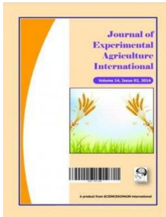

Journal of Experimental Agriculture International

34(4): 1-12, 2019; Article no.JEAI.48113
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Experimental Investigation of Problems of Drift in Aerial Spraying

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v34i430179
Editor(s):
(1) Dr. Suleyman Korkut, Professor, Duzce University, Department of Forest Industrial Engineeering, Division of Wood Mechanic and Technology, Turkey.
Reviewers:
(1) Nyong Princely Awazi, University of Dschang, Cameroon.
(2) Nkwoada Amarachi Udoka, Federal University of Technology Owerri, Nigeria.
(3) Jaime Cuauhtemoc Negrete, Autonomous agrarian Antonio Narro University, Mexico.
Complete Peer review History: http://www.sdiarticle3.com/review-history/48113

Original Research Article

Received 25 January 2019
Accepted 05 April 2019
Published 17 April 2019

ABSTRACT

Agricultural and forestry requirements for agricultural aviation are related to spread of fertilizers, crop protection and protection against pests in forestry. Main topic presented on this paper is the result of experimental investigations in the field of "*the drift in aerial spraying".*
The results of those investigations are formulas for estimating protection zones depending on the type of used pesticides.

Keywords: Agricultural aviation; aerial spraying; drift.

LIST OF MAJOR SYMBOLS

a [ha/m^2]	*: coefficient*
d [μm]	*: average droplet diameter*
d_s [μm]	*: trace droplet diameter*
d_{VM} [μm]	*: volume meridian diameter*
h [m]	*: aircraft altitude*
g [number/cm^2]	*: spray density*
l [m]	*: wingspan*
m [kg]	*: mass*
m_s [dcm^3/s]	*: sedimentation flow rate*
p [N/m^2]	*: wing loading*
A [m^2]	*: area*
B [m]	*: working swath*
D_P [dcm^3/ha]	*: field dose*
D_T [dcm^3/ha]	*: technical dose*

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F	*: agent*
I	*: turbulence intensity*
W [dcm^3/s]	*: flow rate*
V_r [m/s]	*: operating speed*
V_s [m/s]	*: sedimentation velocity*
V_w [m/s]	*: average wind velocity*
T [K]	*: temperature*
U_K	*: constructional design*
Z	*: drift*
α, ß,φ	*: inclination, rolling, yawing*
ψ	*: relative humidity*
λ	*: aspect ratio*

1. THE BIO-AERONAUTICS

The name was given by Southwell (1975), and the definition is *„application of different types of aviation to the development of useful living organisms on the Earth".* As the origin of this field of aviation is considered a patent received by Alfred Zimmermann, a forester from Detershagen (D) on 21th of March 1911. The patent belongs to the problem of Lymantria Monacha L control in Germany forests.

In spite of its small actual operating range on the world scale, bio-aeronautics can play a very important role to the improvement of the nutritional world situation especially for countries in Asia, Africa and South and Central America [1]. In those regions feeble infrastructure, very poor agricultural mechanization and shortage of specialists cause that in some fields of activities the only practical alternative is bio-aeronautics.

The main problems of aerial treatment and wises by agricultural and forestry specialist are the following: Treatments have to be done in time (agricultural time); The risk of environmental pollution and problem of drift has to be minimalized; The distribution quality of the sprayed /spread products; Economic effect (B – max for given coefficient of variation). Below there are short definitions of those terms.

1.1 Agricultural Time

It is a time period during which protection, fertilization or other treatment should be applied, ensuring the highest effectiveness of an agent used. For protection purposes it will be biological effectiveness.

1.2 Quality of Distribution

Applying treatment at an agrotechnical date and specific meteorological conditions, with a set dosage and agent formulation. The dosage applied should be dispersed on a crop (soil) with specific evenness - a determined coefficient of variation. The quality of distribution, as well as the elements induced drift are connected with: disturbances of the flow field around the flying aircraft, especially the vortex sheets travelling from the wings and the disturbances given by the propeller. This effects is mainly join with the construction design of airplanes. The influence of the earth proximity and the type of covering are also taken into account.

The working width (B) adopted in the treatment depends on the constructional design of the agricultural aviation, the type of apparatus and the spreading medium. Its value is assumed in spraying operations:

Atomizers 35 m – 40 m, jet nozzles 20 m – 30 m. For spreading: 20 m – 30 m depending on materials. With an assumption that the coefficient of variation is the order 20%for receiving magnification of (B), in those experimental investigations, incl. wing tips [2,3].

1.3 Problem of Drift

It is "*unintentional effect of treatment caused by movement of chemicals outside of the target. For liquids the movement has direct and indirect form. Direct one belongs to drift of spray in all form of state (particles as a result of evaporation of droplets, liquids, and vapour), Indirect – movement caused by wind of vapour, settled droplets and particles after evaporation of liquids*" [4,5,6,7,8,9,10].

Induced drift is a term describing meteorological conditions in terrain of treatment, disturbances of velocity field caused by flaying aircraft, physical characteristics of dispersed agent, terrain of treatment, flight parameters and quality of a pilot.

Negative effects of spray drift are as following: loss of chemicals, decrease of efficiency of pesticides on the target area, other losses related to the damage or pollution of adjacent crops, water, urban area, gardens, contamination of environment with a possibility of unpredictable secondary effects (residues, interaction, etc.) and a sociological factor, understood as non-scientific media trend of criticizing chemical plant protection treatments leading to baseless social dislike for those, mainly for aerial spray treatments. The above-mentioned have resulted in the European Union issuing a peculiar document called Directive 2009/128/WE of the

European Parliament and of the Council of 21 October 2009. Official Journal of the European Union L 309 of 24 November 2009. In the document in Chapter IV, Article 9, Paragraph 1 reads:

1. Member States shall ensure that aerial spraying is prohibited.
2. By way of derogation from paragraph 1 aerial spraying may only by allowed in special cases provided the following conditions are met (points *a* through *f* of the aforementioned document).

2. THEORETICAL ANALYSIS

Generally, from the mathematical point of view, the four factors have been researched for over 60 years both theoretically and experimentally. The subject bibliography is over 500 titles long, although it is often contributory literature [11].

There are two types of methods that illustrate the motion and distribution of droplets. Methods that do not account for the influence of disturbances in the velocity field behind the aircraft on droplet motion and distribution are called free models. Referred free models were presented in: [12,13, 14,15,16,5,17,18,19].

Bound models are methods that do account for above factor as well as other parameters. Referred bound models are presented by the first Reed W.H. in NACA Report 1954 [20] and [21,22,23,16,18,24,8,9].

There are many papers presented this model, but Pietruszka [23] and AGDISP models [4,25,26,7] look the most interesting.

The Agriculture Dispersal (AGDISP) [4,25, 26,7], is popular and is the current North American Standard. But in this model are some simplifications.

Interesting is also last Seredyn [18] analysis.

3. EXPERIMENTAL INVESTIGATION

3.1 The Method

The method is described in "*The Methods of Testing Agricultural Aircrafts and their Apparatus"* [20], presented in Russian. Methods are used for certification of Agricultural Aircrafts for treatments in agriculture, forestry and other branches of national economy. This methods were "*Acceptance for use*" in: Bulgaria, Cech-Slovakia, DDR, Hungarian, Poland, USSR.

3.1.1 The trials were made to agree with [27] on a former airfield in Gryźliny near Olsztyn, and in lower experimental range in Mielec

Its surface is about 150 hectares and covered with 0.1$\pm$ 0.15m tall grass.

3.1.2 Objects

The airplane An -2R, produced in Polish Aviation Factory - Mielec.

The helicopter Mi -2R, produced in Polish Aviation Factory - Świdnik.

3.2 Model Liquids

To protect workers and the environment, the following model liquids were used:

2% water solution of nigrosine — N;
30% water solution of urea with an addition of 2% nigrosine — M.

Table 1. Apparatus and technical parameters of tests

Airplanes	Apparatus	Nozzles	Nr.	Dose [l/ha]	d_{VM} [µm]	V_r [m/s]	h [m]
An – 2R	atomisers	Au-3000	6	9.65	109.9	44.4	4.5
An - 2R	jet-nozzles	W 7-2	56	48.35	186.1	44.4	4.5
An - R2	Jet-nozzles	W 17-4	52	106.16	223.2	44.4	4.5
Helicopter	atomiser	electrical	1	8.08	93.6	22.2	4.5
Helicopter	atomiser	electrical	1	20.50	125.6	22.2	4.5

Table 2. Physical properties of model liquids

Solution	Density [kg/m^3] *10^3	Surface tension [N/m]*10^3	Viscosity [Pas]*10^3
N	1.001	64.14	1.100
M	1.073	63.80	1.292

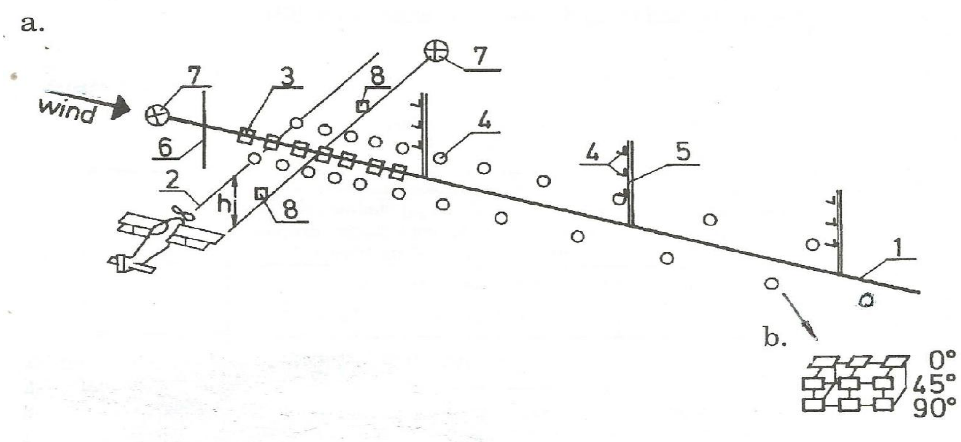

Fig. 1. Scheme of measure line (1-measure line, 2- flight path, 3- mass samplers, 4- droplet samplers, 5- masts, 6- measurements of meteorological parameters, 7- camera, 8- markers)

The physical parameters of liquids are presented in Table 2.

- There are 3 to 5 repetitions of the test
- The test took place from 5amto 8am and from 5pm to 8pm, for better meteorological conditions.

3.3 Measure Line and Samplers

Thirty metres from the zero point of the measure line, a direction line perpendicular to it was determined for the agricultural aircraft flight. It was marked with markers which informed the pilot where to switch the apparatus on and off. This distance was equivalent to 5s of agricultural aircraft flight before and 5s of the flight after the measure line. Each flight was conducted at a speed and altitude accepted in research programmes, and was rectilinear without rolls or yaws. The correctness and height of each flight were controlled by the pilot. Moreover, they were registered by two coupled cameras, perpendicular to each other and close to the measure line, at a height of two metres. (Assmann's method), wind velocity (gust velocity included) and direction of the wind. Fig. 1 shows the scheme of the measure line.

Meteorological conditions during the test were registered. The following data was measured and registered: temperature, ΔT - the difference of temperatures on dry-bulb and wet-bulb thermometers.

After the flight and subsidence of the spray cloud (after 8-10 minutes), samples were collected and replaced by new ones. Following the direction of the wind, an 800m long measure line was established.

The line was composed form the following samplers:

1. To measure mass distribution: Cellophane samplers ($0.01m^2$ each) were distributed horizontally at grass level (0.20m), every two metres over a distance of 200 metres for the plane and 140 metres for the helicopter;
2. To measure liquid dispersion: Dispersion in this case is understood as the number of droplets and the structure of their spectrum obtained from the surface of samplers. Samplers were microfilm negative tapes marked and plasticized with 6µm of thick mineral oil. This tape was then cut and framed for slides. The surface of the samplers at $4.05 \cdot 10^{-4} m^2$ ($4.05 cm^2$) and $7.03 \cdot 10^{-4} m^2$ ($7.03 cm^2$). This method was patented.

The samplers mentioned above were placed on stands (0.20m tall) and distributed horizontally, at an angle of 45° and vertically.

The stands were distributed:

every 5m	from 0 to 100m,
every 10m	from 100 to 200m,
every 20m	from 200 to 300m
every 50m	from 300 to500m,
every 100m	from 500 to 800m.

They were placed in two rows. One row had 9 samplers (three in each exposure) which were replaced after every test flight. The other row had 3 samplers (one in each exposure) which were replaced after each series of three or five test flights agricultural aircraft.

8m tall masts, distributed 100m, 300m and 500m from the beginning of the measure line. The samplers on the masts were distributed every one meter, one vertically and one horizontally along whole mast's length. In opinion of specialists mast's height has to be at least 11m–13m., but they were too difficult to make.

3.4 Analysis of Results

In this paper are presented results of experimental investigation only of An-2R. Results of the test of Mi-2R are in [6].

Mass distribution was analysed using the colorimetric method on a spectral colorimeter with a length range of 580 nm. After recalculations, the distribution was presented in the form of dose distribution as a distance function, Dp=f(y), for each performed flight, meaning value and distribution uniformity analysis. The tests of droplets were conducted using indirect methods, by measuring fixed, coloured traces. The size, surface density (i.e. spray density) and the structure of the droplet spectrum were determined on a computer image analyser, based on fixed coloured droplet traces. The traces were grouped into ranges, according to trace sizes. The collection of droplet traces, arranged according to droplet diameters, was converted into a collection of droplets based on equations presented in Table 3.

The results were recorded in the form of a distributive ordered series from each measuring point, and sum of the number of droplets in classes from the measure line or a part of it, e.g. the masts. These results are presented as size, surface density (i.e. spray density), average diameters (arithmetic and volumetric), and medians (quantitative and volumetric). Cumulative quantitative and volumetric distributions of liquids, which is the basic information about the spectrum structure, are presented graphically.

Analysis determined:

1. The change of dose in relation to drift distance – y direction, and average doses for airborne crop protection treatment working breadth (B=30m),
2. the distribution of surface spray density along an 800m strip,
3. the structure of the droplet spectrum along the 800m strip (i.e. the change of average droplet diameter in relation to drift distance),
4. droplets evaporation and sendimentation in drift distance
5. airborne movements of droplets clout received on masts

3.4.1 The distribution of mas

The mass distribution of a spray in case of a cross-wind is characterized by asymmetry, shift of the centre of mass with the wind in relation to aircraft's flight direction, and a large spray area with a low dose. The average mass distribution from three flights for the technical dose of Dr=48.35dm^3/ha is presented on Fig. 2.

To present drift, mass distribution can be quantized by relating it to a generally accepted working breadth B=30m, used in plant protection treatments performed by aircrafts.

Average values for sprays by atomizers and pressure nozzles are presented in Fig. 3.

A higher settlement in a working breadth of 30m occurs when droplet diameters are larger and when urea is applied as a weighting agent in liquids.

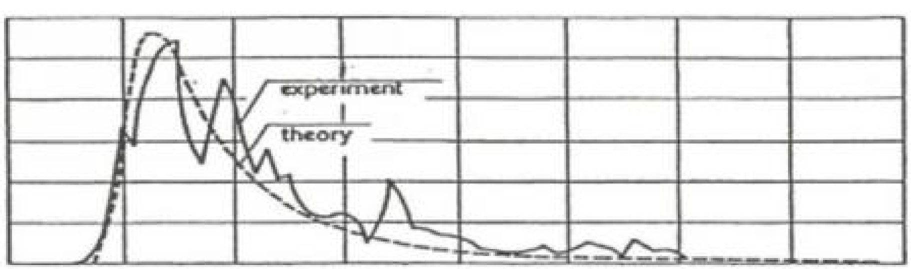

Fig. 2. Example of mass distribution (— experiment, - - theory) [17]
Parameters: D =48.35dm3/ha; Vr = 44.4m/s; Vw=4.5m/s; h=4.5m; dv= 187µm, I = 0.1

Table 3. Scalling equations

No.	Solution	Functional relations d = f(ds)	Diameter
1	N	$d=-0.0087+0.54155ds-0.13643ds^2+0.01459ds^3$	> 0-1.7mm
2	M	$d=100.707+0.56334ds$	> 0- 600mm

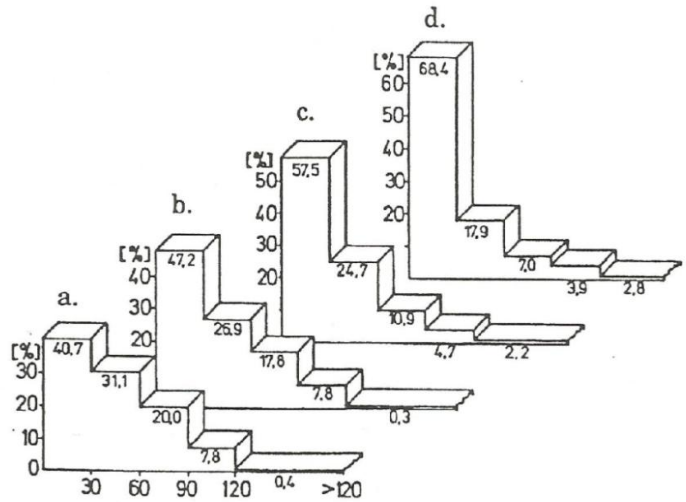

Fig. 3. Percentage mass distribution at 30m intervals

(a - atomizers, 2% water solution of nigrosine; b-atomizers, 30% urea solution in 2% water solution of nigrosine; c- pressure nozzles, 2% water solution of nigrosine; d- pressure nozzles, 30% urea solution in 2% water solution of nigrosine)

Table. 4. Coefficients

Apparatus	Liquids	Coefficient equation 3(A)	Coefficient equation3(A1)	Correlation coefficient	Diameter range [μm]
Atomizers	N	1.3555	- 0.2126	- 0.9330	90 - 150
	M	1.4227	- 0.2050	- 0.8358	150 - 300
Press. nozz.	N	1.8101	- 0.3365	- 0.9550	170 - 300
	M	1.8608	- 0.2897	-0.9897	250 - 400

Because of threats to neighbouring crops, fauna, water regions and urban areas, it is important to define a share of drifted dose in relation to the applied dose (i.e. to define a technical dose in the function of drift distance).

For atomizers, these relationships is:

$$\check{D}=0.1045-0.0211\times\ln y \tag{5}$$

with correlation coefficient: r=-0.9511. for 15 m ≤ y ≤ 140m.

For pressure nozzles, these relationships is:

$$\check{D}=0.4633e^{-0.0246y} \tag{6}$$

with correlation coefficient: r = 0.9792 for 15m ≤ y ≤ 210 m

3.4.2 Settlement of droplets

Examination of settled droplets was based on the analysis of samplers placed along the 800m measure line. The distribution of samplers (discussed in methodology), made analysis possible not only for horizontal samplers, but also for skew and vertical ones. The breadth of the droplet settlement strip was defined as y ≤ 500m. The droplets of urea solution achieved a wider breadth than the nigrosine solution droplets. This phenomenon is connected with lower degree of evaporation and a higher rate of sedimentation for the urea solution droplets. In the experiment there was a discrepancy in breadth of settlement in relation to atomizers and pressure nozzles. This discrepancy can be

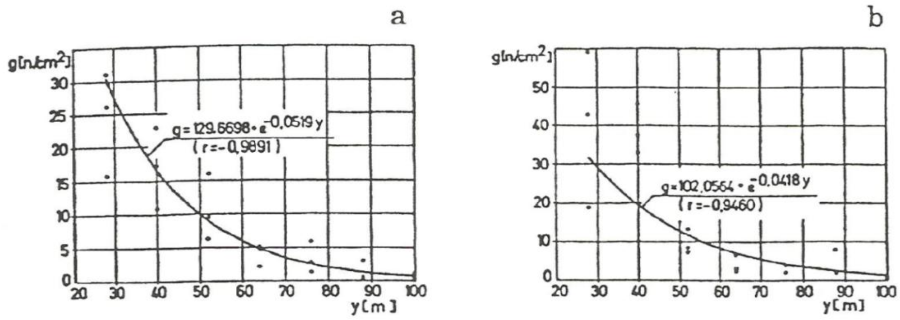

Fig. 4a. Variations of droplet density with drift distance. W7-2 pressure nozzles (a- 2% water solution of nigrosine, b- 30% urea solution in 2% water solution of nigrosine)

explained by disturbances of velocity field behind the flying aircraft and by turbulence. The settlement of droplets sprayed by atomizers on horizontal samplers is characterized by a very low density and shift of spray over significant distances. A higher surface density of spray was obtained for the urea solution than for the nigrosine solution, due to the above-mentioned factors.

The distribution of spray surface density for pressure nozzles has the character of mass distribution. The spray density and the regression function for pressure nozzles are presented in Figs. 4a and 4b.

3.4.3 Droplets evaporation and sendimentation

The droplets, drifting with the wind, undergo a segregation and a process of evaporation. This is why the average diameter of settled droplets in the function of drift distance was examined.

The analysis included all examined spraying sets and both model liquids. The parameters were the relative volumetric diameter[1], and the time after which a droplet settled. The results of the analysis can be presented as the general relationship: The values of coefficients are presented in Table 4.

$$\overline{d_v} = A \cdot t^{A1} \quad (t = y/V_w) \qquad (7)$$

From the data in Table 4 we can see that better compatibility of the function occurred for pressure nozzles producing larger droplets. Smaller droplets are significantly influenced by the field of velocity disturbances behind a flying aircraft. This is confirmed by better repeatability for small droplets calculated for distances 3-4 times longer than the wingspan. In this area the field of velocity disturbances are already disappearing.

3.4.4 Airborne droplets

The shift of spray in an 8m layer of air was defined by analysing droplets settled on samplers which were placed vertically on the masts. Sediment of droplets on these samplers, of the small angle of elevation, best characterizes drifted droplets. The densities of spray for all sets and model liquids are presented in Fig. 5a.

3.4.5 In Mielec

The second experiment took place in Polish Aircraft Plant (PZL) in Mielec. They carried out a crop dusting experiment with the involvement of M18 "*Dromader*" airplane equipped with jet type nozzles. Flying height was 4m and flight speed was $46.4 m \cdot s^{-1}$ along the wind axis and against the wind. Liquid flow rate was $7.1 dm^3 \cdot s^{-1}$ and the volume-median droplet diameter was d_{MV} = 215μm. The modelled liquid was 1% aqueous solution of nigrosine. Every test was repeated 3 times. Droplet evaporation rates were very low due to high relative humidity of 98%. Crosswind speed was $0.2 m \cdot s^{-1}$. Results are in Fig. 6.

3.5 Estimation of Measuring Error

Here is a short analysis of errors. In the above-mentioned experiments treble averaging of samples was applied. To define if this multiplication factor is enough, it was assumed that the averages from 3 groups of measurements and variations of these groups are equal to each other. The alternative hypothesis, that not all of them are equal to each other, was also assumed. To verify these two hypotheses, test F (Snedecor and Bartlett's (f))

[1] Average volumetric diameter in relation to average volumetric diameter of first settled droplets

was applied, with critical value on significance level a=0.01. The values of test statistics were defined. The equality of group variations was also tested.

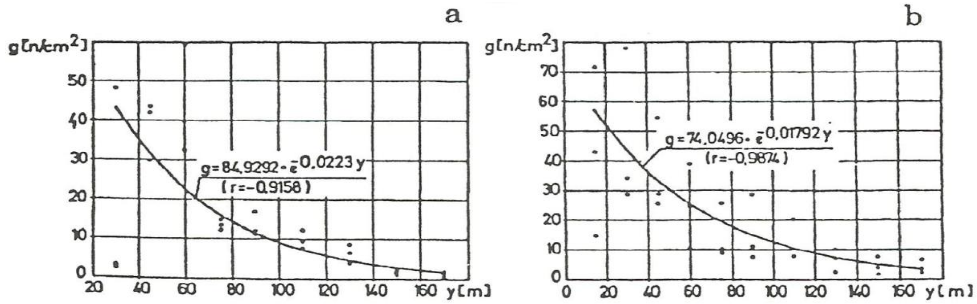

Fig. 4b. Variations of droplet density with drift distance. W 17-4 presser nozzles (a- water solution of nigrosine, b- 30% urea solution in 2% water solution of nigrosine)

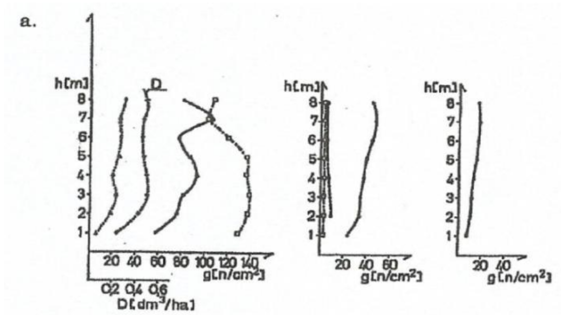

Fig. 5a. Distribution of droplets density on masts
a – 2% water solution of nigrosine (N)

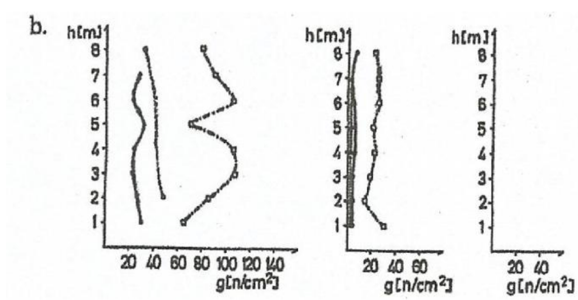

Fig. 5b. Distribution of droplet density on masts
b.- 30% urea solution in 2% water solution of nigrosine

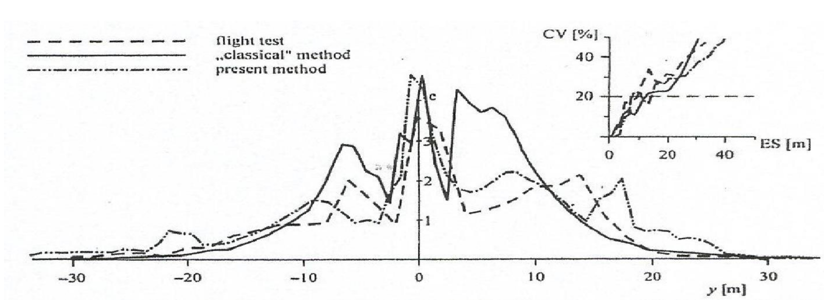

Fig. 6. Lateral distribution of 1% nigrosine aqueous solution determined theoretically and experimentally [23], compare with proposed by [8]

For tests performed with W 17-4 and W7-2 sprayers for both model liquids, there is no basis to reject the hypothesis of average equalities and group variations.

For atomizers, the testing showed that the averages vary significantly, relative values do not differ significantly and they were used in this form for further analyses. Errors of other measurements were also estimated (dosage, rate-of-flow and droplet size included).

3.6 Drift

The amount of drifted liquid is the difference between a technical dose and the field dose[2]. This difference can be presented as the following relative relationship:

$$Z = \frac{D_T - D_P}{D_T} = 1 - \frac{D_P}{D_T} \qquad (8)$$

where:

$D_T = a \cdot W/B\ V_r$ a – coefficient 10^4 [ha/m^2]

After the analysis of many parameters (technical dose and average volumetric diameter of droplets included), a relative amount of drift was related to a volume diameter d_{VM} median which is an essential measure of spray structure. On the basic of research these relationships (for 2% water solution of nigrosine and 30% urea solution in 2% water solution of nigrosine) are as follows:

$$Z = 134.9377\ d_{VM}^{\ -1.0757} \qquad (10)$$

with correlation coefficient: r = 0.8690 for diameter range 100μm ≤ d_{VM} ≤ 250μm

$$Z = 2.3269\ e^{-0.0047\ dvm}$$

With correlation coefficient: r = -0.8470 for diameter range 250μm ≤ d_{VM} ≤ 400μm

In the case of a global analysis of air drift, the following equation can be used:

$$Z = 13.5324\ d_{VM}^{\ -0.5955} \qquad (11)$$

with correlation coefficient: r = -0.6481 for diameter range 100μm ≤ d_{VM} ≤ 400μm

[2]*Field dose is the mass or amount of liquid which settled on samplers in relation to samplers sizes, with in the working breadth and with the assumption that a marker in model liquid does not evaporate.*

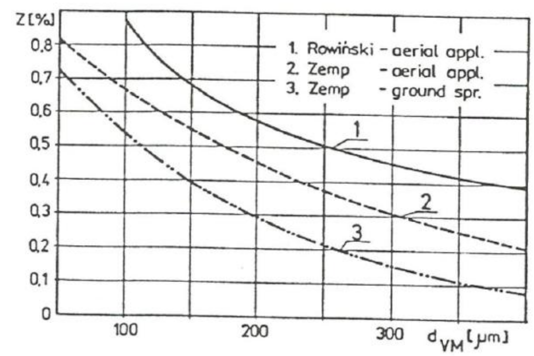

Fig. 7. Drift analysis

Is possible to compare this results with Zemp [10] equations:

for airborne spraying:

$$Z = 1.48^{\ -0.01\ dvm} \qquad (12)$$

for sprays with ground equipment

(9)

$$Z = 1.86^{\ -0.01\ dvm} \qquad (13)$$

The results of analyses are presented in Fig. 7. From tests carried out here it follows that smaller droplets drift more than Zemp's equations state.

Environmental protection, it essential to define the lateral distribution of drifted liquid. The drift may be divided into two processes:

1. In relation to the movement of droplets which settle on crop within the tested area, and
2. In relation to a spray cloud which moves with the wind in the near-ground air layer (the spray cloud may be measured by the structure of spray which settles on the masts)

3.7 Protection Zones

The results of the above experiments confirm the necessity of using protection zones for airborne plant protection treatments. These zones, according to the character of drift process, may be divided into two categories:

- The insulation zone (also called insulation strip), on the lee side of the treated area, where most of the droplets settle, and
- The buffer zone, which provides protection from the negative effects of shift and

settlement of a spray cloud in the near-ground air layer.

The sum of these two zones constitutes to the protection zone (see Fig.8).

From the mass distribution analysis for both liquids applied it is possible to define the relative dose Ď (i.e. the ratio of field dose to technical dose). Unlike equations 7 and 8, a real treatment was considered, where distributions overlap with a shift equal to the applied working swath B=30m. The following results were obtained:

for atomizers:

$$Ď=0.03032-0.0613\ 1ny\ (r = -0.9932) \quad (14)$$

for pressure nozzles:

$$Ď = 0.9136\ e^{-0.0273\,y} \quad (r = -0.9987) \quad (15)$$

Differentiating these equations, we obtain a measure of drop for a relative dose. These values are the following:
for atomisers:

$$(dĎ/dy)_a = -0.0613 * 1ny \quad (16)$$

for pressure nozzles:

$$(dĎ/dy)_p = -0.025\ e^{-0.0273y} \quad (17)$$

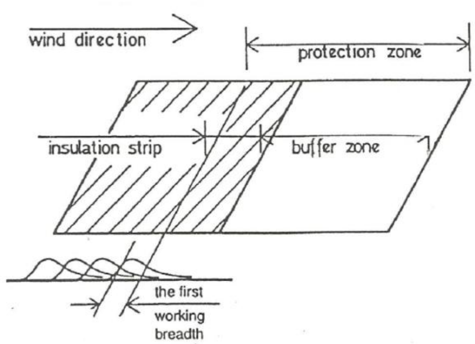

Fig. 8. The protection zone

This means that during airborne treatment, in which pyrethroids are sprayed with atomizers, with an acceptable level of dosage on a field's periphery, e.g. Ď =4%, the area of drift will be y ≤ 73m, and insulation zone 43m (with a working breadth of 30 metres).Analogically, when herbicides are used in airborne treatments, with an allowed dose on the periphery of e.g. Ď=0.5% the drift area is y≤ 190m, and the insulation zone is 160m. These are also the areas where droplets settle (see Figs. 5 and 6). The area of a buffer zone can be estimated only on the basis of dose which settles on vertical samplers on the masts. This will depend on toxic and dynamic properties of the applied pesticide, as well as on the threat it poses to neighbouring areas.

As mentioned above, a spraying conducted with atomizers settles at a distance of 300m in a dose in relation to a technical dose Ď =0.047, and at a distance of 500m for dose Ď =0.015. Assuming a linear distribution of a dose between the masts with the above-mentioned assumption that an allowed dose of pyrethroid Ď =0.04, it is possible to evaluate a drift distance y=350m. For pressure nozzles and the above assumption Ď =0.005, a drift distance is y ≤ 360m. Buffer zones can be evaluated as 320m and 330m respectively, for working breadth B = 30m.The above sizes of protection zones are extreme. They were calculated for the application of herbicides and the threats related to them for the most sensitive cultivated crops (i.e. lettuce and cucumbers). In the case of these plants, a relative dose of 0.1% to 0.5% can make it impossible for the crop to be sold [11].

Data on what doses responsible for crop losses are allowed or what pesticide residues are acceptable make it possible to calculate protection zones (based on equations presented in this paper). These zones will be much narrower for most insecticides and fungicides applied

3.8 Mass Balance

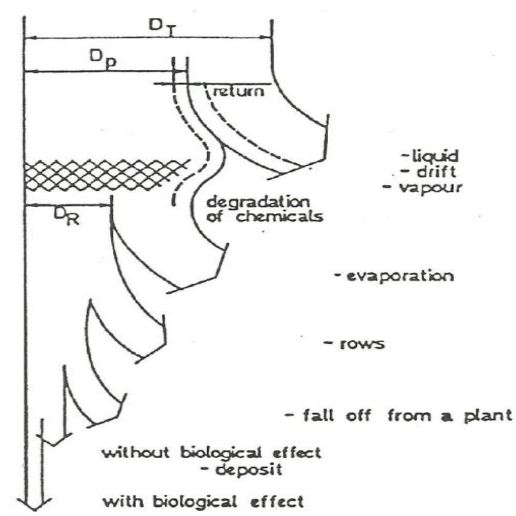

Fig. 9. Mass balance

The process of drift is an element of a broader problem concerning the mass of an expanded factor. Like in Thermodynamics Sankey's figure for engines, the mass balance can be presented in Fig. 9. In this balance (although it does not have any direct influence on the mass), degradation of chemicals due to solar radiation was also marked(evaporation). So far, broader research of the whole process has not been available, and the aviation practice has been basically restricted to biological effects. The balance presented here, although it is extremely difficult in experiments, will enable a complex analysis of plant protection treatment efficiency, as well as the negative effects of treatment on the environment. It is interesting from agriculture engineers to receive the total efficiency of our treatments (D_T/biological effect).

4. CONCLUSION

Because of the Document of EU from 2009 year, forbidding use of airplanes in crop protection treatments, agreement is possible only in a particular situation. Because of that there is no reason to continue very labour consuming and expensive experimental investigation in this field of knowledge. But if continued it should be based on a generally accepted, standard method which would make it possible to compare results. Still more attention should be drawn to model research, mathematical model of drift included, to recognize physics of occurring processes. So far there have been too many segment tests.

What is more, application of pesticides requires establishing protection zones (insulation and buffer zones included) on the lee side. The breadth of these zones ranges from 50m up to 330 m, depending on threats certain pesticides imply and the type of equipment.

Lastly, inference The method was acknowledged by Ministry of Agriculture and Rural Development, The Institute of Environmental Protection, The Forest Research Institute, as a better than EU Directive to use airplanes in crop protection treatment and formally agree after analyse presented the method to use treatments “Mospilan 20 SP” in insecticide control in forest.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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