"Experymental Investigations Problems of Drift in Aerial Spraying"

Abstract

Agricultural and forestry requirements for agricultural aviation related to spread of fertilizers, crop protection and protection against pests in forestry are presented. Some mathematical models describing aerial spraying and the distribution of liquid droplets on a target are discussed, but the main problems presented on this paper are results of experimental investigations in field of *"the drift in aerial spraying"*

Key words: agricultural aviation, aerial spraying, drift

1. List of major symbols:

a [ha/m^2] - coefficient
d [µm] - droplet diameter (average, d_V, d_{MV} …)
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
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.

1.1.The possibilities of the Bio-aeronautics.

In spite of its small actual operating range on the World scale, the bio-aeronautics can play very important role to the improvement of the nutritional World situation especially for countries of Asia, Africa, South and Central America.[3]. In those regions a feeble infrastructure, a very poor agricultural mechanization and a shortage of specialists cause that in some fields of activities the only practical alternative is the bio-aeronautics.

1.2.The main fields of activity of bio-aeronautics are:

- control of human and animal disease vectors (tsetse fly, onchocerciasis
- control of mass infestations (Locust, Quelea)
- plan protection treatment (cereals, cotton, rice, maize, root crops and others)
- application of fertilizers
- reclaiming, erosion control, ground stabilisation
- delivery of agricultural and others products
- health control

Parallel with test of new apparatus, new aircrafts for use in agriculture and forestry, took place the analyse some most important problems of aerial treatment concern:

1.3.Treatments.

- The main problems of aerial treatment and wises by agricultural and forestry specialist are: Treatments must do in time (agricultural time)
- Minimalizing the risk of environmental pollution, problem of drift
- The distribution quality of the sprayed /spread products
- Effect of economy. (B – max for data CV)

1.4.The agricultural times.

Jest to przedział czasowy, w którym powinien być wykonany zabieg ochrony, nawożenia, inny, zapewniający najwyższą skuteczność stosowanego środka. Dla ochrony, będzie to skuteczność biologiczna.

1.5.Quality of distribution.

Rozumie się przez to wykonanie zabiegu w terminie agrotechnicznym, przy określonych warunkach meteorologicznych, przyjętą dawką i formulacją środka. Stosowana dawka winna być rozłożona na uprawie (glebie) z określoną równomiernością - ustalonym współczynnikiem zmienności. 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. Uwzględnia się również wpływ bliskości ziemi i charakter pokrycia.

1.6. Working width (B)

Przyjęta w zabiegu szerokość robocza zależna od constructional design of the agricultural aviation, typu aparatury, rozprzestrzenianego środka. Przyjmuje się jej wartość w zabiegach opryskiwania: atomizers 35 m – 40 m, jet nozzles 20 m – 30 m. For spreading: 20 m – 30 m. depends of materials. Make an assumption for the coefficient of variation of the order 20%,for receive magnification of (B), were experimental investigations, wing tips. [11],[17]

1.6.Problem od drift.

It is "*unintentional effect of treatment cause movement of chemicals outside of the targed. 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 with wind vapour of settled droplets and particles after evaporation of liquids*".[2],[16],[20],[25],[26],[27],[29]

Induced drift:

- Meteorological conditions in terrain of treatment
- Disturbances of velocity field caused by flaying aircraft

Physical characteristics of dispersed agent. Liquid: droplets size and formulation.

Solids: granulation, dusty agents, crystalline agents, taking their humidity into account

Terrain of treatment

- Flight parameters and quality of a pilot.

Negative effects of spray drift:

- The loss of chemicals
- The 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.)
- 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 analyses

Generally, from mathematical point of vie, 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 [6]. To recapitulate, the above factors can be presented as four functions that mutually influence each other. They are bound as follows:

$$K = f1\ (Uk, \lambda, p, l) \tag{1}$$

$$L = f2\ (Vr, , h, \alpha, \beta, \phi) \tag{2}$$

$$M = f3\ (Vw.\ T, Tr, \psi) \tag{3}$$

$$C = f4\ (m, d, F, A) \tag{4}$$

where:

K –construction design
L – flight parameters
M –meteorological conditions
C – propagation of agents

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. Referred “free models”. Presented by: [1],[4],[7],[8],[13],[16],[18],[21],[23].

2.1.Free models.

1.In a spray cloud, droplets concentration have Gaussian distribution with standard deviation σ_y along the y-axis in the direction of the wind and σ_z – relative to the vertical z – axis
2.The cloud becomes dispersed due to sedimentation, turbulence and wind motion.
3.Droplets are small, implying that sedimentation velocity is low
4. Droplets evaporation rates have been taken into account
5. Average wind speed and coefficient of turbulent diffusion remain constants with change in height.
6.All droplets leave the cloud when it reaches the top of the crop and penetrates it.

Use the CSANADY^S [5] concentration function, is possible to receive the dose distribution in (y,z) direction.

2.2.Bound models.

Methods that do account for above factor as well as other parameters. Referred “ bound models”. Presented by the first Reed W.H. in NACA Report 1954 [14] and [9],[10], [12],[13],[21],[22],[26],[27]. Were also many papers presented this model, but Pietruszka [12] and AGDISP models[2],[19],[24],[25] look the most interesting.

The model propose by Pietruszka [12] take in to account;

1.The wing wake is modelled by inviscid and incompressible flow of 22 vortex line
2.Vortex displacement from propeller axis and deformation of the propeller wake due to wing interference were taken into account
3.additionaly the velocity field is modified by the influence of ground proximity
4.droplets evaporation have been taken in analyse
5.the logarithmic wind velocity profile near the ground is determined by the height of crop plans.

The Agriculture Dispersal (AGDISP). [2],[19],[24],[25], is popular and is the currently Nord American Standard. But in this model are some simplifications:

1.the wing wake is modelled by only one vortex line
2.the propeller wake has too big simplification
3. is the same problem with equations of circulation especially for helicopters

Interesting is also last Seredyn [21] analysis.

3.Experimental investigation

3.1.The method is in “*The Methods of the Test Agricultural Aircrafts and they Apparatus”* [14], presented in Russian language. Methods are for certification of Agricultural Aircrafts for treatments in agriculture, forestry and other branches of national economy. This methods was “*Acceptance for use*” by: , Bulgaria, Cech-Slovakia, DDR, Hungarian, Poland, USSR.

3.2. The trials were made agree with [15]:

on a former airfield in Gryźliny near Olsztyn, and in lover experimental range in Mielec.

In Gryźliny.

Its surface is about 150 hectares and covered with 0.1+0.15m tall grass.

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

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

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

3.4.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.

The physical parameter of liquids are presented in the table 2.

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

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

3.5. 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. This 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 rolling or yawing. The correctness and height of each flight were controlled by the pilot. Moreover, they were registered by two coupled cameras, perpendicular to each other’s Close to the measure line, at a height of two metres, meteorological conditions during the test were registered. The following data were measured and registered: temperature, ΔT - the difference of temperatures on dry-bulb and wet-bulb thermometers (Assmann's method), wind velocity (gust velocity included) and direction of the wind. Figure 1 shows the scheme of the measure line.

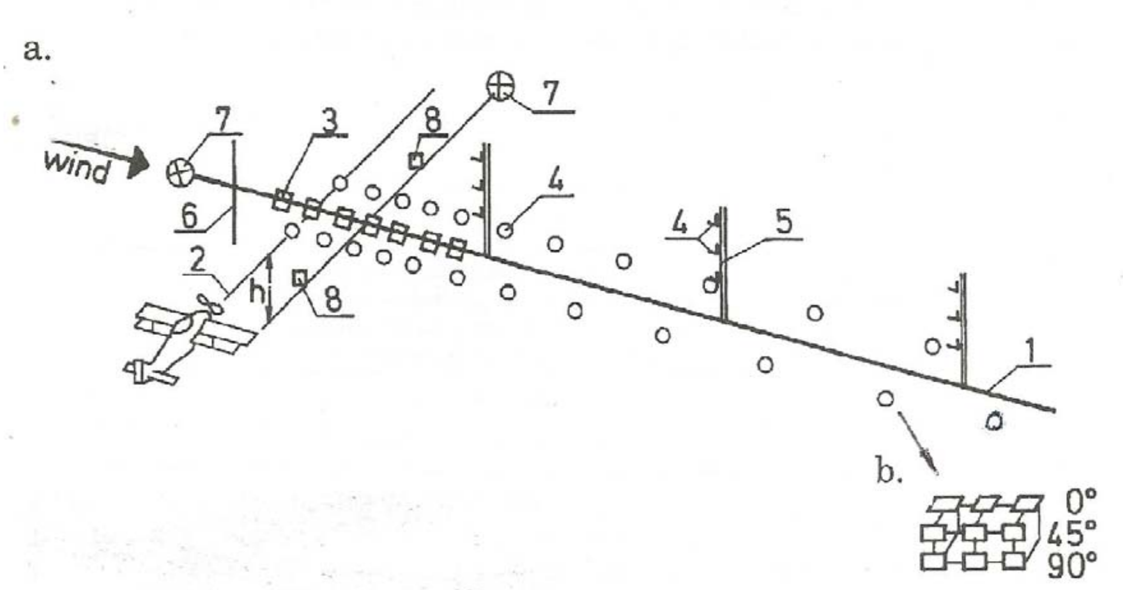


Fig. 1. Scheme of measure line (1-measure line, 2- flight path, 3- mass samplers, 4- droplet samplers,
5- masts, 6- measurements of meteorological parameters, 7- camera, 8- markers).

After the flight and subsidence of the spray cloud (after 8+10 minutes), the samples were collected and replaced by new ones. Following the direction of the wind, an 800 metre 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•10 $^{-4}$m^2 (4.05cm^2) and 7.03 •10^{-4}m^2 (7.03cm2). This method was patent.

The above-mentioned samplers were placed: on stands (0.20m tall) and distributed horizontally, at an angle of 45^0 and vertically.

The stands were distributed:

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

The stands with samplers 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.

8 metre-tall masts, distributed 100m, 300m and 500m from the beginning of the measure line. The samplers on the masts were distributed every one metre, one vertically and one horizontally along the whole mast length. In opinion of specialists mast's tall have to be at list 11 m– 13 m., but was too difficult to did it.

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 [20].

Mass distribution was analysed using the colorimetric method on a spectral colorimeter with a length range of 1 =580nm. After recalculations, the distribution was presented in the form of dose distribution in a distance function, Dp=f(y), for each performed flight, mean 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.

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

The results are 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 pan 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

4.1. The distribution of mas

The mass distribution of a spray in the case of a cross-wind is characterized by asymmetry, the shift of the centre of mass with the wind in relation to an aircraft 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 in figure 2.

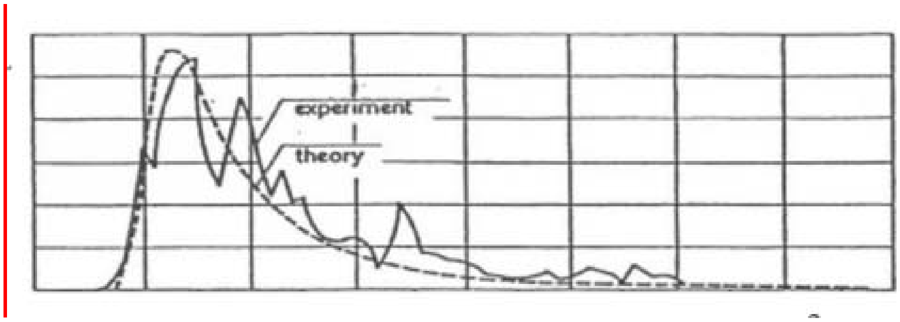


Fig. 2. Example of mass distribution (— experiment, - - theory) [18]. Parameters: D =48.35dm^3/ha; Vr = 44.4m/s; Vw=4.5m/s; h=4.5m; d_v= 187µm, I = 0.1

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 aircraft.

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

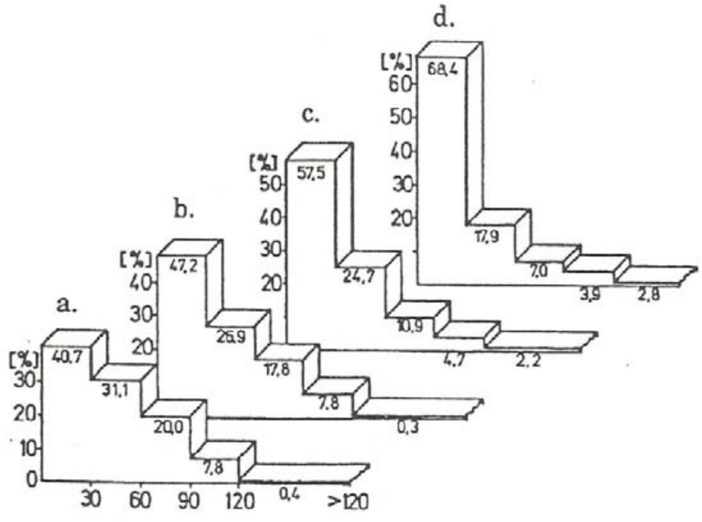


Fig.3.Percentage mass distribution at 30m intervals (a - atomizers, 2% water solution of nigrosine, b-atomizers, 30% urea solution in 2% water solution of nigrosine, c- pressure nozzles, 2% water solution of nigrosine, d- pressure nozzles, 30% urea solution in 2% water solution of nigrosine)

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.

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 are the following:

$$\check{D}=O.1045-O.0211 \ln y \qquad (5)$$

with correlation coefficient: $r=-0.9511$. for $15\ m \leq y \leq 140m$.

For pressure nozzles, these relationships are:

$$\check{D}=0.4633e^{-0.0246y} \qquad (6)$$

with correlation coefficient: $r = 0.9792$ for $15m \leq y \leq 210\ m$.

4.2. The settlement of droplets

Examination of settled droplets was based on the analysis of samplers placed along the 800 metre 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 ys500m. 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 the breadth of settlement in relation to atomizers and pressure nozzles. This discrepancy can be explained by disturbances of the velocity field behind flying aircraft and by turbulence. The settlement of droplets sprayed by atomizers on horizontal samplers is characterized by a very low density and by the 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 arepresented in figures 4a and 4b.

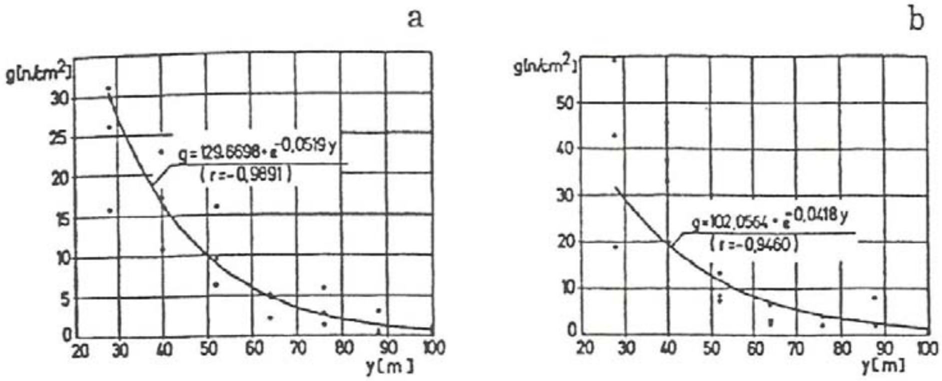


Fig. 4a. Variations of droplet density with drift distance. W7-2 pressure nozzles (a- 2% water solution of nigrosine, b- 30% urea solution in 2% water solution of nigrosine)

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)

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 , 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.

$$\bar{d}_V = A\, t^{A1} \qquad (t = y/V_W) \qquad (7)$$

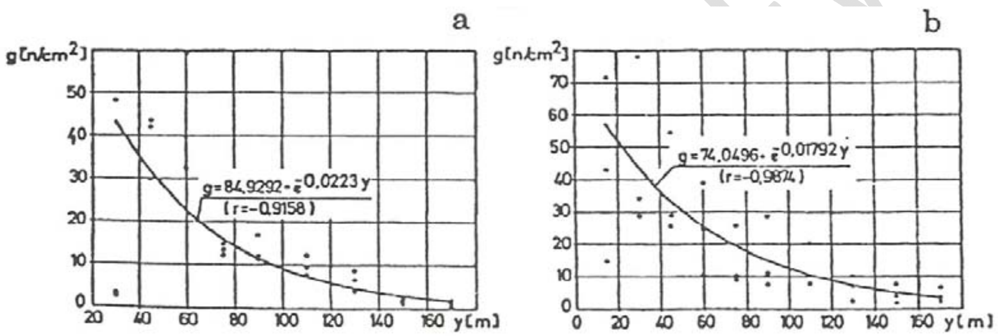


Fig. 5. Average diameter of settled droplets in the function of drift distance

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

From the data in table 4 it follows that better compatibility of 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 wingspan. In this area the field of velocity disturbances is already disappearing.

4.4.Airborne droplets.

The shift of spray in an 8-metre 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 figure 6a.

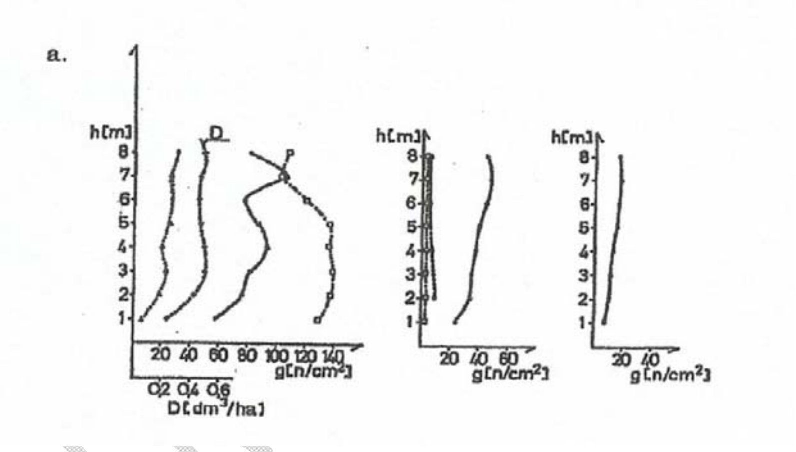


Fig. 6a. Distribution of droplets density on masts
a – 2% water solution of nigrosine (N)

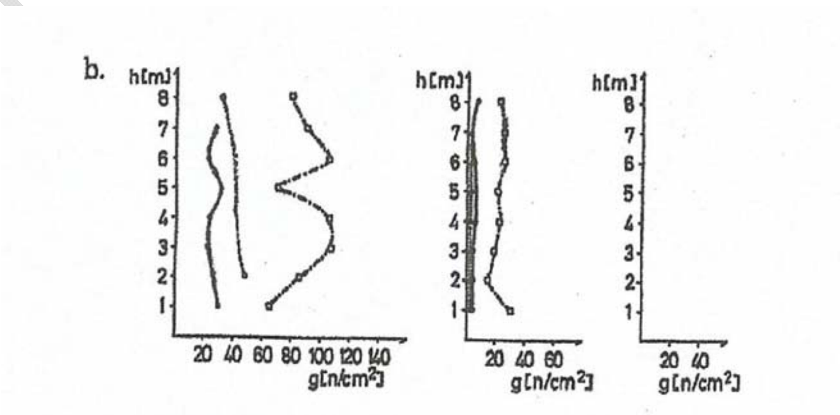
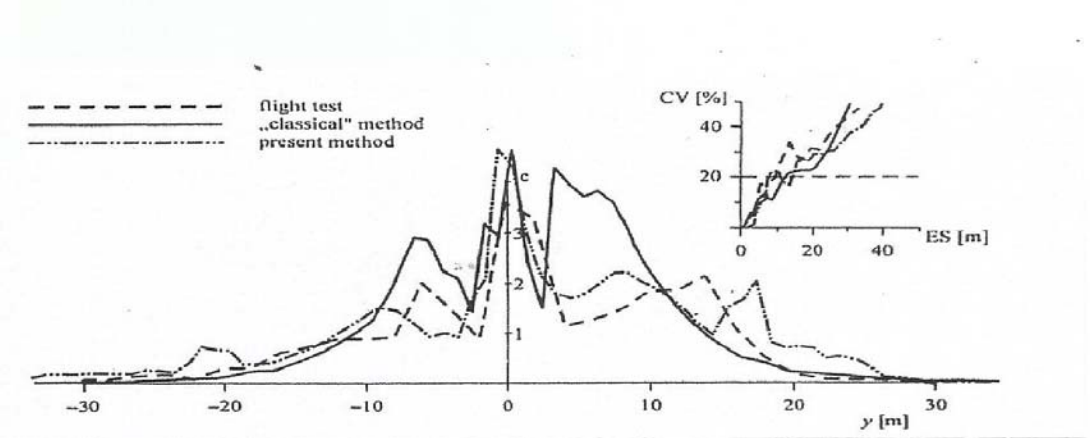


Fig.6b. Distribution of droplet density on masts,
b.- 30% urea solution in 2% water solution of nigrosine (M)

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 the M18 "*Dromader*" airplane equipped with jet type nozzles. Flying height was 4 m and flight speed was 46.4 m·s^{-1} along the wind axis and against the wind. Liquid flow rate was 7.1 dm^3·s^{-1} and the volume-median droplet diameter was d_{MV} = 215 µm. The modeled liquid was 1% aqueous solution of nigrosine. Every test was performed in 3 replications. Droplet evaporation rates were very low due to high relative humidity of 98%. Crosswind speed was 0.2 m·s^{-1}.



Results are in Fig.7.

Fig.7. Lateral distribution of 1% nigrosine aqueous solution determined theoretically and experimentally [12], compare with proposed by [26].

5. Estimation of measuring error

Here is a short analyse od 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)) 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.

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).

6.Drift

The amount of drifted liquid is the difference between a technical dose and the field dose[1]. 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: $D_T = a\, W/B\, V_r$ a – coefficient 10^4 [ha/m^2] (9)

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 100 µm ≤ d_{VM} ≤ 250 µm

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

With correlation coefficient: r = -0.8470 for diameter range 200 µm ≤ d_{VM} ≤ 400 µm

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

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

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

Is possible to compare this results with Zemp [29] equations :

for airborne spraying: $Z = 1.48^{\,-0.01\, dvm}$ (12)

for sprays with ground equipment $Z = 1.86^{\,-0.01\, dvm}$ (13)

The results of analyses are presented in fig.8.

The results of analyses are presented in figure 8. 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

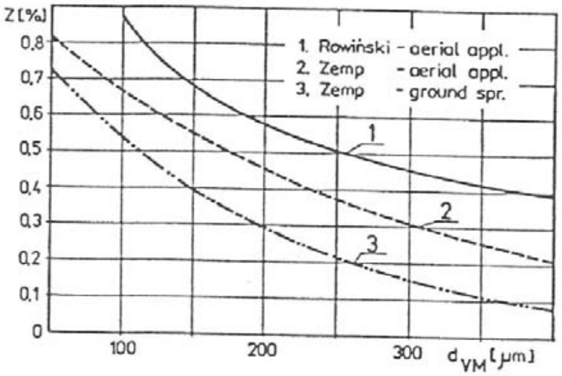


Fig.8. Drift analysis

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[1] 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.

9. 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 the protection zone (see fig.9).

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:

$$\check{D}=0.03032-0.0613\ \ln y \qquad (r = -0.9932) \qquad (14)$$

for pressure nozzles:

$$\check{D} = 0.9136\, e^{-0.0273\, y} \qquad (r = -0.9987) \qquad (15)$$

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

for atomisers:

$$(d\check{D}/dy)_a = -0.0613 * \ln y \qquad (16)$$

for pressure nozzles:

$$(d\check{D}/dy)_p = -0.025\, e^{-0.0273y} \qquad (17)$$

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 figures 6 and 7). 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.

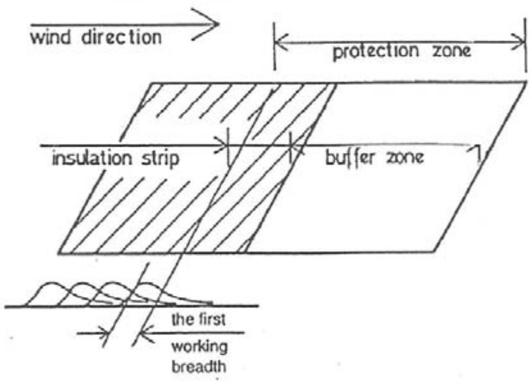

Fig.9. The Protection zone

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 [6].

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

10.Mass balance

The process of drift is an element of a broader problem concerning the mass of an expanded factor. Like in Thermodynamics Sankey' figure for engines, the mass balance can be presented in figure 10. 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- roses aviation practice has been basically restricted to biological effects. The balance presented here, although it is – fall off from a plant 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)

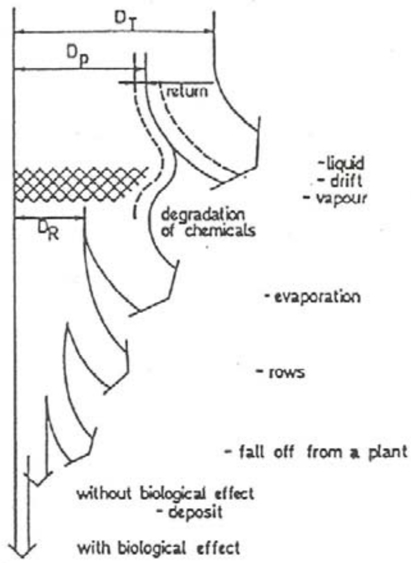

Fig.10.Mass balance

11. Conclusions

1. The Document of EU from 2009 year, forbidden use of airplanes in crop protection treatments, and agreement is possible only in a particular situation. From that no reason to continue very labour consuming and expensive, experimental investigation, in this field of knowledge. But if will be continued should be based on a generally accepted, standard method which would make it possible to compare results.
2. Still more attention should be payed to model research, mathematical model of drift included, to recognize the physics of occurring processes. So far there have been too many segment tests.
3. Application of pesticides require establishing protection zones (insulation and buffer zones included) on the lee side. The breadth of these zones ranges from 50m to 60m up to 330 m, depending on threats certain pesticides imply and the type of equipment.

12.Inference

The method was acknowledge 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.

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