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THE USE OF COMPARATORS FOR AUTOMATIC CLASSIFICATION OF THE SPLASHED RAIN DROPS

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ABSTRACT

The paper deals with measurement and classification of the size of the splashed drops of rain using a new formula of classification. According to the new idea a measuring instrument was constructed, in which fast comparators are used. This method of classification offers more exact measurement of the number of drops in every class of size. The older apparatus lost some of the splashed drops, so estimation of the distribution of the effects of the splash was less exact.

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Key words: comparator, charging and receiving electrodes, splash of a raindrop, measurement of the drop size, plant diseases

INTRODUCTION

The spores of diseases of a number of economically important plants are transferred through the splash of raindrops on the ground or the plant parts. Hence, the risk of plants' infection is related to a great extent to the distance covered by the splashed drops. Beyond a certain limit value of the reach of the splash, a very fast development of a disease takes place in a canopy of plants. As follows from the studies conducted by INRA in Paris, the splash of a raindrop can be considered as the second most important factor (the foremost being the wind) of the spread of infection in a canopy [2]. However, for a certain group of diseases of such plants as *Septoria nodorum, Septoria tritici* and *Rhynchosporium secalis*, transportation of spores by the splash is the basic mechanism of their transport within a canopy [1, 4]. Therefore, in order to predict the occurrence of an epidemic of plant diseases it is necessary to establish the size of this factor.

The basic difficulty appears when measuring the capability of the splash of a raindrop and its reach in natural rain. Natural rainfall is a physical phenomenon of very complicated character and it contains the whole spectrum of drop diameters, which, during the rain, can change very often and very quickly. Besides, the kinetic energy of a raindrop is a vector sum of a number of factors such as the mass and speed of a raindrop, the vertical and horizontal speeds of the wind. During the rain, all these factors can undergo great and very fast changes, which results in little efficiency of classical atmospheric measurements for an estimation of the factor sometimes called the violence of rainfall, that is for an estimation of the kinetic energy possessed by its drop.

MATERIALS AND METHODS

The new, electronic method, which measures the size and mass of raindrops created as a result of the splash and which uses the electro kinetic measurer of the splash, makes it possible to measure the vertical and horizontal reach of water particles, and – as a consequence – to determine the effect of the splash.

The principle of the work of this device relies on a configuration of two electrodes. The first, fed with high voltage, serves to transmit the electric charge of a raindrop during the splash. The other – called a receiving one – takes this charge and after an amplifier strengthens it, it measures and records the signal in an electronic measuring and recording block.

A device with such a structure of charging and receiving electrodes simulates very well the real conditions of the splash occurring in plant cultivation. In order to adapt the parameters to the cultivation, it is possible to change the distance between the electrodes and their dimensions.

The scheme of the arrangement of electrodes is shown below in Figure 1.

Any changes concerning the size of electrodes and the distance between them result in changing the number of drops reaching the receiving electrode. This effect can be described through coefficient E of the efficiency of the receiving electrode (equation 5). It should be added that changing the distance and dimensions of electrodes for the distances used in predicting diseases does not affect the size of the charge, but only the number of drops reaching the receiving electrode. Calculations on the changes of the efficiency of the receiving electrode are presented below.

Figure 1. A scheme of the arrangement of electrodes

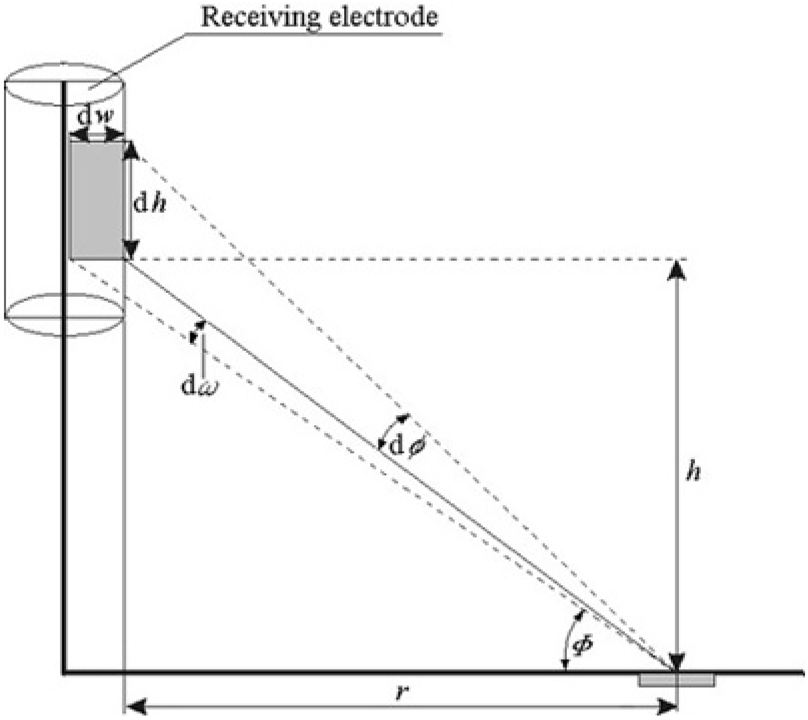
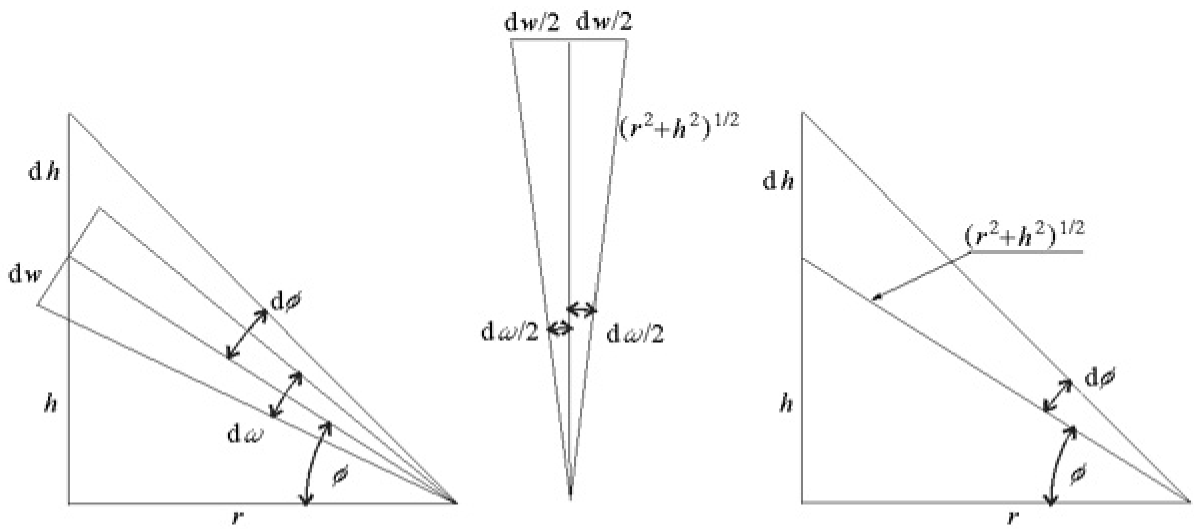


Figure 2. The scheme of horizontal and vertical changes of the splash angle



Let us consider an arrangement of electrodes from Figure 1, where *h* is the vertical distance between the electrodes and *r* is the mean radius of the receiving electrode. Let us view an element of the receiving electrode with the height of d*h* and width d*w* that is placed on height *h* over the charging electrode. It constitutes the target for the raindrops splashed on the charging electrode with the mean radius *r*. The angle between the receiving electrode and the point when a drop hits is equal to Φ, and it changes by dϕ accordingly to the vertical range d*h*. The horizontal range of the splash d*w* corresponds to the angle dω.

Considering the above, it can be written as follows:

$$\mathrm{tg}\frac{\mathrm{d}\omega}{2} \overset{\mathrm{d}\omega\to 0}{=} \frac{\mathrm{d}\omega}{2} = \frac{\mathrm{d}w}{2(r^2+h^2)^{1/2}} \;,\; \mathrm{tg}(\phi+\mathrm{d}\phi) = \frac{h+\mathrm{d}h}{r},\; \mathrm{tg}\,\phi = \frac{h}{r}$$

and after the appropriate transformations we obtain:

$$\left(r^2+h^2\right)^{1/2}\mathrm{d}\omega = \mathrm{d}w \;,\; \frac{r^2+h^2}{r}\mathrm{d}\phi = \mathrm{d}h \quad (1)$$

Therefore, for the constant parameters of raindrops the number of raindrops following the splash and reaching the area dhdw will be proportional to:

$$I \propto \frac{r}{\left(r^2+h\right)^{3/2}}\mathrm{d}h\mathrm{d}w \quad \text{and of course to:} \quad I \propto \mathrm{d}\omega\mathrm{d}\phi \quad (2)$$

If we take into consideration the height of the receiving electrode, whose lower edge is at height h_1, while the upper at height h_2, then splash I reaching the charging electrode in the area between h_1 and h_2 will be proportional to:

$$I \propto \int_L\int_{h_1}^{h_2}\frac{r}{\left(r^2+h^2\right)^{3/2}}\mathrm{d}h\mathrm{d}w \quad \text{where } L \text{ is a circle:} \quad (3)$$

It should be observed that, $\frac{r}{\left(r^2+h^2\right)^{1/2}} = \cos\phi \;,\; \frac{r}{\left(r^2+h^2\right)^{3/2}}\mathrm{d}h\mathrm{d}w = \frac{1}{r}\mathrm{d}w\cos\phi\,\mathrm{d}\phi$

besides $h = r\,\mathrm{tg}\phi$ so we have $\phi = \mathrm{arctg}(h/r)$.

After changing the variables and integrating the following is achieved:

$$I(h_1,h_2) \propto \frac{c_w}{r}\left[\sin\phi\right]_{\phi=\mathrm{arctg}(h_1/r)}^{\phi=\mathrm{arctg}(h_2/r)} \quad (4)$$

where c_w is the circuit of the receiving electrode.

In order to calculate the relative coefficients of effectiveness E for particular dimensions of the receiving electrode, $I(h_1, h_2)$ has to be divided by $I(0, \;)$, which results in the following

$$E = \sin\left[\mathrm{arctg}(h_2/r)\right] - \sin\left[\mathrm{arctg}(h_1/r)\right] \quad (5)$$

Formula (5) showing changes of the effectiveness of the receiving electrode, following the changes in geometric dimensions of the electrodes, makes it possible to compare the results of measurements obtained from a few measuring devices with different arrangements of electrodes.

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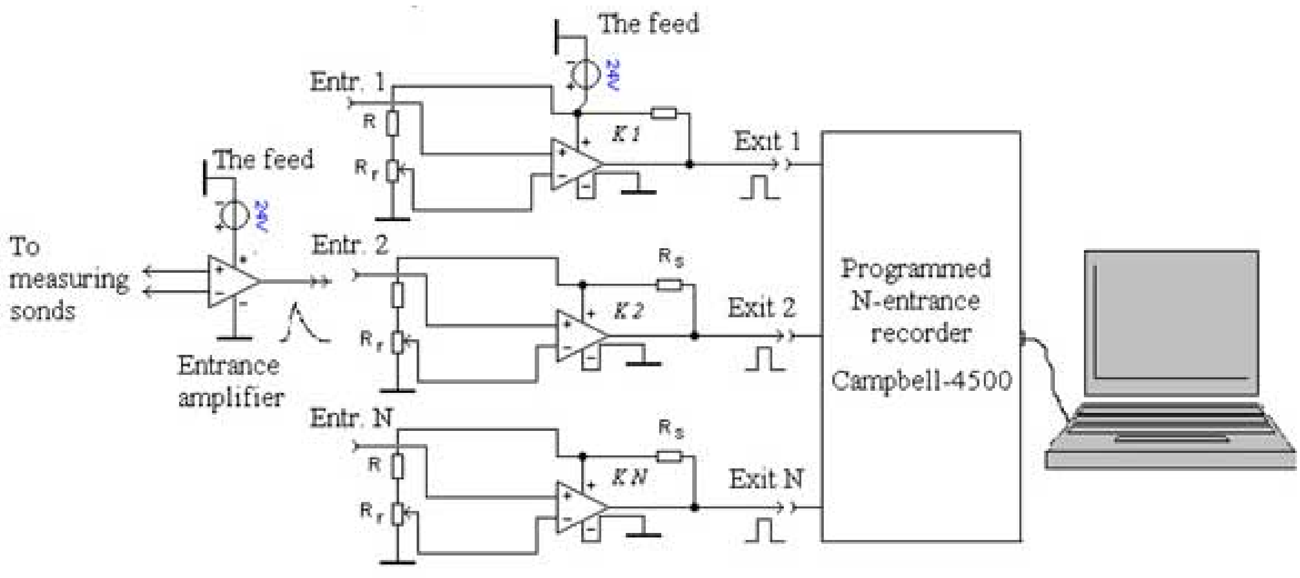
RESULTS

In order to measure electric charges transported by the splashed raindrops in an effective way an electronic device called "Electro-kinetic measurer of the splash" was constructed [3].

In order to mark the reach of the splashed water drop, the instrument makes use of very small electric charges that are taken by the drops at the moment of their splash caused by the hit onto the charging electrode. The charged raindrops fall onto the measuring electrode (sounder) and give back their charge, whose size is measured by the measuring – recording electronic block.

This device, through the measurement of the size of the electric charge carried by the drops, estimates the size of the drops that reach the receiving electrode and includes them under the adequate class of size using a program contained in the measuring – recording block.

Figure 3. A scheme of the measuring-recording block

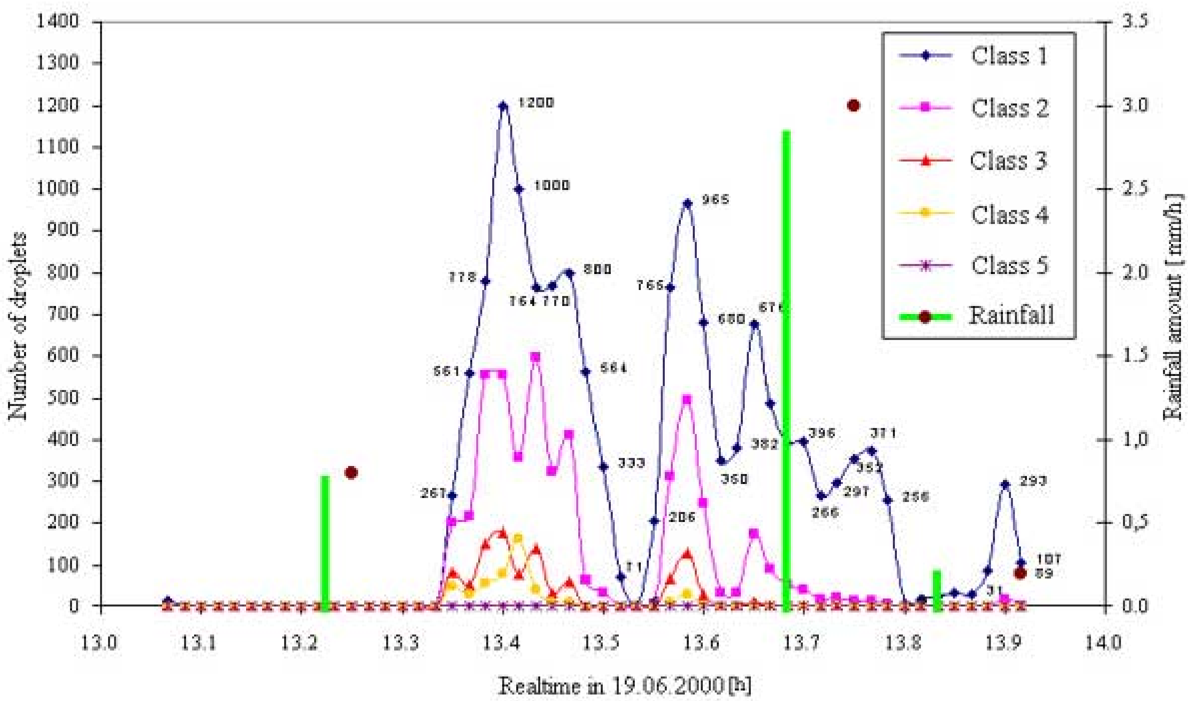


The measuring-recording block, the scheme of which is shown in Figure 3, consists of a precise amplifier of the signal and a joined block of fast comparators *K* joined parallel. Comparators *K1* to *KN* react to the level of the signal coming from the amplifier, and then, after the threshold value earlier set by regulating resistance is exceeded, they transmit a short normalized impulse to the recorder, where it is recorded in the proper memory area. Thanks to such connection, it is possible to determine any number of sections into which the sizes of the splash products (limited only by the number of the accessible entrances of the recorder) are divided, and the sizes of particular sections. The recorded and classified numbers of the splashes are then transmitted to the computer, where they are calculated according to formula 5, which considers the effectiveness of the receptor. Because both the size and the number of the splashed drops have a significant influence for the estimation of the character of the rainfalls, the drops are grouped by the measuring-recording block into the size classes and next counted in each class.

DISCUSSION

The presented measuring method makes it possible to classify the size of the raindrops on any number of sections, however, the use of too many sections makes the results illegible. Hence, in the present studies the splashed drops were divided into 5 size classes. The division of the range was regular every 0.2 mm, and class 1 corresponded to the drops with the size less than 0.2 mm, while class 5 corresponded to the drops bigger than 0.8 mm. During the measurement the distance between the electrodes h was 50 cm, while the diameter of the charging electrode $r = 60$ cm. Adopting such dimensions is connected with the limit range that the splashed raindrops have to cover to transport the plant spores or the infected spots onto the healthy plants in such a way that significant spread of a disease takes place. Figure 4 presents changes in the number of splashes in particular size classes taking place during a stormy rainfall and recorded with the new measuring device. Figure 4 also shows the results of measurements of the size of rainfalls (in mm) performed using the traditional method. The horizontal axis presents the course of time, while the vertical one (on the left of the diagram) shows the number of the recorded splashes in particular size classes and the size of the rainfall (the right vertical axis). It follows from the results that the lowest number of the smallest raindrops is obtained in the process of the splash. However, so small particles have little capability of transporting the spores, which means that the greatest importance in the development of a disease is played by the number of raindrops recorded in the classes of bigger sizes. The apparatus has remarkable regulation abilities and the measuring range of the device can be set in such a way that the most important section of the raindrop size can be focused on.

Figure 4. The splash measured and classified according to size



The studies, the results of which are presented in Figure 4, were conducted in June 2000 in an argometeorological park INRA in Paris.

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CONCLUSIONS

The use of an electro-kinetic measurer of the splash equipped with a block of fast comparators makes it possible to record and analyse the splashes sending a short measurement impulse and following very quickly after one another. This allows for precise measurement even of violent stormy rainfalls.

Such characterization of the violence of rainfalls is very important in forecasting the plant diseases, where the mechanism of their spread through the splash has the basic or significant importance. Estimating the violence of the rainfall is also important in studying the soil erosion, where this factor has a considerable influence on the course of this process. Simple regulation of the device and calculation of the effectiveness of the measuring electrode make it possible to use it both to predict the spread of plant diseases and the effect of the character of the rainfall on the soil erosion.

The results presented on Figure 4, show that correlation between amount on the rainfall and the number of rain splash is very weak. In consequence this popular and facile measured parameter of the natural rain, has small usefulness as a factor for prognostic models of the development the plant diseases epidemics, with spread mechanism based on the rainsplash.

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