Normative Reference Protocol for Field Measurement of Spray Drift Deposition from Agricultural and Horticultural Spraying Systems

Foreword

This guidance applies to the conduct of field studies to measure spray drift deposition (drift fallout). These measurements are made to provide data to demonstrate the capability of candidate ‘low drift’ application systems to reduce spray drift fallout in comparison with equivalent conventional application systems. Demonstration of this capability is an essential factor in validating claimed ‘low drift’ performance of spraying systems, or their components, which are to be operated under conditions of LERAP (Local Environmental Risk Assessment for Pesticides).

As a normative reference, every effort has been made to provide clear and helpful guidance which, if followed, will enable successful measurements to be achieved. However, this does not mean that alternative procedures which achieve results of equivalent value may not be followed. Moreover, the inherent complexity of the subject matter places limitations upon any single protocol to address all foreseeable study conditions. For these reasons it is suggested that individual proposals for conduct of such field work may be discussed with the authors[1] of this guidance document to obtain supplementary advice specifically relating to their own circumstances.

1. Scope

Spray drift is defined as that quantity of applied product (representing pesticide active ingredient) which is deflected out of the treated area by the action of air currents during the application process. Spray drift deposition (drift fallout) is that part of spray drift which impacts on the ground by vertical flux from the spray drift passing overhead. Drifting material may take the form of droplets, dry particles or vapour. This protocol is concerned only with the sampling and estimation of droplet drift (and dry particles where applicable), but not with vapour.

This protocol relates principally to the comparative field measurement of spray droplet drift deposition arising from tractor mounted, trailed and self-propelled agricultural sprayers operating in arable field crops (boom type sprayers). Measurements of drift fallout from arable field crop sprayers will be made with sprayers operating outdoors on a defined flat, level field surface without any appreciable height of crop cover.

The underlying principles of this protocol may be applicable to studies with other types of spraying system. However, to encompass sprayers for hops, vines, bush and tree fruit crops (including air-assisted broadcast sprayers) special consideration must be given to operating the sprayer within representative conditions of crop canopy (structure and foliar density). Sampling for drift fallout should, however, be done as above.

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Measurements of the atmospheric conditions in the location of the drift sampling at the time of spraying will be made as part of the test procedure.

This protocol does not apply to hand held spraying equipment.

2. <u>Essential Elements of a Test</u>

A spray drift deposition test comprises the application of spray liquid containing a suitable analyte (pesticide active ingredient, a tracer dye material or both) to a defined test area of crop while deposition of spray is measured using an array of sampling matrices placed at known locations within the test area of crop and the drift fallout is measured similarly in the adjacent area immediately downwind.

The measured analyte must be representative of applied pesticide in solution in order to facilitate quantitative analysis of the mass of pesticide deposits collected by target items.

The spray should be applied by travelling in an appropriate pattern of passes at a measured forward speed where the direction of forward progress of the spraying system is arranged to be at right angles to the predominant direction of the wind.

Results for drift fallout are thus obtained by calculating measured drift fallout as a proportion of the measured applied spray deposition rate.

Results are normally expressed as a profile of results from samples taken at individual locations within the sampling array, under measured meteorological conditions and with respect to (sets of) parameters governing the spray application. In view of the difficulties inherent in controlling for all extraneous variables under anticipated field and weather conditions it is usual to carry out comparative measurements of fallout from any ‘test’ spraying system(s) against an internal standard ‘reference’ spraying system in order to reduce the number of tests needed to obtain valid, meaningful results.

2.1 The trial area

The designated trial site should be freely exposed with the minimum of obstructions that may influence the air flow in the region of the measurement. A suitable site should allow repeatable trial results to be gathered. It should be of an adequate size for the task and be of a shape which will allow the correct orientation of the sampling layout with wind direction to be obtained. Its surface should be suitable and its surroundings should avoid any major hazards and vulnerable areas.

The designated trial site shall be divided into two regions, comprising the treatment area (which will be sprayed) and the downwind area in which to support sampling stations (Figure 1).

Appendix 1 describes the ‘X, Y, Z’ convention used in this protocol.

2.1.1 Treatment pattern

The treatment area will be sprayed according to a planned pattern of swaths, depending on the type of sprayer. Arable sprayers not applying pesticide may use a single swath (repeated spraying) pattern (Figure 2).

All sprayers applying pesticide should use only a multiple adjacent swath pattern (sprayed only once) to avoid over-dosing.

Orchard type sprayers should use the multiple adjacent swath pattern to examine the effect of foliage within unsprayed buffer-zone swaths upon drift fallout measured beyond the treated area.

2.1.2 Spraying systems.

In all tests, measurements with a reference spraying system (Table 1) should be included in the field trial programme to allow comparative measurements to be made against other candidate spraying systems.

For comparative tests with orchard sprayers the reference spray should not be applied within the furthest downwind rows serving to represent the unsprayed buffer-zone. The test sprayer may apply to some or all of those rows to demonstrate the effect of spraying them upon drift fallout beyond the orchard. Alternatively, consideration may be given to including a reference sprayer consisting of a vertical boom fitted with the same reference nozzles used for arable spraying at a forward speed of 4 km/h. These nozzles should be spaced at 0.5 m intervals, with the lowest set at 0.5 m above the ground and the boom height matching as closely as possible the height of the target crop to be sprayed. This reference sprayer should be operated in the alley nearest the downwind edge of the sprayed area of crop.

2.2 Measurements

2.2.1 Measurement of spray.

The rate of deposition of applied spray within the treatment area must be always be measured to provide verification of sprayer output, serving as a basis for expression of spray drift as a proportion of the output spray.

Horizontal collection surfaces shall be placed at ground level in the sampling area and used to determine the quantity of spray liquid sedimenting in this area. One of a range of suitable drift fallout collectors or sampling systems may be used. It has been found that circular filter papers mounted in clean petri dishes are suitable for this purpose if used in sufficient numbers.

A good collection system will have:

(a) a defined collection area;

(b) a surface such that pesticide active ingredient or tracer dye materials can be accurately and reliably recovered from this surface.

Deposition and drift fallout measurements will be made at set distances within and downwind of the treated area. For arable systems using a single swath pattern targets may be located according to the example layout (Figure 3), with target locations (Table 2) and sizes (Table 3) recorded using a suitable convention (see Appendix 1).

For orchard sprayers consideration should be given to supplementary sampling of spray fallout within unsprayed buffer zone areas, as well as to alternative target types that are more representative as samples of spray targeted at foliage.

2.2.2 Suitable Analytes.

Analytes should be selected which provide valid results and be safe to persons and the environment (complying with all relevant regulatory requirements).

The analyte must represent a quantitative equivalent to the pesticide spray and results must be possible to verify as being free from extraneous contamination or losses that would alter the measured result. Laboratory and field procedures must be undertaken to verify the performance of the analyte in order to validate results.

Validation procedures include:

2.2.2.1 Efficiency of recovery.

Fortification (spiking) at a range of levels and extraction of all target objects should be carried out following the same laboratory protocol to be used for the for extraction procedure throughout the tests. This procedure should be repeated for ranges of time interval between fortification and extraction as typically expected to be required from the field protocol.

2.2.2.2 Stability.

The stability of the analyte both in the spray solution and as dried residues on target objects, should be established for field conditions (under a range of weather conditions - notably examining strong ambient sunlight) and for the laboratory extraction process.

2.2.2.3 Limit of detection.

Sensitivity of analysis, minimum determinable level and maximum spray volume capacity of each target object (this depends also on the type of object).

2.2.2.4 Controls

Negative and positive control samples should be prepared, as follows:

Negative : There must be zero background contamination of samples from the test environment or from target objects themselves. Laboratory assessment of unexposed selected target objects should be carried out following field exposure of a clean example of each, making sure to avoid contamination by spray liquid. Analytes should be selected which are not naturally found in the ambient environment used for field trials to avoid false positive results.

Positive : To ensure minimal loss of analyte from adsorption by target object or breakdown - test over range of time periods and ambient conditions likely to be experienced in conduct of field trials. While 100% recovery of tracer is ideal, consistent performance, within reasonable limits, is acceptable. Field spiking (fortification) of all target objects is used to confirm experimental recovery of spray output from target items. Control samples should be exposed to identical ambient conditions and storage and transport arrangements as experimental samples collected from the field.

2.2.2.5 Tank samples.

These must be taken at the beginning and end of the spray application (ideally also at regular intervals throughout, if lengthy) and analysed for analyte content.

2.2.2.6 Safety to persons and the environment

Use of artificial tracer substances (e.g. visible dyestuffs) should be supported by an assessment of their safety to persons, animals and the environment. Where artificial tracers (e.g. dyestuffs) are employed destruction of contaminated food crops and exclusion of live stock from the treated area prior to cutting and removal of grass is recommended as an additional safeguard. Approved pesticides should only be applied within their conditions of approval, never overdosed (e.g. by repeated spraying of a single swath), nor applied in circumstances where there is a risk of spray drifting into neighbouring properties adjacent to the designated test site.

2.2.3 Measurement of Meteorological Conditions

Measurements of the meteorological conditions at the time of a test shall be made upwind of the centre of the sprayed area. A mast supporting sensors will be used to determine:

- the wind velocity at a minimum of two heights (expressing wind direction with respect to the Y axis i.e. normal to the orientation of the spray track);

- the temperature difference between a minimum of two heights;

- the mean air temperature and wet bulb depression (or other measure of relative humidity);

The ratio of the upper and lower measurement heights should be 4:1 with the lower height selected to be close to the top of the crop (e.g. boom height of 0.5m, and 2m above ground level).

Tests shall be carried out in atmospheric conditions within the following ranges:

(i) Wind

All tests should be conducted in conditions of consistent wind speed and direction. A series of at least two tests should be conducted at different wind speeds representative of the range between 3 and 5 m/s. The wind direction during tests should not vary unacceptably from the ideal direction (the Y axis). Acceptable limits are recognised as a mean direction not more than thirty degrees from the ideal, with peak deviations greater than thirty degrees from the ideal for no more than 30% of the duration of a spray run.

(ii) Temperature

The temperature at which tests are conducted shall be between 5 and 25^{o}C.

2.2.4 Sampling and analysis.

2.2.4.1 Processing of field samples.

Following the completion of spray application each target item should be promptly collected, placed in a clean container labelled with the items unique identification code. Clean gloves should be worn when handling target objects and care must be taken not to contaminate them nor allow them to come into contact with ambient spray deposits. Collect first the items located furthest downwind and work toward the treated area to minimise the risk of cross-contamination.

2.2.4.2 Laboratory analysis.

All collected field samples including exposed target objects and controls should be extracted with a measured volume of the required solvent. It is advantageous to use the minimal extraction volume consistent with full recovery of analyte because this achieves maximal concentration of samples for quantitative analysis, which increases the minimum determinable level of analyte possible to measure on any target object for a given analytical apparatus.

Evaporation or dilution steps can be performed to adjust the concentration of sample extracts if required to suit the calibrated range of the analytical apparatus (measuring instrument). The concentration of analyte in each sample extract should be measured and recorded, and the result calculated to express the measurement in terms of mass of analyte recovered from that target item.

The mean value for the analyte concentration in the spray liquid can then be used to further calculate the volume of spray liquid the recovered mass represents. The variation between pre- and post spraying tank sample concentrations should be less than 15%.

2.2.4.3 Calculation of results:

The results of laboratory analysis (i.e. mass or volume of analyte collected per target object), regarded as the raw data, should be recorded showing how all the steps in the evaluation were performed.

Normalised results may then be derived from the raw data, taking into account repeated spray passes in the run and relative dimensions of target objects to enable expression of values in terms of percentage of applied spray volume rate per target.

Calculated values may be further derived from the normalised results, such as plotting the decay curve for drift fallout against downwind distance.

Generally a single spray run will serve to expose an array of targets, which are collected following the completion of spraying. However, multiple (sequential or simultaneous) spraying runs may be completed to expose the same array of target items where use of contrasting analytes, possible to measure in each others presence, will allow the different sprays to be separately analysed after extraction from the targets, and where target objects have the capacity to collect the total volume of liquid spray drift concerned without losses due to run off.

2.3 Results

2.3.1 Conduct and recording of spray treatment

All the factors with units that control the spray application should be recorded for all spraying systems under evaluation in the report (Table 1, with example values).

The following data (where applicable) will be recorded for each test condition:

- sprayer type;
- manufacturer;
- measured boom length, boom height, swath width and forward speed;

- nozzle type, operating pressure, measured flow rate(s), number and spacing of nozzles;
- arrangements and adjustment settings and position of any spray drift engineering control system;
- the manufacturers recommendations for limiting operational parameters

2.3.2 Factors relating to the crop and surface in the drift sampling zone

Records will be made of:

- surface type, condition and stage of growth;
- row width.
- swath patterns

2.3.3 Presentation of Results

A report of the results will include:

(i) a record of spraying system as operated, field layout and meteorological conditions during the time of the measurement;

(ii) the measured ground spray drift deposition values.

(iii) All data and methods of calculation.

FIGURE 1: Plan view of general layout of trial site.

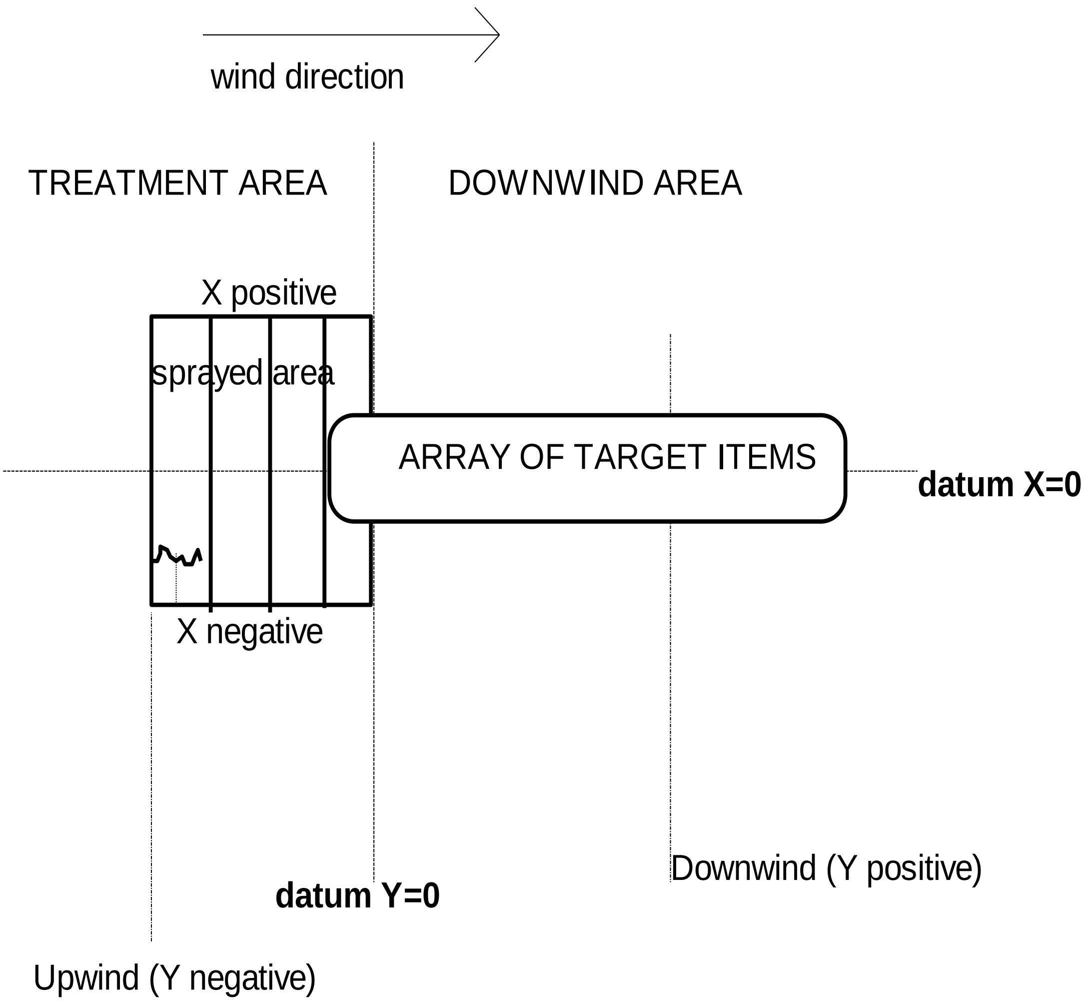
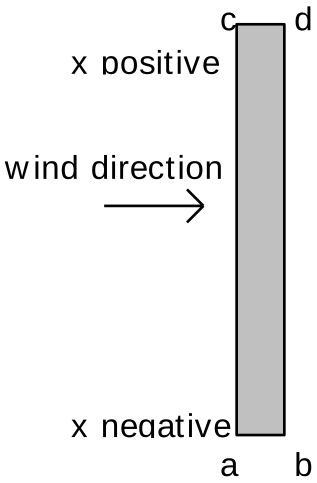


FIGURE 2: Plan view of sprayed swath patterns.



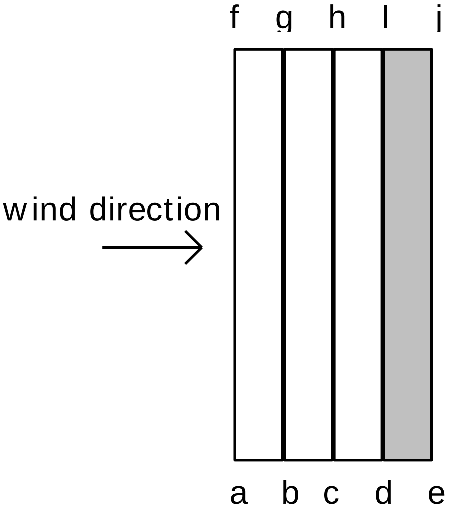
single swath

abdc = treated area

ab = cd = swath width (-Y dimension)
bd = Y dimension datum line (y = 0m)

ac = bd = swath length (X dimension)
Assume spraying begins at x=negative, or state otherwise.

State whether sprayed once, or repeatedly.



(four) matching adjacent swaths

de = ij = swath width (first sprayed swath)

cd = gh = swath interval = swath width

ej = Y dimension datum (y = 0m)

ej = af = swath length (X dimension)

aejf = treated area

Assumes sprayed once (state if not).

Note: Overlapping adjacent swath patterns may alternatively be used if required.

FIGURE 3:   Plan view of target object locations in a downwind array.

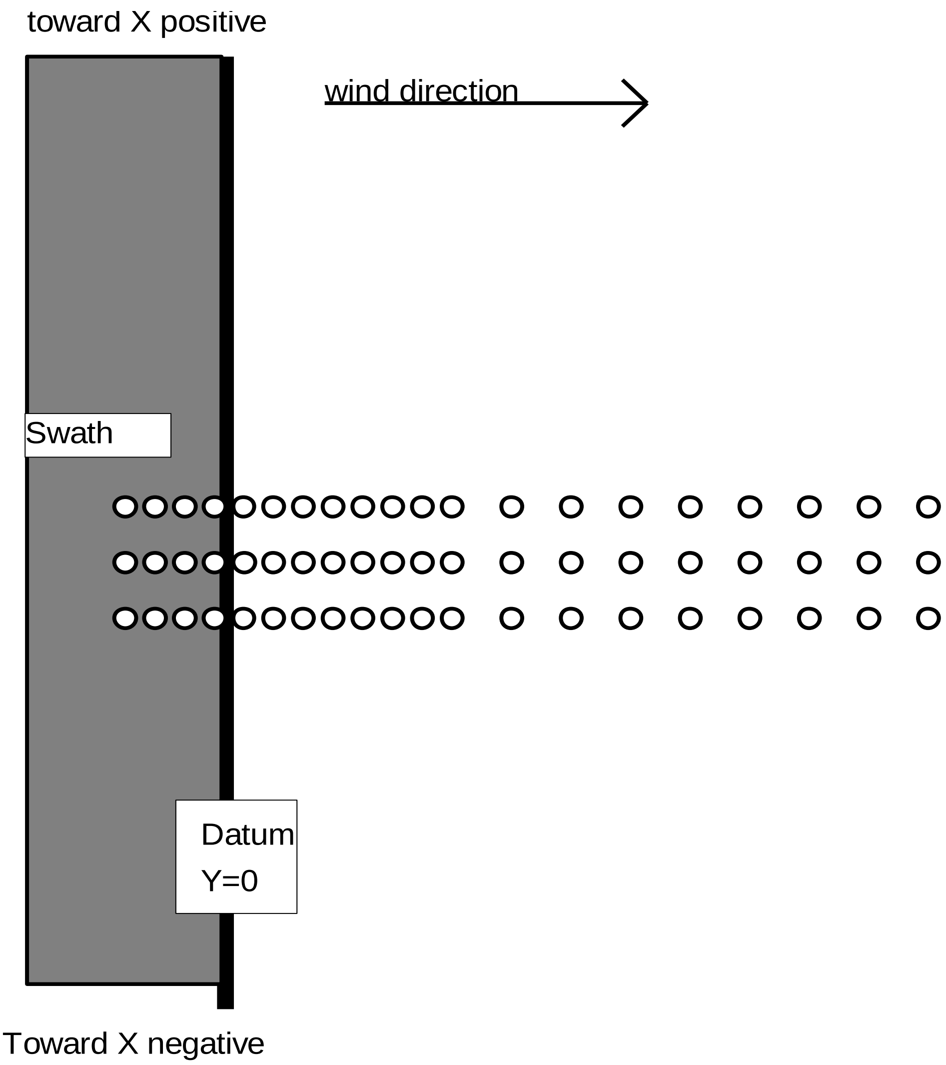


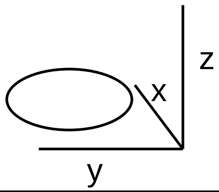
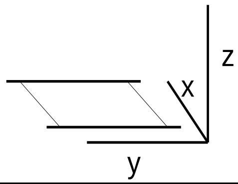
TABLE 1 Factors defining spray application (with units and example values) for reference sprayers treating alternative sprayed swath patterns.

Crop Type Factor	Arable	Orchard / Vines / Hops
Dose Rate (l or kg/ha)		
Volume Rate (l/ha)	180	400 - 800
Swath Pattern (Fig 1a)	Single	Matching adjacent
Number Of Swaths	1	4
Repeat Spraying	6 times	single
Treatment Area (ha)	0.09	0.15
Swath Length (m)	75	75
Swath Width (m)	12	5
Boom height (m)	0.5	
Nozzle spacing (m)	0.5	
Nozzle type	110 deg Flat Fan	
Size	03	
Flow rate l/min	1.2	
Pressure (bar)	3	
Forward speed (km/h)	8	
Row / Tramline Gap (m)	-	5
Swath Interval (m)	-	5
Furthest upwind swath (-Ymax for first swath)	Not applicable (- 12m)	4 swaths (e.g. -20 m)
Vertical Dimension (m) i.e. crop height	0	2
Downwind Boundary (X,Y,Z)	no obstruction	? wind break
Downwind Surface	Grass	Grass

TABLE 2. Scheme for defining items (item = object at location) in the array.

ITEM (Unique number)	Target object name :	X Locus (X_L)	Y Locus (Y_L)	Z Locus (Z_L)
1	Paper circle	-3	-6	0
2	Paper circle	0	-6	0
3	Paper circle	3	-6	0
4	Paper circle	-3	-4	0
5	Paper circle	0	-4	0
6	Paper circle	3	-4	0
7	Paper circle	-3	-2	0
8	Paper circle	0	-2	0
9	Paper circle	3	-2	0
10	Paper circle	-3	0	0
11	Paper circle	0	0	0
12	Paper circle	3	0	0
13	Paper circle	-3	0.5	0
14	Paper circle	0	0.5	0
15	Paper circle	3	0.5	0
16	Paper circle	-3	1	0
17	Paper circle	0	1	0
18	Paper circle	3	1	0
19	Paper circle	-3	1.5	0
20	Paper circle	0	1.5	0
21	Paper circle	3	1.5	0
22	Paper circle	-3	2	0
23	Paper circle	0	2	0
24	Paper circle	3	2	0
25	Paper circle	-3	2.5	0
26	Paper circle	0	2.5	0
27	Paper circle	3	2.5	0
28	Paper circle	-3	3	0
29	Paper circle	0	3	0
30	Paper circle	3	3	0
31	Paper circle	-3	3.5	0
32	Paper circle	0	3.5	0
33	Paper circle	3	3.5	0
34	Paper circle	-3	4	0
35	Paper circle	0	4	0
36	Paper circle	3	4	0
37	Paper circle	-3	5	0
38	Paper circle	0	5	0
39	Paper circle	3	5	0
40	Paper circle	-3	6	0
41	Paper circle	0	6	0
42	Paper circle	3	6	0
43	Paper circle	-3	7	0
44	Paper circle	0	7	0
45	Paper circle	3	7	0
46	Paper circle	-3	8	0
47	Paper circle	0	8	0
48	Paper circle	3	8	0
49	Paper circle	-3	9	0
50	Paper circle	0	9	0
51	Paper circle	3	9	0
52	Paper circle	-3	10	0
53	Paper circle	0	10	0
54	Paper circle	3	10	0
55	Paper circle	-3	11	0
56	Paper circle	0	11	0
57	Paper circle	3	11	0
58	Paper circle	-3	12	0
59	Paper circle	0	12	0
60	Paper circle	3	12	0

TABLE 3. Scheme for defining target objects - an illustration of specific three dimensional data for size and orientation of target objects in an array.

Object number	**Target Object Name**	**Target object (T) diagram with (x,y,z) reference dimensions**	**Object size data (m) (as oriented in array)**
1	Paper circle		$T_X = 0.10$ $T_Y = 0.10$ $T_Z = 0$
2	Paper strip		$T_X = 0.05$ $T_Y = 1.0$ $T_Z = 0$
3	other		
etc			

APPENDIX 1

General convention for co-ordinating locations and targets by X, Y, Z system

It is recommended that the following convention is adopted to describe directions, locations, movements and target sizes and orientations by consistent reference to three dimensions (X, Y and Z) such that:

the X dimension denotes the axis of the direction of the sprayer moving along the sprayed swath. The datum point corresponding to X = 0m is located half way along the swath. Sprayers advance from the 'negative' end toward the 'positive' end of the swath, with the wind blowing from the left of the sprayers direction of travel.

the Y dimension denotes the other horizontal axis at 90 degrees to the X axis. The Y axis is always set to match the expected wind direction. The datum corresponding to Y = 0m is along the straight line locating the downwind side of the sprayed swath. Distances along the Y axis are negative in the upwind direction and positive in the downwind direction. The swath width thus has a negative Y value (e.g. -12m). The maximum positive Y value is the furthest downwind target station and the maximum negative Y value equals the upwind edge of the sprayed area.

the Z dimension denotes the vertical axis (90 degrees to X and Y). The datum corresponding to Z = 0 is at the swath ground surface level. Distances along the Z axis increase with height above the ground and decrease with depth below the ground (into ditches, down to water courses, etc.).

the central datum point which corresponds to 0 m in the X, Y and Z dimensions is located on the ground on the downwind edge of the sprayed swath at the mid-point of the sprayed swath.

The size and orientation of targets (as deployed) may be defined by reference to the point representing the geometric centre of each collector matrix object.