructure and Water Management), 2022. Activiteitenbesluit Milieubeheer; valid since 21 September 2022; https://wetten.overheid.nl/BWBR0022762/2022-09-21 (in Dutch)

TCT, 2017. Meetprotocol vaststellen driftreductie spuittechnieken [versie 1 juli 2017]. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

TCT, 2022a. Lijst met indeling van spuittechnieken in Driftreducerende Techniek-klassen (DRT-klassen) (DRT lijst). Versie 29 juli 2022. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

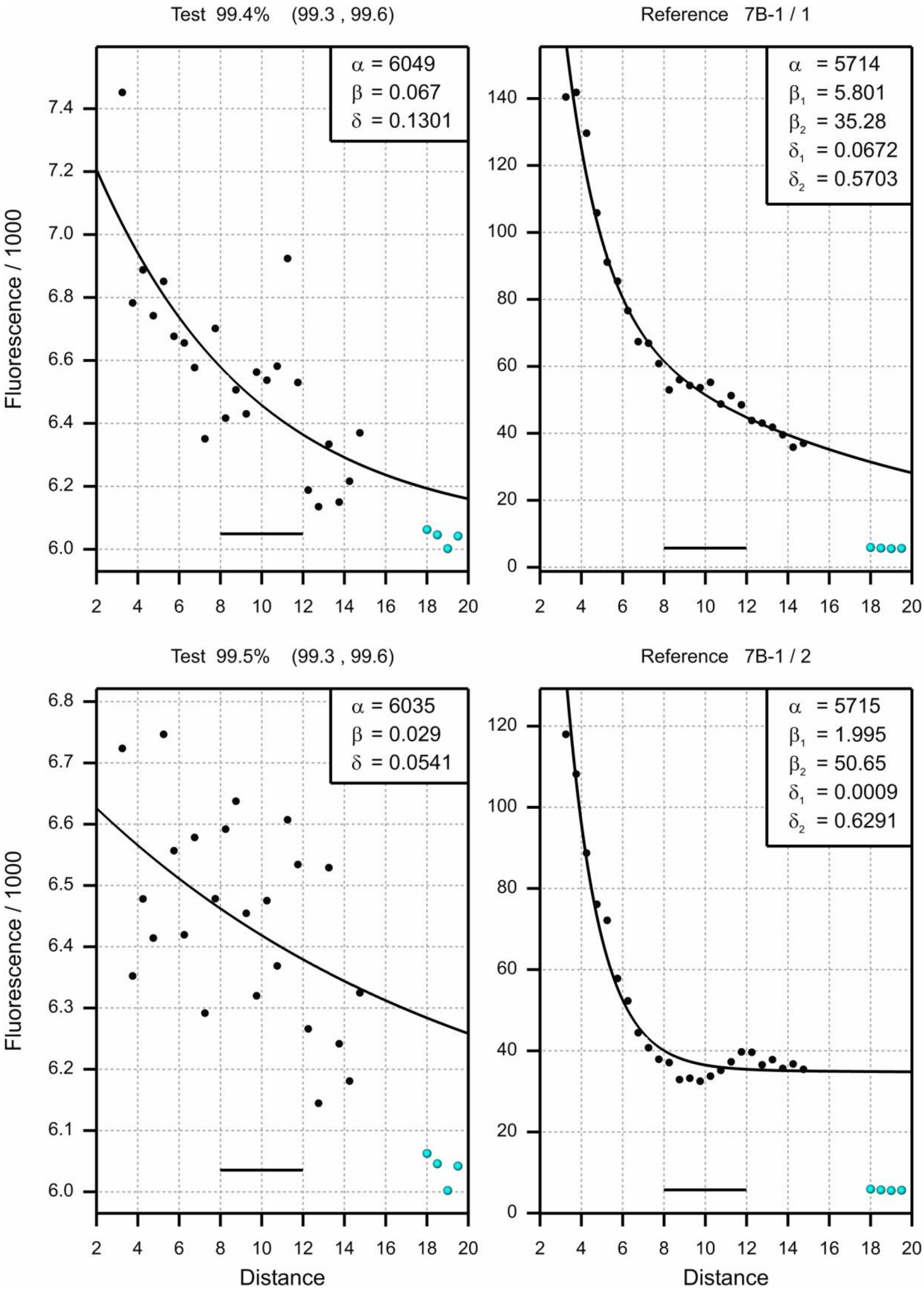
TCT, 2022b. Lijst met indeling van spuitdoppen in Driftreducerende Dop-klassen (DRD-klassen) (DRD-lijst). Versie 29 juli 2022. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

Zande, J.C. van de, M.C. Butler Ellis, M. Wenneker, P.J. Walklate & M. Kennedy, 2014. Spray drift and bystander risk from fruit crop spraying. International Advances in Pesticide Application, Aspects of Applied Biology 122, 2014. p. 177-186.

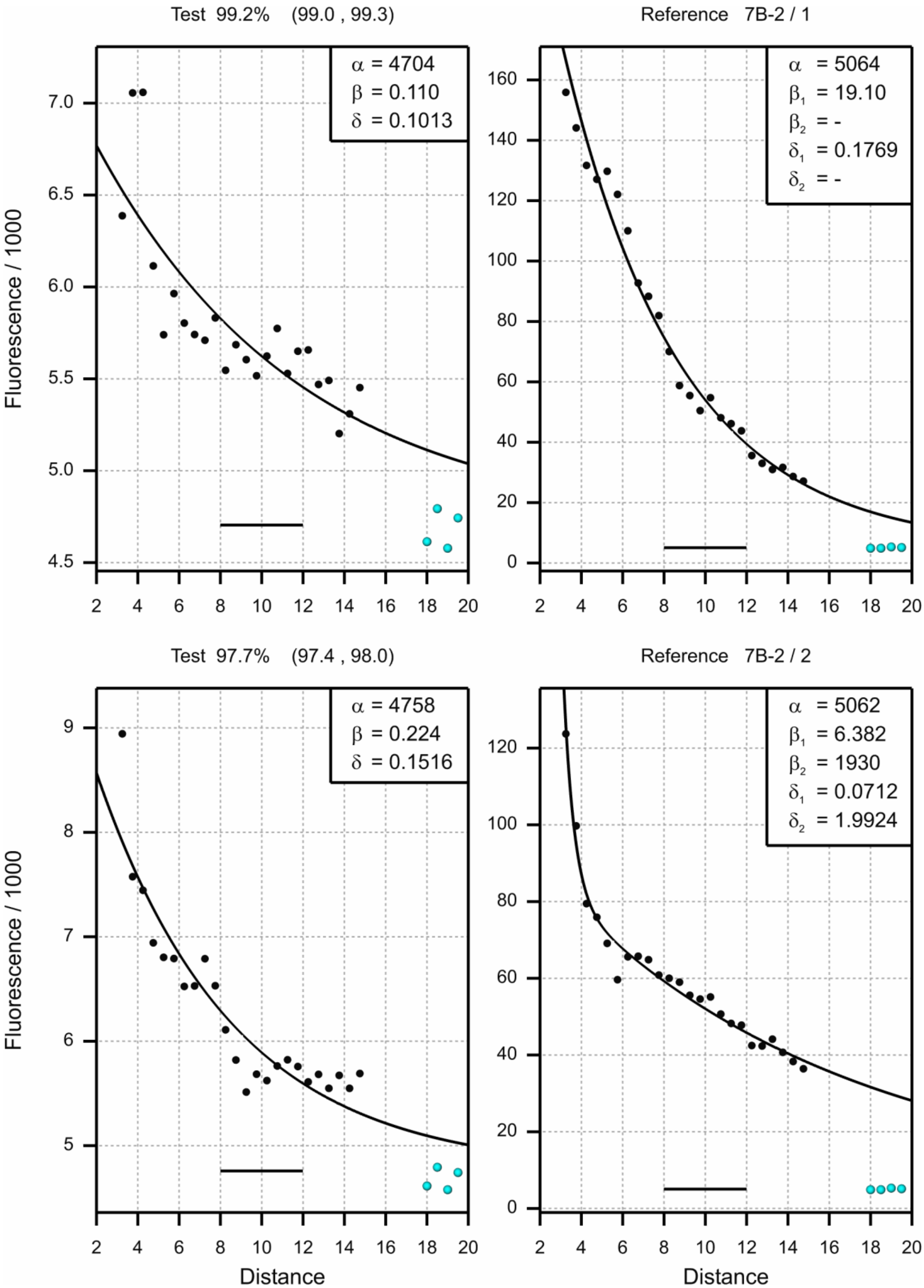
# Appendix 1 Estimated exponential curves

Each page shows the two strips for a single experiment. On the left are the figures for the test machine and on the right for the corresponding reference machine. Above the test figures the estimated drift reduction for the specific row is given with the corresponding confidence interval. Above the reference figure is the date of the experiment and the number of the experiment (in brackets, object number - repetition / experiment strip).

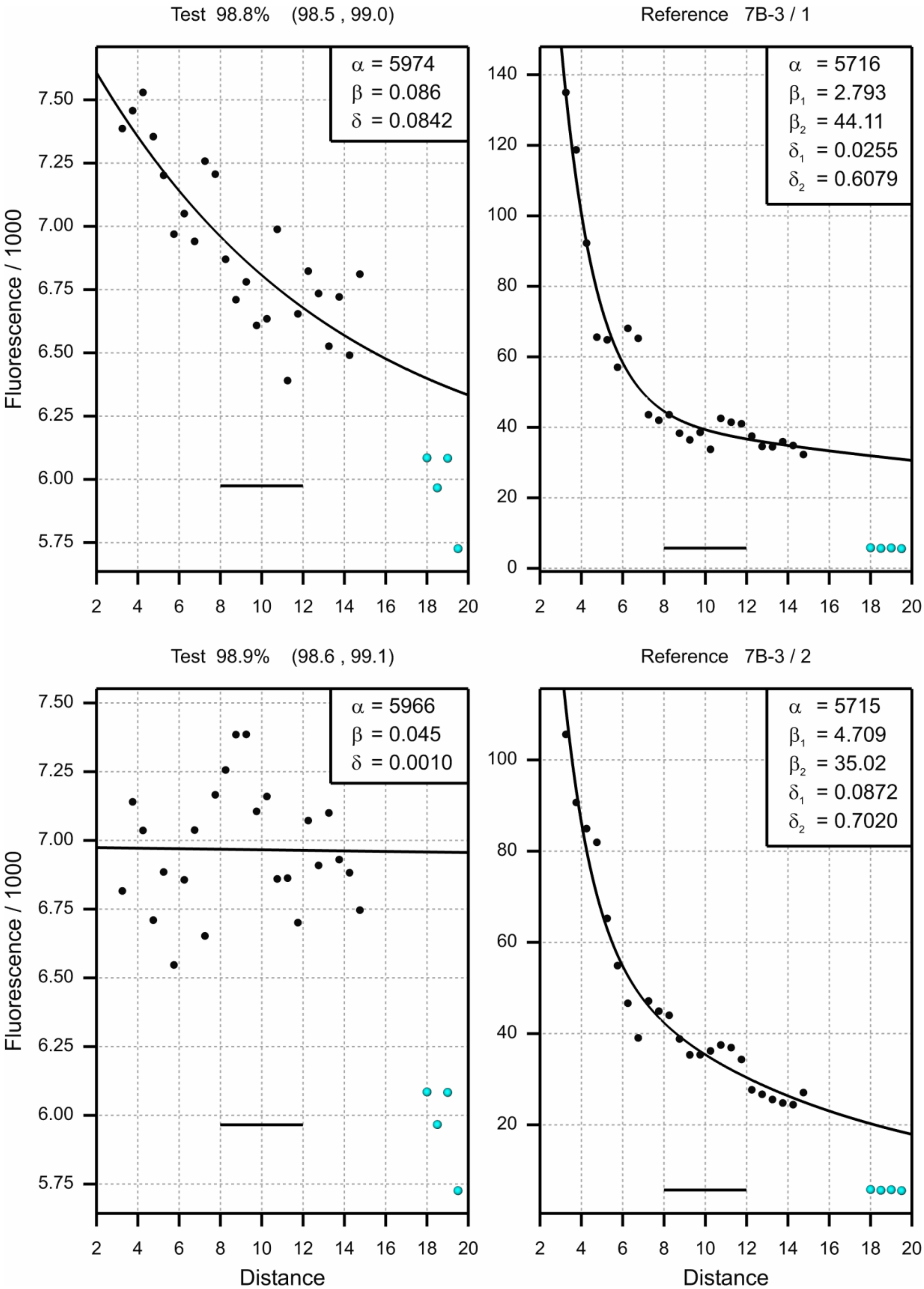
In each figure, the estimated parameters of the exponential curve are given in the upper right corner. The black dots represent the measured cloth corrected fluorescence of the collectors, red dots were not used when fitting the exponential curve. The blue dots are the collector corrected fluorescence of demineralized water belonging to the measurement series, the distance at which they are shown is fictional, the corresponding distance according to the exponential model is actually infinity. The black horizontal line between 8 and 12 m. is the estimated asymptote to which the exponential curve runs, this corresponds to the *alpha* parameter.



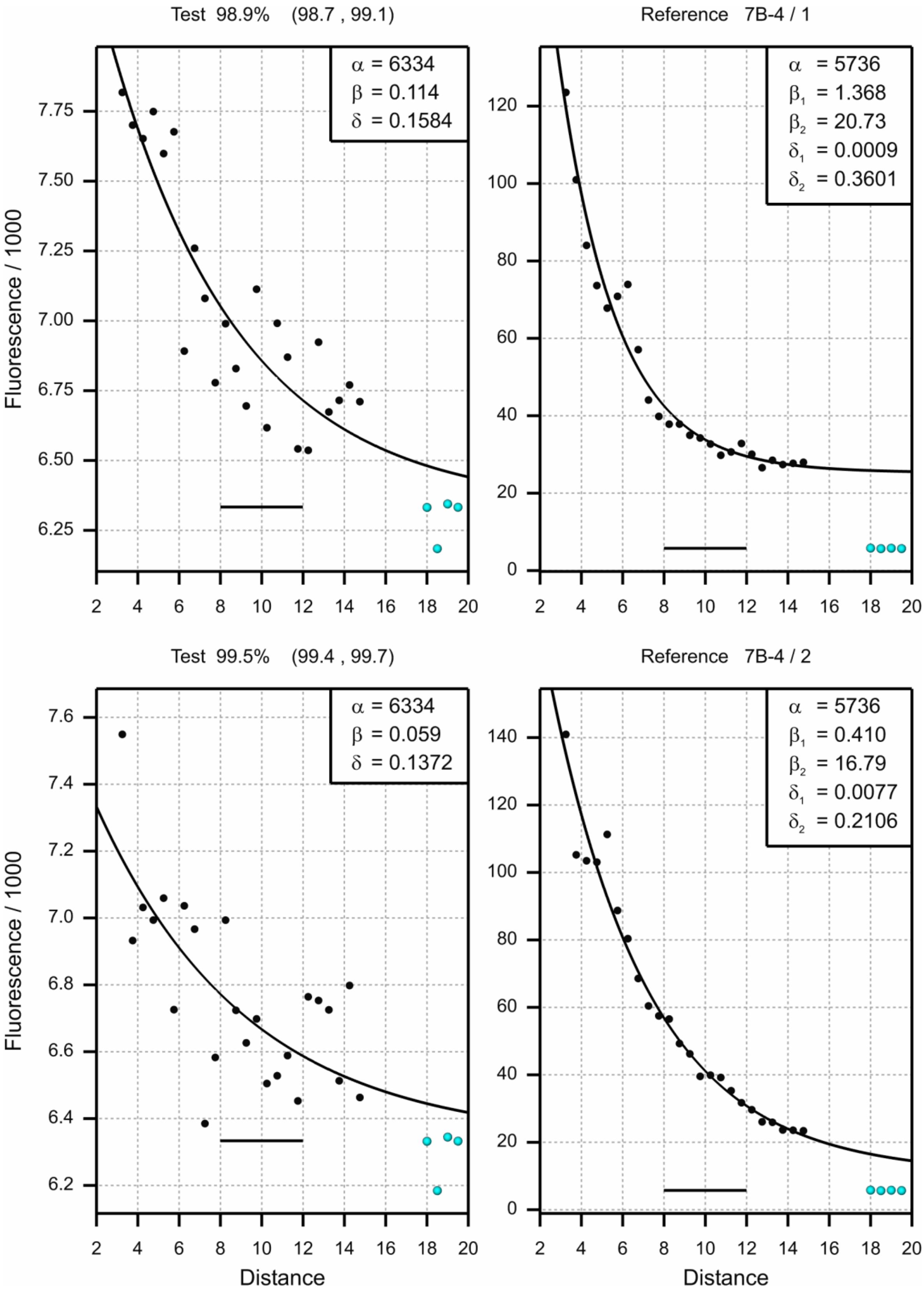
Test 99.4% (99.3 , 99.6)
α = 6049
β = 0.067
δ = 0.1301
Reference 7B-1 / 1
α = 5714
β1 = 5.801
β2 = 35.28
δ1 = 0.0672
δ2 = 0.5703
Test 99.5% (99.3 , 99.6)
α = 6035
β = 0.029
δ = 0.0541
Reference 7B-1 / 2
α = 5715
β1 = 1.995
β2 = 50.65
δ1 = 0.0009
δ2 = 0.6291
Fluorescence / 1000
Distance



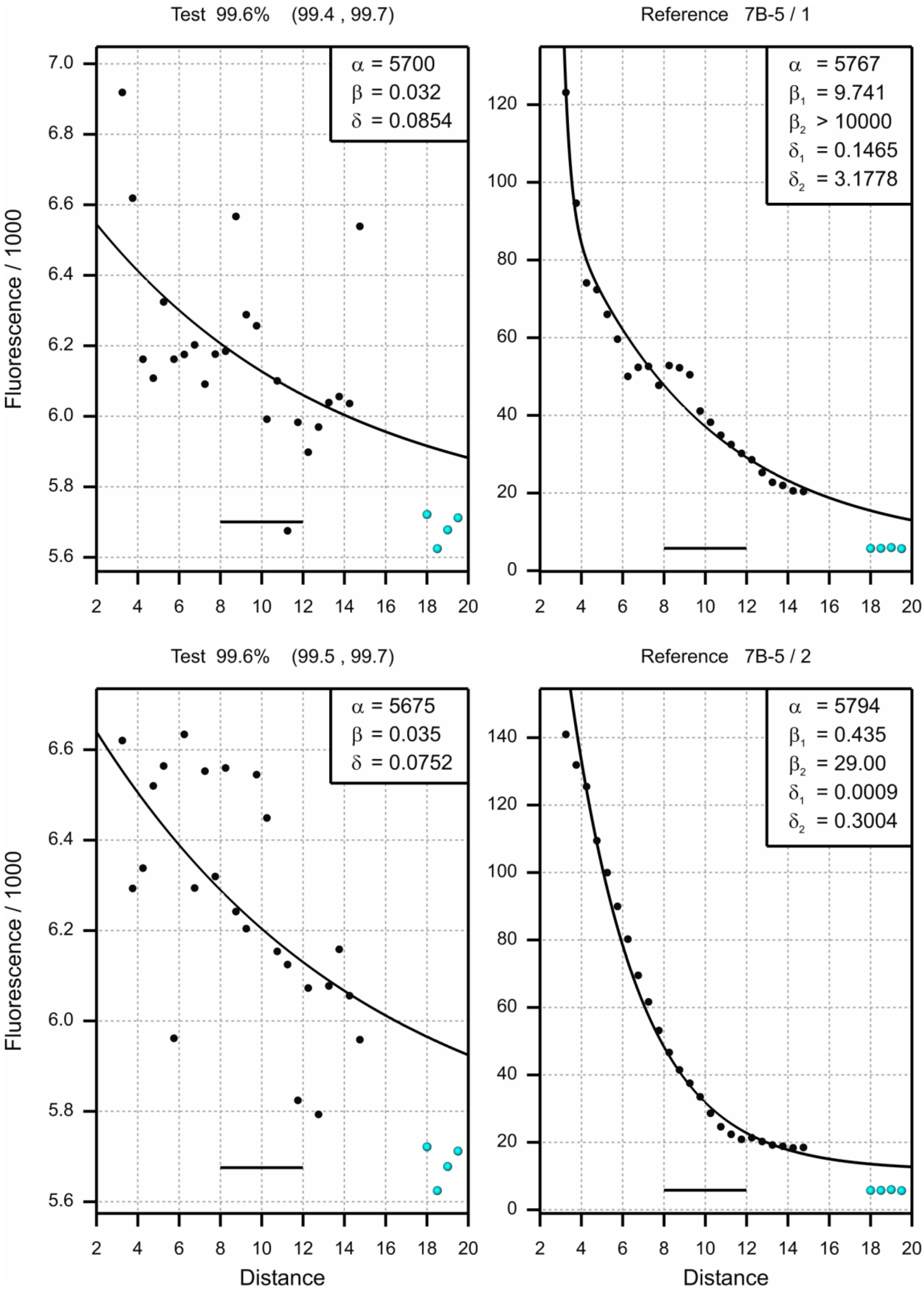
Test 99.2% (99.0 , 99.3)
α = 4704
β = 0.110
δ = 0.1013
Reference 7B-2 / 1
α = 5064
β1 = 19.10
β2 = -
δ1 = 0.1769
δ2 = -
Test 97.7% (97.4 , 98.0)
α = 4758
β = 0.224
δ = 0.1516
Reference 7B-2 / 2
α = 5062
β1 = 6.382
β2 = 1930
δ1 = 0.0712
δ2 = 1.9924
Fluorescence / 1000
Distance



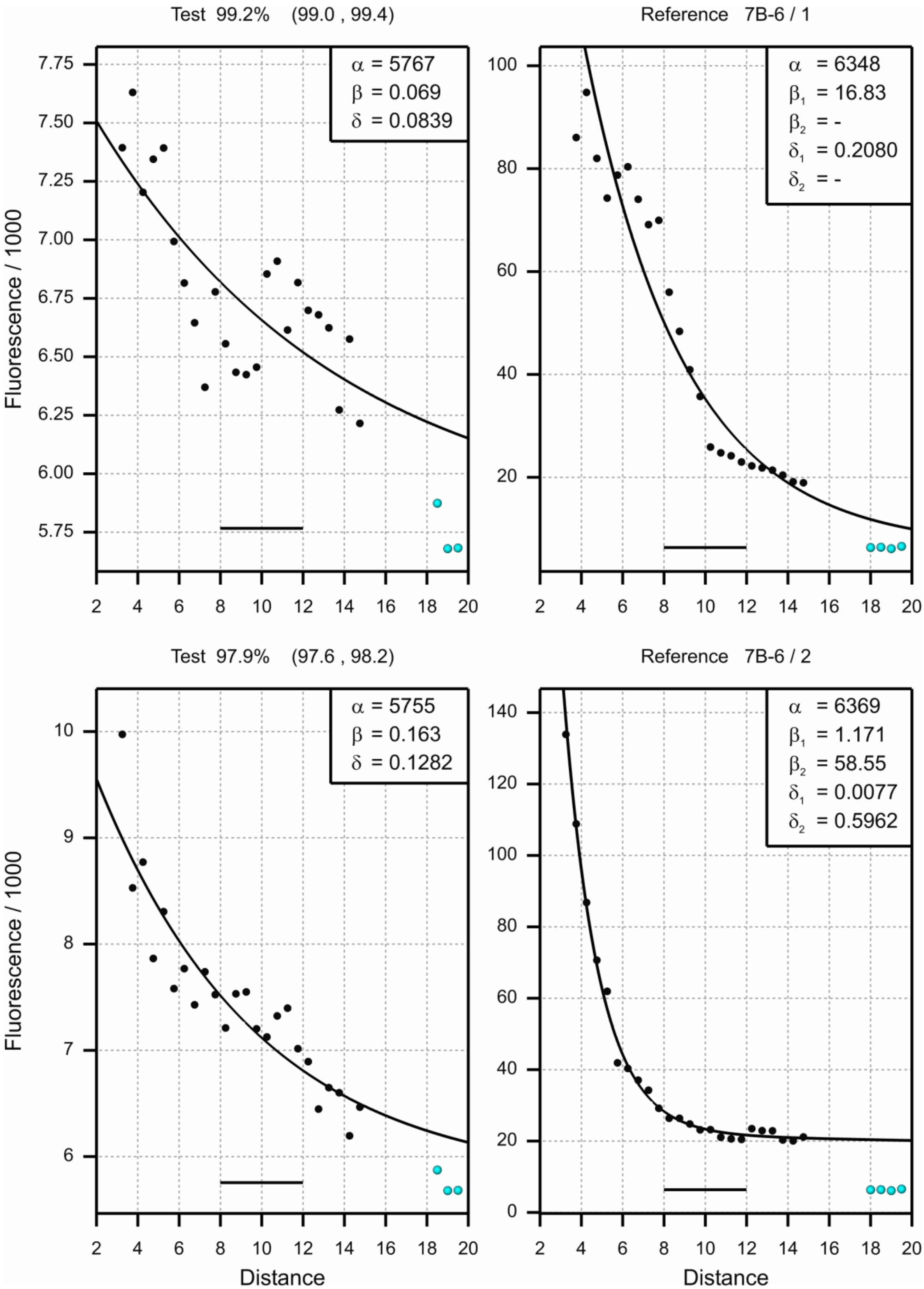
Test 98.8% (98.5 , 99.0)
α = 5974
β = 0.086
δ = 0.0842
Reference 7B-3 / 1
α = 5716
β1 = 2.793
β2 = 44.11
δ1 = 0.0255
δ2 = 0.6079
Test 98.9% (98.6 , 99.1)
α = 5966
β = 0.045
δ = 0.0010
Reference 7B-3 / 2
α = 5715
β1 = 4.709
β2 = 35.02
δ1 = 0.0872
δ2 = 0.7020
Fluorescence / 1000
Distance



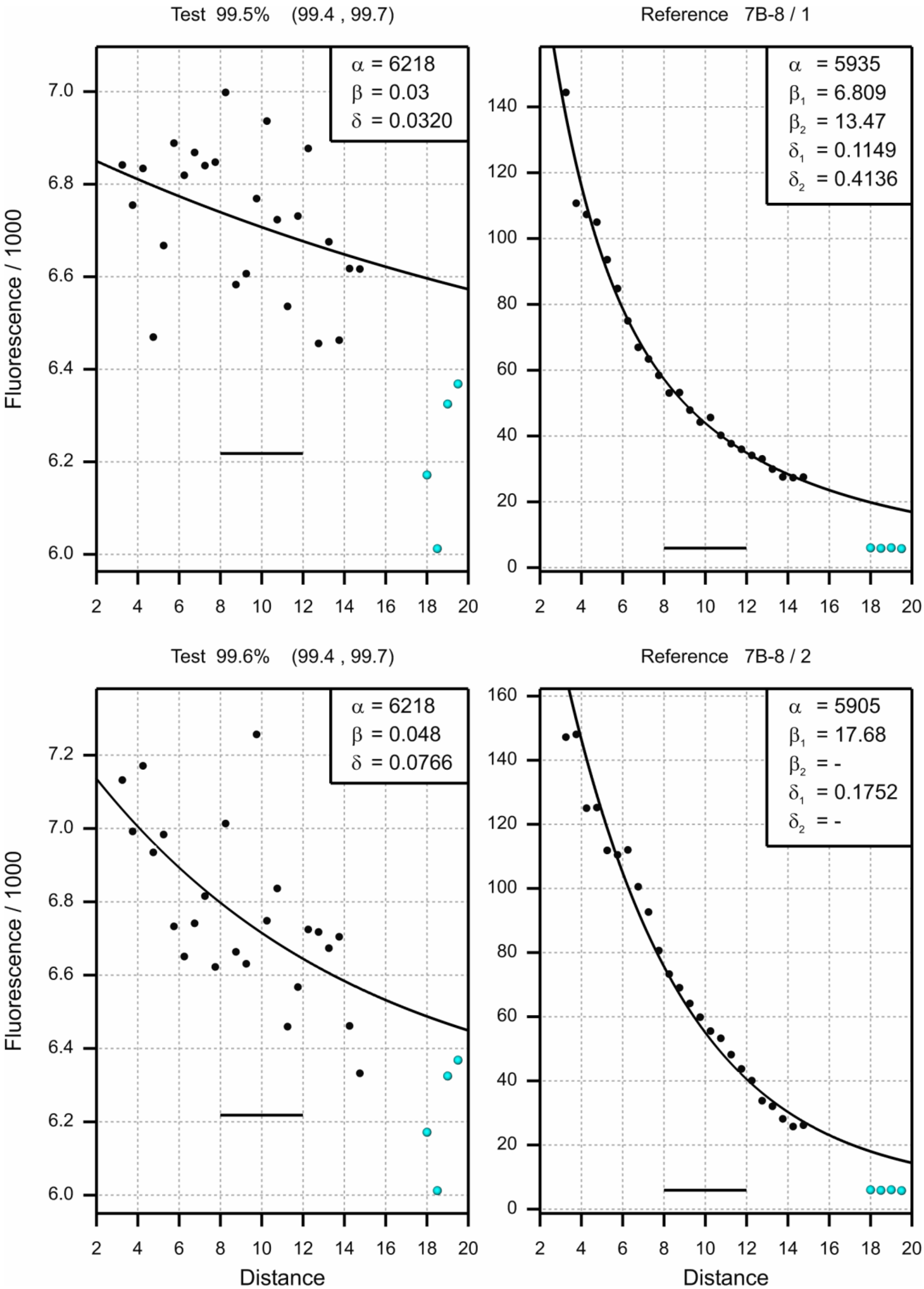
Test 98.9% (98.7 , 99.1)
α = 6334
β = 0.114
δ = 0.1584
Reference 7B-4 / 1
α = 5736
β1 = 1.368
β2 = 20.73
δ1 = 0.0009
δ2 = 0.3601
Test 99.5% (99.4 , 99.7)
α = 6334
β = 0.059
δ = 0.1372
Reference 7B-4 / 2
α = 5736
β1 = 0.410
β2 = 16.79
δ1 = 0.0077
δ2 = 0.2106
Fluorescence / 1000
Distance



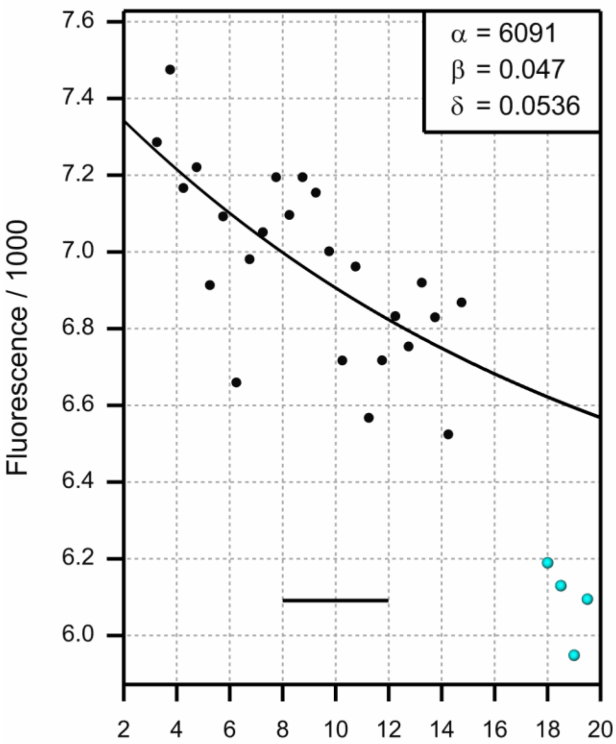
Test 99.6% (99.4 , 99.7)
α = 5700
β = 0.032
δ = 0.0854
Reference 7B-5 / 1
α = 5767
β1 = 9.741
β2 > 10000
δ1 = 0.1465
δ2 = 3.1778
Test 99.6% (99.5 , 99.7)
α = 5675
β = 0.035
δ = 0.0752
Reference 7B-5 / 2
α = 5794
β1 = 0.435
β2 = 29.00
δ1 = 0.0009
δ2 = 0.3004
Fluorescence / 1000
Distance



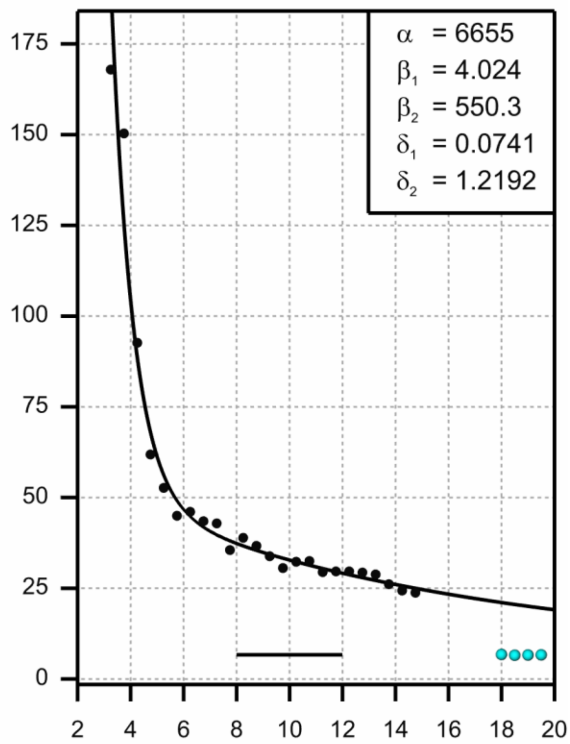
Test 99.2% (99.0 , 99.4)
α = 5767
β = 0.069
δ = 0.0839
Reference 7B-6 / 1
α = 6348
β1 = 16.83
β2 = -
δ1 = 0.2080
δ2 = -
Test 97.9% (97.6 , 98.2)
α = 5755
β = 0.163
δ = 0.1282
Reference 7B-6 / 2
α = 6369
β1 = 1.171
β2 = 58.55
δ1 = 0.0077
δ2 = 0.5962
Fluorescence / 1000
Distance


Test 99.5% (99.4 , 99.7)
Reference 7B-8 / 1
Test 99.6% (99.4 , 99.7)
Reference 7B-8 / 2
α = 6218
β = 0.03
δ = 0.0320
α = 5935
β1 = 6.809
β2 = 13.47
δ1 = 0.1149
δ2 = 0.4136
α = 6218
β = 0.048
δ = 0.0766
α = 5905
β1 = 17.68
β2 = -
δ1 = 0.1752
δ2 = -
Fluorescence / 1000
Distance

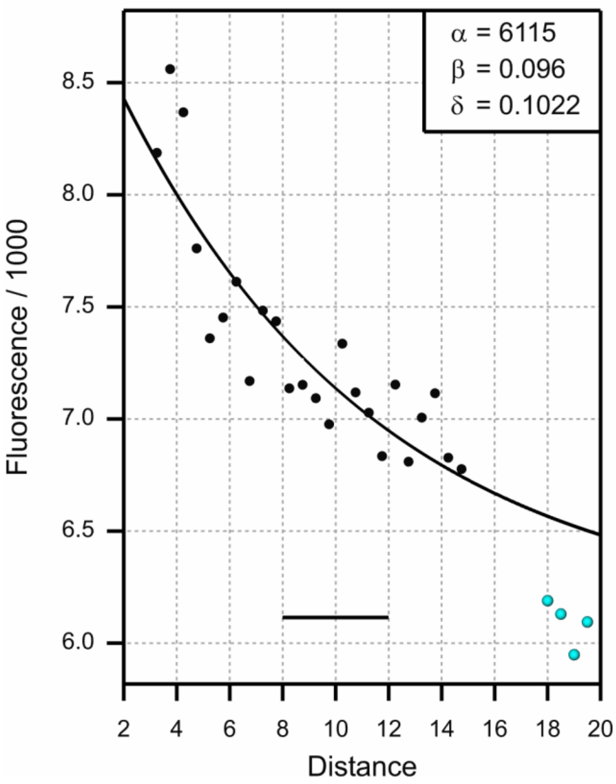
Test 99.1% (98.9 , 99.3)



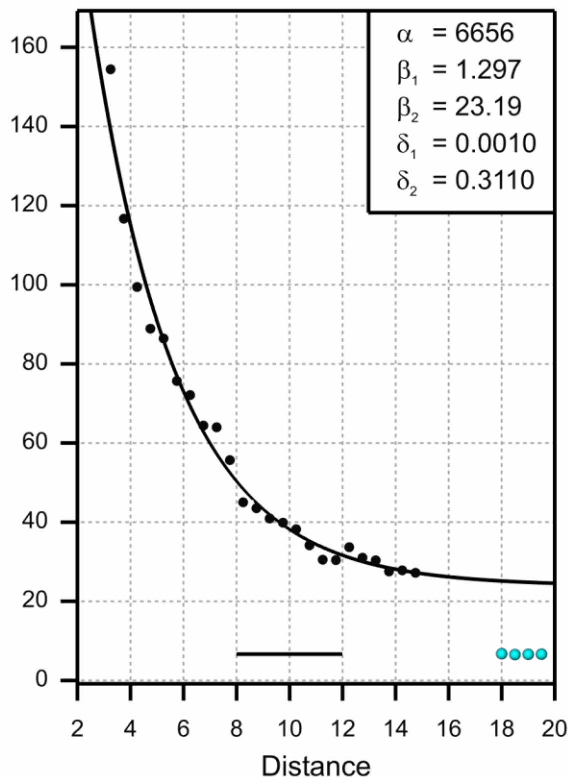

Reference 7B-7 / 1




Test 99.1% (98.9 , 99.2)



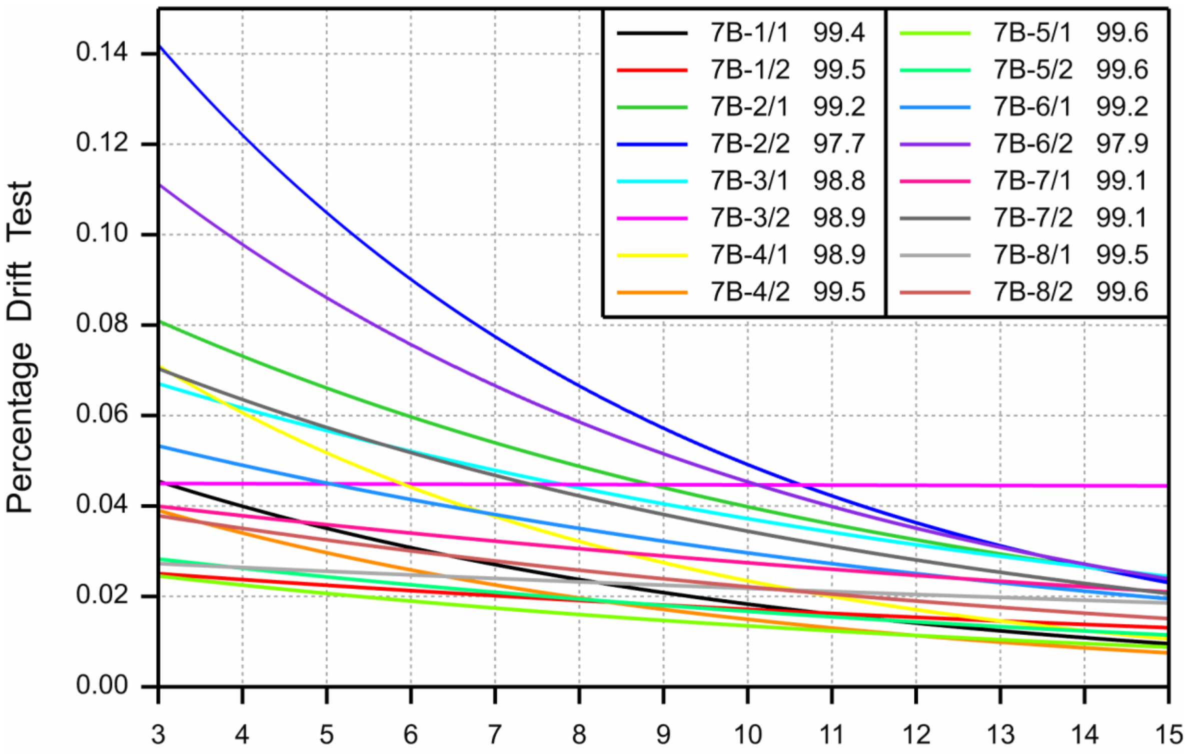

Reference 7B-7 / 2

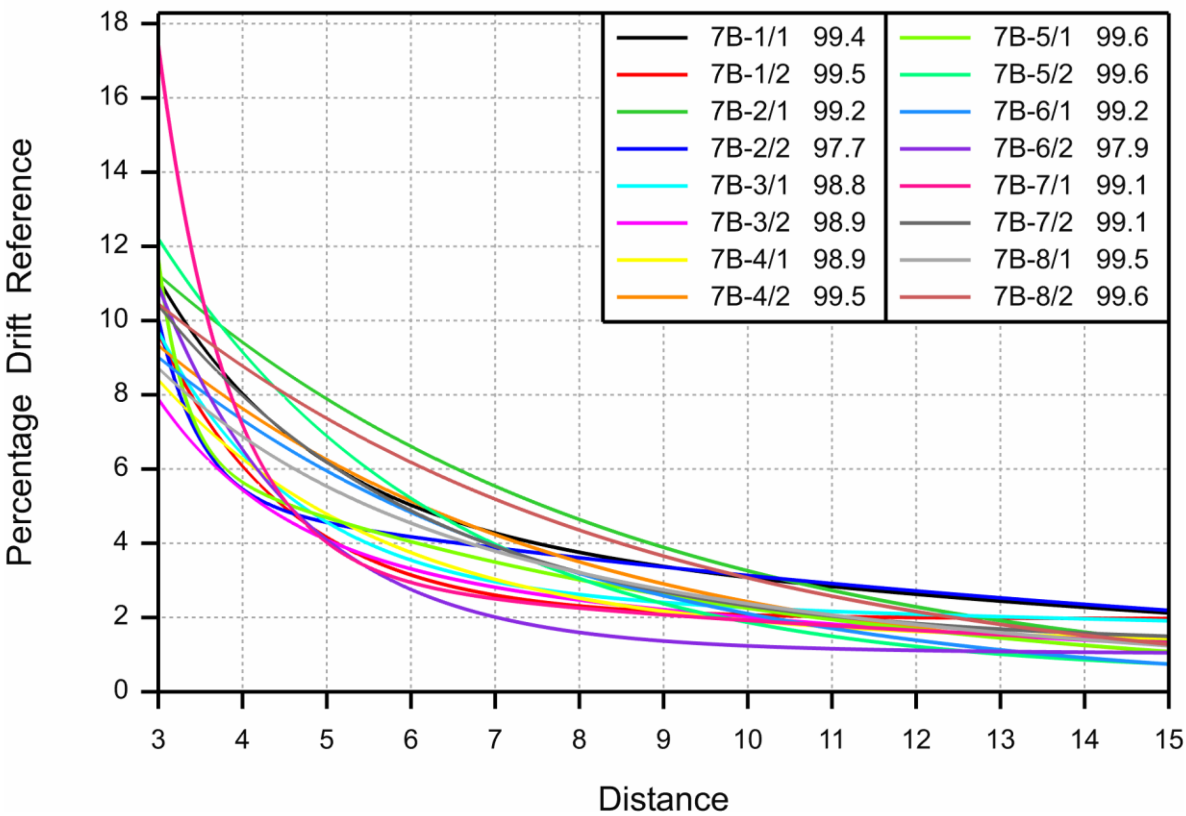


# Appendix 2 Weather conditions during drift measurements

| Technique | date | | temperature [$^0$C] at | | RH | Wind direction | windspeed [m/s] at | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | # | 0.5 m | 4 m | % | perpendicular=$0^0$ | 0.5 m | 2 m | 3 m | 4 m | 10 m |
| reference | 06-Oct-22 | 1 | 16.6 | 15.0 | 57 | -8 | 1.3 | 2.3 | 3.4 | 3.8 | 5.5 |
| | 06-Oct-22 | 2 | 15.4 | 14.4 | 57 | -10 | 1.1 | 2.1 | 3.2 | 3.8 | 6.2 |
| | 06-Oct-22 | 3 | 17.9 | 16.4 | 52 | -14 | 1.2 | 1.8 | 2.5 | 2.9 | 4.6 |
| | 06-Oct-22 | 4 | 17.4 | 16.0 | 51 | -11 | 1.2 | 1.8 | 2.4 | 2.8 | 4.7 |
| | 19-Oct-22 | 5 | 14.7 | 13.0 | 61 | 8 | 1.0 | 1.9 | 2.5 | 2.9 | 5.1 |
| | 19-Oct-22 | 6 | 15.3 | 14.0 | 56 | 23 | 1.5 | 2.4 | 3.0 | 3.5 | 5.4 |
| | 19-Oct-22 | 7 | 16.2 | 14.9 | 46 | 16 | 1.3 | 2.1 | 2.8 | 3.3 | 4.9 |
| | 19-Oct-22 | 8 | 14.0 | 13.9 | 51 | 18 | 0.8 | 1.2 | 1.7 | 2.1 | 3.6 |
| Streamliner | 06-Oct-22 | 1 | 16.5 | 14.9 | 57 | -14 | 0.9 | 1.7 | 2.6 | 2.9 | 4.2 |
| | 06-Oct-22 | 2 | 17.6 | 15.7 | 53 | -15 | 1.2 | 2.2 | 3.2 | 3.5 | 5.2 |
| | 06-Oct-22 | 3 | 16.4 | 15.4 | 55 | -10 | 1.2 | 2.0 | 2.8 | 3.2 | 5.4 |
| | 06-Oct-22 | 4 | 15.2 | 15.0 | 58 | -16 | 0.7 | 1.6 | 2.3 | 2.8 | 4.6 |
| | 19-Oct-22 | 5 | 14.0 | 12.1 | 62 | 10 | 1.0 | 1.9 | 2.4 | 2.8 | 4.7 |
| | 19-Oct-22 | 6 | 16.5 | 14.6 | 52 | 18 | 1.2 | 1.9 | 2.6 | 3.0 | 4.6 |
| | 19-Oct-22 | 7 | 16.3 | 14.6 | 48 | 27 | 1.4 | 2.4 | 3.2 | 3.7 | 5.7 |
| | 19-Oct-22 | 8 | 11.9 | 12.3 | 67 | 7 | 0.6 | 1.1 | 1.7 | 2.0 | 3.5 |

# Appendix 3 Individual drift deposition curve fits



Correspondentie adres voor dit report:
Postbus 16
6700 AA Wageningen
T 0317 48 07 00
www.wur.nl/plant-research

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Corresponding address for this report:
P.O. Box 16
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
www.wur.nl/plant-research

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