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METHODS OF MEASURING THE INTERCEPTION OF PRECIPITATION IN STANDS OF CULTIVATED PLANTS

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A b s t r a c t. The interception of atmospheric precipitation in plants is the first hydrological process which differentiates precipitation at the ground surface. That is why the problem of measuring the interception of precipitation has attracted the attention of many scientists. This paper includes a characterization of the measuring instruments and the methods of investigation used in previous studies. It also shows the authors' conception of measuring this phenomenon with the help of a gutter rain gauge. Interception passed with this instrument proved its satisfactory usefulness for measuring the interception of precipitation in stands of cultivated plants.

INTRODUCTION

In our climate conditions the main factor reinforçing soil with water is atmospheric precipitation. Precipitated water does not reach the ground surface in total; most of it is stopped by the plant cover; that is, it is intercepted. This interception has been defined as the difference between the magnitude of the precipitation actually falling on a given area and that part which reaches the ground.

Interception is the first hydrological process which differentiates precipitation at the ground surface. Because of the importance of the quantitative seizure of this process to the proper estimation of the precipitation magnitude utilized by plants, this problem has attracted the attention of many scientists. Until now most investigations concerned the interception of precipitation in different types of forest stands, i.e., under trees and shrubs, while much less attention was devoted to other green forms.

Gutry-Korycka [3] corroborated that the structure of the mathematical model of the interception subsystem should result from the kind of phytocenosis and the structure parameters of its main components. In Poland, most of forest communities are composed of four layers penetrating each other: crowns of trees (coniferous and deciduous), undergrowth and, finally, mosses, fungi, and lichens.

From the above it follows that we still do not know enough about what part of atmospheric precipitation is stopped by cultivated plants. An answer to this question is very important in practice, because without it, it is impossible to determine the precipitation regime in the agriculture aspect and to prepare the elements of the soil water balance [1-12].

METHODS AND RESULTS

Review of research methods used for measuring the interception of atmospheric precipitation in stands of cultivated plants

The first measurements of the interception of atmospheric precipitation were made in the 1860's. In the present century similar studies were carried out in many countries: in the former Soviet Union, the USA, Canada, Germany, Czecho-Slovakia, Poland and many others [1-14]. According to Gutry-Korycka [3] knowledge of the process defining precipitation losses caused by the interception is known fairly well, but mainly by foreign scientists and with respect to woodland flora. In Poland much less is known about these problems. Gutry-Korycka notes that the foreign scientists mainly estimate the approximate value of the maximum capacity of the interception in different types of plant cover. This corresponds to the highest plants' wetting in the phase of maximum vegetation at the long-lasting naval rain. It was found that trees intercept from 15 to 50 % of atmospheric precipitation, the exact amount depending mainly on the height of plants, their density, rainfall intensity, the speed and direction of the wind, etc. [1,2,5,6].

The problem of interception of precipitation in stands of cultivated plants was intensively studied in many countries of the former Soviet Union. One of the most interesting methodological solutions to the problem was proposed by Kalesnik and Tkacenko at the hydrological station near Kijov. To study the interception of atmospheric precipitation in winter wheat, potatoes and in massive forest stands, they used Davitay's field rain gauge with a 30 cm^2 collecting area. There were five rain gauges like this in the forest and eight on fields with cultivated plants. Bulawko [6], on the other hand, used special slit rain gauges of the dimensions: 5 cm x 100 cm, which provided a surface equal to the collecting area of a pluviograph used at that time in the Soviet Union, i.e., 500 cm^2. On each experimental plot he placed six rain gauges, which were connected to one reservoir. Their total surface reached 3 000 cm^2 and was equal to the evaporative surface of the GGI-3000 apparatus [6]. Vinogradov [14] installed rain gauges with collecting surfaces of 500 cm^2 in a cereal field. He filled them up with soil monolith saving the sowing structure, like that on the experimental plot. The soil surface in the rain gauge was inclined at a given angle and covered with paraffin. This way he collected the entire precipitation reaching the ground surface including that flowing down over the plant stalks. The mean value of precipitation under the plant cover was counted from the measures made with 58 rain gauges [14]. Rowe used a very similar method while studying interception under grass cover. All authors using the described method noted the problem of choosing a proper plastic material [2].

Another methodological solution was offered by Stangej and Spak [13], who covered the ground surface with an impermeable membrane, over which water flowed down to special measuring reservoirs. A much simpler solution was presented by Kontorscikov and Jaremina [7]; they just tipped plants in water and from the increment in weight they defined their ability to retain the water.

Independently of previously described methods, analogical experiments were carried out by Crouse *et al.* (cited by [6]) in California. In an experimental plot they placed metal collars of 10 inches in diameter on plants after sprouting. When the grass reached about 3 inches in height, they covered the ground around the collar with a special emulsion put on the sand layer. On one side of the collar a conduit was fastened to drain off the rain water and the water coming from the plants' stalks into the measuring container.

Hoyningen-Huene [4] also used the gutter rain gauges to study the interception in stands of plants. The rain gauges had various collecting surfaces: from 0.025-0.05 m^2 in cereal crops to 0.25 m^2 in maize, without any explanations of the reasons for such a difference. Current solutions to the problem of measuring interception have not considered the characteristics during the entire growing season of cultivated plants. Most authors concentrated their attention on studies of interception at the final stage of plant vegetation, when they are the biggest.

Research instruments and methods used in measuring the interception of atmospheric precipitation in stands of cultivated plants at the Agrometeorological Observatory of the University of Agriculture in Lublin

At the Department of Agrometeorology of the University of Agriculture in Lublin a method has been developed which enables us to carry out measurements of interception in stands of cultivated plants from the very moment this phenomenon occurs until the crops are harvested. For this purpose a 5 x 40 cm gutter rain gauge was constructed (Fig. 1); such dimensions match the collecting surface of Hellman's rain gauge. This makes possible comparison of the results of the precipitation interception with the results of precipitation on free surfaces. The bottom of the constructed gutter rain gauge has a concavity along the long axis with a little inclination into the outlet drain tube 70 cm long. This makes a quick run-off of rain waters possible. A glass reservoir, collecting the precipitation running down from the gutter, is placed in a soil pit at a depth of about 40 cm. It has a closed cover with a small hole which enables deaeration. Such a solution secures precipitation from evaporation. The hose pipe connecting the gutter rain gauge with the reservoir completely eliminates trampling the plants.

To measure all water reaching the ground surface a different type of instrument was constructed (Fig.2). The fundamental part of this instrument is a ring of the same cross-section as Hellman's rain gauge. The ring is driven into the ground in the cultivated field. Inside the rain gauge a small conical heap is made on which water flows down to the tube mounted on one side of the instrument. The ground surface inside the rain gauge is sealed with an impermeable and elastic layer. The following water draining off is similar to that in the gutter rain gauge. Both these instruments can be connected with a clock and self-re-

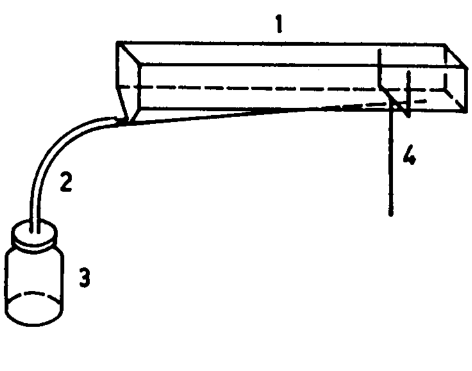

Fig. 1. The gutter rain gauge placed in the canopy of the cultivated plant: 1-rain gauge; 2-pipe draining water; 3-container for draining water; 4-clamp stabilizing the rain gauge.

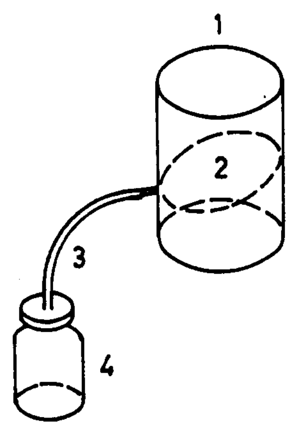

Fig. 2. The rain gauge with the plants inside the instrument: 1-rain gauge; 2-soil covered with impervious layer; 3-pipe draining the water; 4-container for drained water.

cording instruments. To ascertain the ability of the described instrument to measure interception in the meteorological garden under grass, 10 gutter rain gauges were set up at a distance of 50 cm from each other at the same orientation in relation to geographical directions. The investigations were performed during three months of the vegetation season: May, June, and July. Preliminary results of these investigations, shown in Table 1, proved the satisfactory ability of the new instrument to measure the interception. Although the variability coefficients for performed measuring series ranged widely from 2 to 63 %, with a mean value 14 %, the highest distributions were caused only by small amounts of precipitation, 0.1-0.5 mm, that is, the rain which in practical terms does not reach the ground surface in cultivated plants' stands.

Within the above described experiments, to obtain better characterization of the ability of the elaborated rain gauge to measure interception, three days in July 1991 with very different rainfall amounts were chosen. The measurements were performed in 10 replications under several cultivated plants: winter wheat, winter rye, spring barley with red clover as a companion crop and broad bean. The extreme dates, i.e., the 2nd and the 13th of July, delimit the 11-day period, in which the plants' height did not change too much (the height of wheat ranged from 95 to 97 cm; that of rye was around 168 cm; broad bean ranged from 83 to 95 cm; and spring barley ranged from 85 to 90 cm).

T a b l e 1. Characteristics of the atmospheric precipitation measurements carried out with the help of 10 gutter rain gauges placed in grass

Date 1976	$\bar{x}$	V
May 26	0.8	9.4
May 27	12.8	4.0
May 28	4.7	4.4
May 29	0.3	51.5
May 30	0.9	18.5
May 31	1.1	27.1
June 1	0.1	63.6
June 12	4.8	3.1
June 13	9.6	2.9
June 15	13.6	5.4
June 16	2.3	7.5
June 17	0.7	9.0
June 18	0.1	50.0
June 20	8.9	2.3
July 6	0.2	21.7
July 9	2.4	4.5
July 10	18.2	4.9
July 11	3.7	5.4
July 12	0.6	15.6
July 13	0.6	18.1
July 20	10.3	3.0
July 22	3.4	3.4
July 23	2.0	5.0
July 26	1.6	5.5

$\bar{x}$ - rainfall sum mean (mm) from 10 gutter rain gauges; V - coefficient of variability (%).

The results given in Table 2 confirm the known fact that the magnitude of the interception decreases with an increased precipitation which, in fact, does not depend on the construction of the rain gauge. That is why we gave up additional discussion of the subject. More interesting appeared to be other observations. The dispersion of the precipitation sums' height measured under plants usually depended on the amount of precipitation measured at the ground level on the surfaces without plant cover. The highest dispersion was recorded on the 2nd and the 4th of July under spring barley with the companion crop, while the lowest was recorded on the 13th of July, when the precipitation was the lowest, i.e., 1.8 mm, under all the plants tested.

Analyzing the relative variability in 10 measured heights of precipitation one may observe that in the described cases the lowest values were noted under winter wheat and winter rye on the 2nd and 4th of July, and the highest were under broad bean on the 13th of July (during the lowest precipitation). However, under this plant the lowest value was also stated in the 4th of July, during the highest precipitation. This proves that there are some problems with gaining possibly similar results in successive series consisting of 10 repetitions.

The highest standard deviation characterizing the dispersion of 10 precipitation

Table 2. Characteristics of atmospheric precipitation measurements carried out with the help of 10 gutter rain gauges in stands of cultivated plants

Date 1991	Rainfall at the ground surface	Characteristics*	Broad bean	Spring barley	Winter wheat	Winter rye
		I	70.6	55.0	63.9	61.1
July 13	1.8	$\bar{x}$	0.53	0.81	0.65	0.71
		σ	0.18	0.18	0.16	0.20
		V	35.6	23.6	26.4	30.0
		I	65.2	56.1	56.1	39.4
July 2	6.6	$\bar{x}$	2.34	2.90	2.87	4.02
		σ	0.50	0.66	0.39	0.59
		V	22.5	23.8	14.5	15.6
		I	56.5	49.0	48.7	38.8
July 4	14.7	$\bar{x}$	6.40	7.48	7.53	9.02
		σ	1.93	2.13	1.40	1.41
		V	31.9	30.0	19.6	16.5

* I - interception value (%); $\bar{x}$ - rainfall sum mean from 10 gutter rain gauges; σ - standard observation (mm); V - coefficient of variability (%).

measurements was observed under spring barley on July 4th. The amount of precipitation measured that day inside the barley plot, at the ground surface, reached 14.7 mm. The results of the 10-repeated measurements of precipitation under the barley stand were as follows: 5.5, 10.0, 8.2, 10.4, 7.1, 10.3, 8.0, 5.8, 4.9, and 4.6 mm. In the series described above the lowest precipitation amount was 4.6 mm, and the highest was 10.4 mm, 2.3 times higher than the lowest one. Such a great difference between the values gained at similar conditions proves the great complexity of this phenomenon. We should remember that the above results concern the stand of cultivated plants which are much lower than wood stands and that may be why we have a much bigger problem with gaining uniform or undifferentiated data. Several factors play an important role here: the changing morphology of plants' canopy, some other climatic conditions of the canopy changing over time; and the manner in which rain gauges were installed.

DISCUSSION AND CONCLUSIONS

Assuming it is proper to continue carrying out research aimed at measuring atmospheric precipitation, both the interception and in standard conditions, we should be able to overcome many difficulties resulting from various causes. The measurements of atmospheric precipitation in standard conditions are troubled by the wind, changing the course of rain drop or snow-flake; the evaporation of rain waters from the rain gauge, leaving a part of the rainfall adhered to the internal walls of the rain gauge; and inaccurate emptying of the instrument during pouring out of the rain water, losses due to improper maintenance and levelling of the rain gauge [8]. Certainly these causes can disturb measurements of atmospheric precipitation including those which concern rainfall interception.

Another important problem consists of the nonuniformity of precipitation accumulation that has been observed during special research. The results of such investigations proved that precipitation entering the last air layer near the ground surface undergoes considerable disturbances which lead to the formation of so-called precipitation cells, constituting the elements of a spatial structure of the precipitation field. It has been stressed, in the above investigations, that the distribution of precipitation sums inside the isolated precipitation cells, especially during heavy rain showers, is characterized by an exceptional inequality [9].

Among many factors causing differentiated measurements of precipitation, particularly in comparative series, many authors pay attention to the important role played by the speed and direction of the wind. It has also been stressed that the microlocalization of instruments may itself be a very important factor influencing the differentiation of the precipitation sums height [5]. No doubt the factors described above played a specific role in the experiment carried out by us in the stands of cultivated plants.

Taking into account the above statement as well as the results obtained in field experiments we may conclude that the constructed instrument for measuring the rainfall interception in the canopies of cultivated plants can be widely applied in various studies of the cultivated field climate.

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SPOSOBY POMIARU INTERCEPCJI OPADOWEJ W ŁANACH ROŚLIN UPRAWNYCH

W opracowaniu dokonano syntetycznego przeglądu metod pomiaru intercepcji opadów atmosferycznych, wykonywanych głównie w lasach. W Katedrze Agrometeorologii Akademii Rolniczej w Lublinie opracowano, korzystając częściowo z rozwiązań wcześniejszych, dwa typy deszczomierzy do pomiaru opadów w łanach roślin uprawnych. Obydwa deszczomierze mają powierzchnie zbiorcze równe po 200 cm^2: jeden w kształcie okręgu z roślinami wewnątrz przyrządu, drugi ma kształt prostokąta (5 x 40 cm) i jest ustawiany w łanach roślin. Deszczomierzami w kształcie prostokąta wykonano kilka serii pomiarów, po 10 powtórzeń w serii, w trawie i w roślinach uprawnych: bobiku, jęczmieniu jarym, pszenicy ozimej i życie ozimym. Obliczono średni opad z 10 powtórzeń, wielkość intercepcji, odchylenie standardowe i współczynnik zmienności, które wykazały znaczną zmienność warunków, ale również przydatność przyrządu do pomiaru intercepcji.