Work simulation of the sprayer field beam with the use of R program

Symulacja pracy belki polowej opryskiwacza z wykorzystaniem programu R

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Abstract

In this work the possibility of using R program to stimulate transverse distribution of sprayed liquid deposition and coefficient of variation (CV) obtained on the virtual field beam. Agricultural flat fan nozzles were tested by testing equipment where individual influence from the nozzle with a constant pressure and transverse distribution of the sprayed liquid deposition were characterized. Deposition was collected on the patternator with grooves of 50 mm wide, deposition quantity was automatically measured in measuring vessels and obtained quantities were saved in the equipment database. Sprayed liquid deposition from a single nozzle with a definite influence is saved as a normal distribution. "R" computer program enables to set distributions obtained from single nozzles in such a way so that it was possible to stimulate the work of a field beam at 50cm agricultural nozzle spacing. In this way one can evaluate regularity of a sprayed liquid deposition and determine coefficient of variability for "virtual" field beam of the agricultural sprayer.

Keywords: coefficient of variation (CV), field beam, flat fan nozzles, R program, testing equipment

Streszczenie

W pracy przedstawiono możliwość wykorzystania programu komputerowego „R" do symulacji rozkładu poprzecznego opadu rozpylonej cieczy i współczynnika zmienności CV, uzyskanego na wirtualnej belce polowej. Rozpylacze rolnicze płaskostrumieniowe badano na urządzeniu testującym, gdzie określano wypływ jednostkowy z rozpylacza przy stałym ciśnieniu i

rozkład poprzeczny opadu rozpylonej cieczy. Opad zbierano na stole rowkowym o szerokości rowków 50 mm, wielkość tego opadu była automatycznie mierzona w naczyniach miarowych a uzyskane wielkości były zapisane w bazie danych urządzenia. Opad rozpylonej cieczy z pojedynczego rozpylacza przy określonym wypływie jest zapisany w postaci rozkładu normalnego. Program komputerowy „R" umożliwia ustawienie rozkładów uzyskanych z pojedynczych rozpylaczy w taki sposób, aby można było zasymulować pracę belki polowej opryskiwacza rolniczego z rozstawem rozpylaczy na belce co 50cm. W taki sposób można ocenić symulowaną równomierność opadu rozpylonej cieczy i określić współczynnik zmienności dla „wirtualnej" belki polowej opryskiwacza rolniczego.

Słowa kluczowe: belka polowa, program R, rozpylacz płaskostrumieniowy, urządzenie testujące, współczynnik zmienności CV,

Introduction

Nowadays requirements concerning a safe use of pesticides are of a greater importance. In many countries mandatory testing of agricultural nozzles was introduced. In Poland this requirement is regulated by the act of 18th December 2003 (Dz. U. z 2004 r. Nr 11 poz. 94 z późn. zm. – Official Law Journal, 2004, No 11, item 94 with later changes).

This research is aimed at checking if equipment for using the pesticides is in working order and fulfills statutory requirements about the safety of pesticide application and environment which these substances are used in (Sawa, 2009). The most important part of the sprayer is a nozzle which decides about quality and regularity of obtained sprayed liquid stream. That is why these parts of the sprayer are tested in appropriate conditions and with the use of the appropriate equipment taking ISO 5682-2:1997 norm requirements into consideration (Equipment for crop protection - Spraying equipment)

The subject of the norm are methods for determination of quality of hydraulic nozzle spraying used in agricultural sprayers. Doing such tests is troublesome because these tests are carried out on sprayers aggregated with tractors and are made in definite conditions consistent with elaborated methods of research. (Langman and Pedryc, 2003) stated in their work that there is lack of automatic devices to test thoroughly the agricultural nozzles disassembled from agricultural sprayers.

Taking this into consideration at University of Life Science in Lublin equipment for complex testing of agricultural nozzles within the research project MNiSW 493/N-Belgia/2009/0 called „Opracowanie metod i urządzenia do kompleksowych badań jakości pracy rozpylaczy rolniczych oraz walidacja tych metod.""The study of methods and equipment for complex testing of work quality of agricultural nozzles and validation of these methods." was developed. This device is fully automatic and allows to determine such parameters of the nozzles as: specific discharge, regularity of sprayed liquid stream, stream asymmetry and spray angle with assumed pressure of the test (Parafiniuk, 2011b) Together with the device a computer program was

developed to analyze obtained results of nozzle tests on testing equipment. This program is written in R language (R Development Core Team, 2012).

R is a programming language and at the same time it is an environment for statistical computing (Biecek, 2008). R program is free. Its installation version can be downloaded on http://www.r-project.org/. This program can be also activated without any installation. R is distributed on GPL (General Public Licence) which allows to use it free to any purposes.

Evaluation results of nozzles accepted as a fulfilling norm requirements but tested on the patternator of a testing equipment with a groove span of 50 mm (according to norm mentioned above) will undergo conversion by the program (Nozzles), to requirements of standard patternator (1000 mm). It is necessary due to the requirements connected with valid testing methodology of the field beams of agricultural sprayers. This program will define also the order of nozzle setting on the beam.

Materials and methods

Theoretical assumptions

In stations controlling sprayers in use, manual patternators over which nozzles are placed on the beam on a given height at d distance (usually 50 cm) one from another are used. Distribution of transverse deposition of sprayed liquid collected in grooves at a given span is tested. Number of grooves depends on their span and length of the beam.

One of the tested parameters of liquid distribution is coefficient of variation of a liquid volume collected in grooves. This coefficient of variation is calculated according to the formula: $V=(S*\dot{x}^{-1})*100\%$

where: $\dot{x}=\sum x_i*n^{-1}$, $S^2=\sum(x_i-\dot{x})^2*n^{-1}$,

$x_i*(i=1,\ldots,n)$ is a liquid volume collected in this i-groove,
n- number of grooves on the patternator.

In calculations of a coefficient of variation a certain number of extreme grooves from both sides is not taken into consideration. In general, this number is selected in such a way to take all grooves into account from the axis of the first nozzle to the last. A large value of a coefficient of variation shows an irregularity of liquid spraying. It is obvious that a change of the nozzle order causes the change of a coefficient of variation of a liquid volume collected in grooves. So, a coefficient of variation obtained in the control time is not maintained, if a farmer changes the order of placed nozzles.

An alternative of field research can be an electronic table of the nozzle testing equipment with grooves k=30 with span h=50mm. Each nozzle is placed over the table and liquid volume collected in grooves is measured. On the basis of obtained measures on the electronic measuring table we can evaluate a coefficient of variation for any nozzle setting over a patternator. It is assumed that liquid volume in a groove of the manual table arises by adding a liquid volume in grooves of electronic table for nozzles adjacent to one another. The

range of sprayed liquid for one nozzle is equal to the length of the electronic table, ie. k*h.

In general, grooves on the manual table have a twice bigger span (width) than on the electronic table. In this connection it is assumed that volume in each groove of the manual table is a volume sum of two grooves of the electronic table.

The way of evaluation of liquid volume in grooves of the manual table is presented visually in Figure 1. To make it simple, only 4 nozzles (numbered I-IV) and grooves k=10 on the electronic table were taken into consideration.
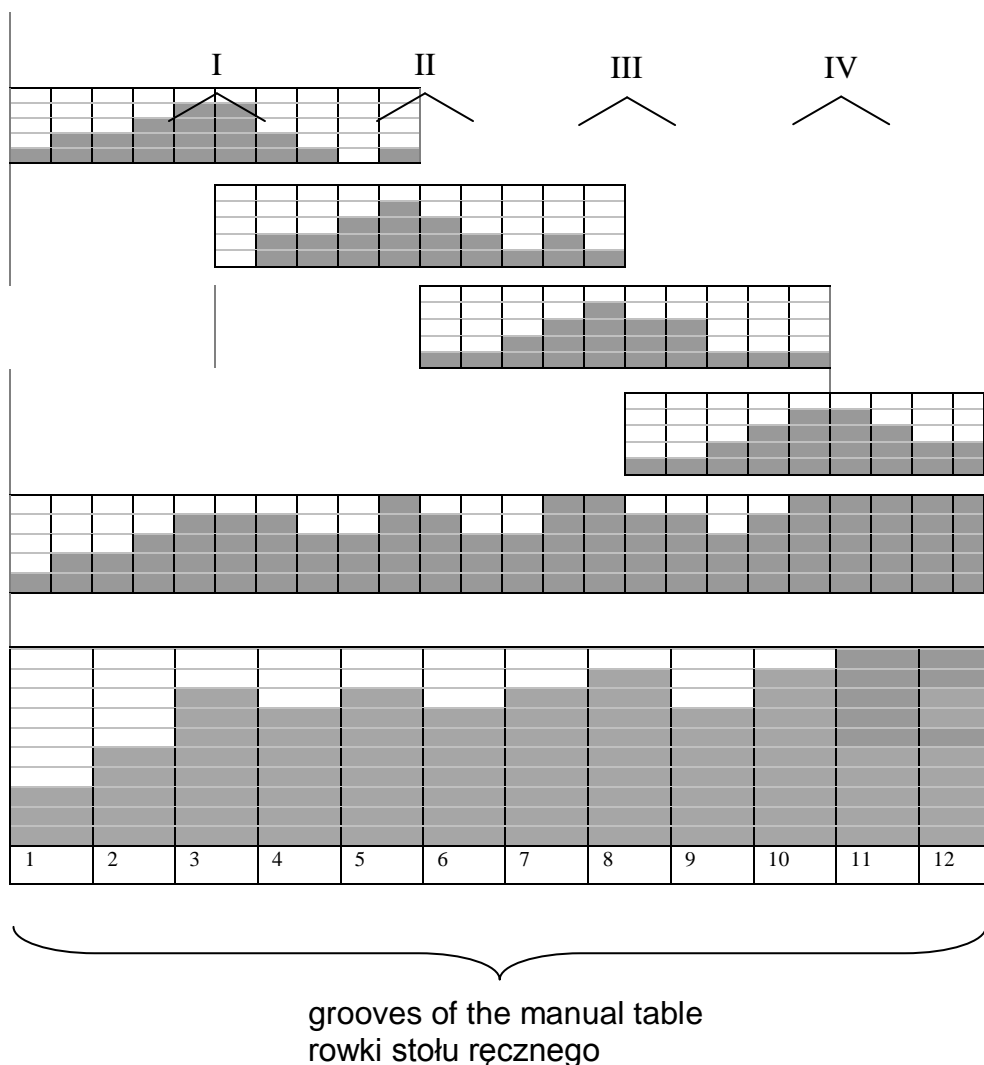

grooves of the manual table
rowki stołu ręcznego

Figure 1. The way of calculating the liquid volume in grooves of the electronic table into grooves of the manual table.

Rysunek1. Sposób przeliczenia objętości cieczy w rowkach stołu elektronicznego na rowki stołu ręcznego

Figure 2 shows the liquid volume in grooves of the manual table determined on the basis of real measures conducted for 20 TEEJET nozzles on the electronic table with 30 grooves with the span of 50 mm.

It was assumed that the distance between axes of nozzles over the manual table equals d=50 cm. In the picture distribution of nozzles in agreed order was taken into account (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20).

Extreme grooves which are not taken into account when calculating a coefficient of variation are marked white. For data presented in figure 2 we have $\dot{x}$=237,28; S=34,83 and v =14,7%.

Figure 3 was drawn on the basis of the same measures but with a different randomly chosen order of nozzle distribution over the manual table. This order is as follows (9,12,8,5,10,17,6,15,1,14,16,20,7,19,13,11,2,18,3,4).

For the manual table presented in Fig. 3 we have $\dot{x}$=236,56; S=31,07 and v =13,1%.

As you can see, a coefficient of variation may take values from quite a wide range, depending on the order of nozzle distribution over the manual table.
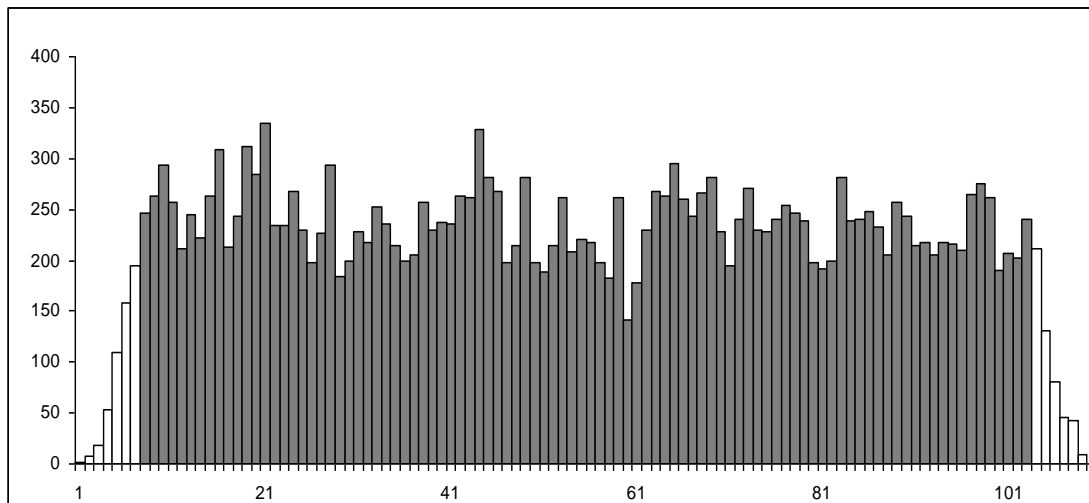

Figure 2. Liquid volumes in grooves of the manual table calculated for 20 nozzles tested on the electronic table. The nozzle order (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20).

Rysunek 2. Objętości cieczy w rowkach stołu ręcznego przeliczone dla 20 rozpylaczy przebadanych na stole elektronicznym. Kolejność rozpylaczy (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20).
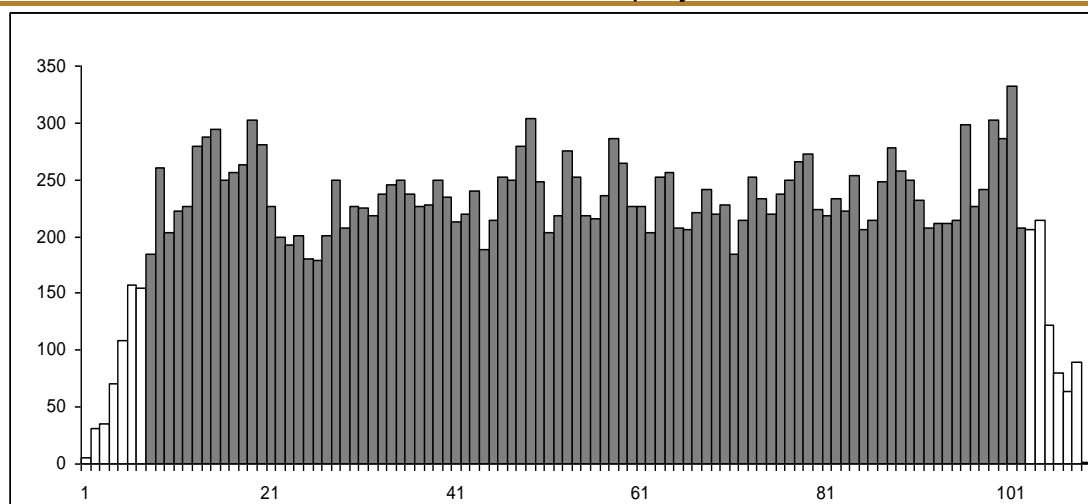
Figure 3. Liquid volumes in grooves of manual table calculated for 20 nozzles tested on the electronic table. The nozzle order (9,12,8,5,10,17,6,15,1,14,16,20,7,19,13,11,2,18,3,4).

Rysunek 3. Objętości cieczy w rowkach stołu ręcznego przeliczone dla 20 rozpylaczy przebadanych na stole elektronicznym. Kolejność rozpylaczy (9,12,8,5,10,17,6,15,1,14,16,20,7,19,13,11,2,18,3,4).

There are 20 all possible settings of nozzles over the manual table in this case, i.e. around $24 \cdot 10^{17}$.

In general, if N is the number of nozzles tested on the electronic table, the number of all possible settings of these nozzles over the manual table equals the number of permutation, i.e. N!. Each of them gives a different value of coefficient of variation.

We are interested in distribution of these coefficients of variations. It is not possible to find this distribution exactly due to a great number of all permutations. It is possible to evaluate by choosing randomly some large (e.g. 10 000) number of permutations.

The program.R file includes a code of the program calculating for a given number randomly generated setting such characteristics of distribution of coefficient of variation like the average, variance, standard deviation, coefficient of asymmetry, coefficient of kurtosis, the lowest and the highest coefficient of variation and equivalent settings of nozzles.

Preparing data collection

In catalogue C: which the program Rozpylacze (Nozzles) was saved in, one should create a text file named dane.txt and write there in the next lines the following data:
1. number of nozzles,
2. distance between nozzles over the manual table (in cm),
3. number of grooves on the electronic table,
4. width of grooves on the electronic table (in cm),

5. number of extreme grooves on both sides of manual table which is to be omitted when calculating a coefficient of variation,

6. in following lines one should write data from the electronic table for the following nozzles, separating numbers in lines with tabulation characters.

Table 1. An exemplary file with data should look as follows (distributions from three nozzles were taken into account):

Tabela 1. Przykładowy plik z danymi powinien wyglądać następująco (uwzględniono rozkłady z trzech rozpylaczy):

20											
50											
30											
5											
15											
1000											
0	1	2	5	7	11	18	35	53	57	71	86
	86	89	102	107	109	100	82	52	53	38	22
	14	11	4	0	0	0	0				
0	1	5	15	20	17	18	36	80	80	77	89
	77	86	103	100	96	87	84	64	61	48	30
	17	12	9	20	6	0	0				
0	0	2	11	15	12	13	26	49	66	104	95
	84	82	89	71	64	108	117	82	110	65	9
	4	8	6	5	1	0	0				

Files with results

The program will create two resultant files in the same catalogue in which there is a file dane.txt:

1. a file Histogram.pdf including a histogram of received coefficients of variation with randomly generated settings with Gaussian curve matched to it,

2. a text file wyniki.txt in which the following characteristics of distribution of coefficients of variation for M randomly generated settings in program will be given:

− average coefficient of variation $\dot{x}=\sum v_i * M^{-1}$,

− variance of coefficients of variation $S^2=\sum(v_i-\tilde{v})^2 * M^{-1}$,

− standard deviation of coefficients of variation $S = \sqrt{S^2}$,

− asymmetry coefficient of distribution of coefficients of variation $As=m_3 * S^3$, where $m_3=\sum(v_i-\tilde{v})^3 * M^{-1}$,

- kurtosis of distribution of coefficients of variation $K=m_4*S^4$, where $m_4=\sum(v_i-\tilde{v})^4 *M^{-1}$,

- the lowest coefficient of variation $v_{min}=min\ (v_i)$ and the setting for which it was obtained,

- the highest coefficient of variation $v_{max}=max\ (v_i)$ and setting for which it was obtained.

Table 2. The exemplary content of the wyniki.txt.

Tabela 2. Przykładowa zawartość pliku wyniki.txt.

| |
|---|
| average coefficient of variation: 0.1426143 |
| średni współczynnik zmienności: |
| variance of coefficients of variation: 8.997853e-05 |
| wariancja współczynników zmienności: |
| standard deviation of coefficients of variation: 0.009485701 |
| odchylenie standardowe współczynników zmienności: |
| coefficient of asymmetry for coefficients of variation: -0.01841617 |
| współczynnik asymetrii dla współczynników zmienności: |
| kurtosis of coefficients of variation 2.826941 |
| kurtoza współczynników zmienności: |
| the lowest coefficient of variation: 0.1142554 |
| najmniejszy współczynnik zmienności: |
| the best permutation (setting of nozzles): |
| najlepsza permutacja (ustawienie rozpylaczy): |
| 16, 4, 9, 5, 6, 3, 12, 1, 7, 2, 19, 17, 14, 10, 20, 13, 8, 15, 18, 11, |
| the highest coefficient of variation: 0.1741387 |
| największy współczynnik zmienności: |
| the worst permutation (setting of nozzles): |
| najgorsza permutacja (ustawienie rozpylaczy): |
| 20, 6, 12, 4, 1, 9, 10, 16, 3, 2, 13, 11, 19, 8, 14, 5, 18, 15, 7, 17 |
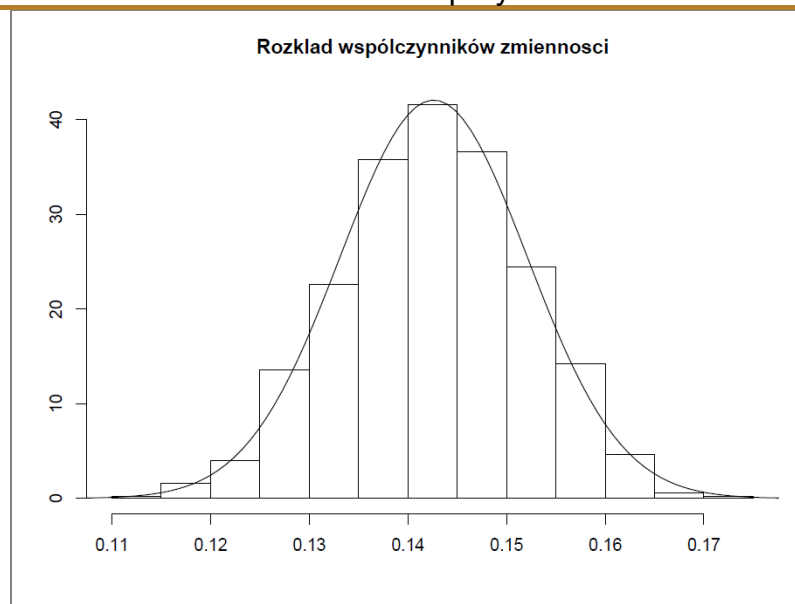
Figure 4. The exemplary content of the Histogram.pdf

Rysunek 4. Przykładowa zawartość pliku Histogram.pdf

Discussion

Evaluation of a technical condition of agricultural nozzles is of a great importance for quality of treatment of plant protection. ISO 5682-2 norm tells about two ways of evaluation of a technical condition, i.e. outflow intensity and distribution of sprayed liquid. Both methods have advantages and disadvantages, however, they do not tell clearly about the whole characteristics of the nozzle work. Deposition of sprayed liquid can be collected on patternators with grooves 50 or 100 mm wide. As (Świechowski et al., 2006) stated different results are obtained depending on the width of the grooves. It is also confirmed by (Sawa et al,. 2002) who states also that each change of a location of the nozzle on the sprayer beam gives a different result of CV.

A degree of wear of nozzle working slot influences also the change of spray quality and causes that it is difficult to obtain the assumed spray dose (Ozkan et al,. 1992). Tests of agricultural nozzles on equipment for their complex tests allow to eliminate worn-out nozzles both with regard to the nominal influence different from requirements and also such as those which have inappropriate spraying asymmetry (Sawa et al., 2012). Obtaining on the testing equipment the transverse distribution from single nozzles enables to combine them in a virtual field beam. Such a combining may be done in a spreadsheet program, for example in Excel both for a theoretical patternator with grooves of 50 and 100 mm wide. Difference of such a combination from the real test on electronic patternator may amount 3 percentage points (Parafiniuk et al,. 2011a). Modeling in a spreadsheet program may be done only for a definite setting of distributions of sprayed liquid. A way of modeling and simulation of the virtual work of the field beam with the use of R program discussed in the work allows to evaluate the transverse distribution for a definite setting of the nozzles like it

is possible in the spreadsheet program. The additional advantage of modeling with the use of R program is that the program can automatically generate the order of setting of nozzles in such a way to obtain possibly the best or the worst result of coefficient of variation (CV). Additionally, we obtain other statistical information both descriptive and graphic which may allow for more accurate evaluation of modeling such a spraying process.

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