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INTERCEPTION OF ATMOSPHERIC PRECIPITATION IN STANDS OF CULTIVATED PLANTS

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A b s t r a c t. Interception of atmospheric precipitation in stands of four cultivated plants, broad bean, spring barley with red clover as companion crop, winter wheat and winter rye, was examined at the Experimental Agriculture Station in the south-east part of Poland in the years 1987-1990. The interception in the above plants' canopies ranged from 22.4 % (winter rye) to 46.5 % (spring barley). However, the lowest relative variation, characterized by the coefficients of variability, was found for the values of interception under spring barley, while the highest was under winter rye. Positive coefficients of skewness that have been used to characterize the type of distribution of the interception values mean that higher interception values are prevalent under all the studied crops. Classifying all the observations into class ranges of 10 %, it is evident that most frequent interceptions under broad bean, spring barley and winter wheat are within the class range from 30 to 40 %, while under winter rye from 40 to 50 %. In class ranges of higher limits the number of cases was even higher. The correlation coefficients between the total amount of rainfall on free spaces and the values of interception were negative in all the cases analysed. This proves there is a decrease in the percentage amount of water intercepted by plants with an increase in the total amount of precipitation.

INTRODUCTION

A rational steering of water management in agriculture needs an exact recognition of all the components of such a complex system. One of the most essential elements of water management is the interception of atmospheric precipitation. This phenomenon already interested scientists at the end of the 19th and the beginning of the 20th century. It involves the process of intercepting part of the atmospheric precipitation by plants, both those growing wild and those cultivated [3]. According to many authors the magnitude of rainfall interception depends, above all, on the features of the rainfall itself, i.e., its amount, duration and intensity, as well as on the wind speed, evaporation, morphological features of plants exposed to rain waters, etc. Recent investigations on the interception in Poland mainly concerned the occurrence of this phenomenon in forests [2, 3].

The small number of works devoted to interception of atmospheric precipitation in stands of cultivable plants forced agrometeorologists, agronomists and specialists in land melioration to intensify their research on these topics. The present paper deals with the interception of rainfall water in canopies of some basic crops cultivated in the south-east part of Poland.

METHODS

Studies on the interception of rainfall water by cultivated plants were conducted on experimental fields of the Agrometeorological Observatory of the University of Agriculture in Lublin in the years 1987-1990. The Observatory is located at Felin near Lublin (51°14' N, 22°38' E, 215 m a.s.l.). Observations of interception were performed on the canopies of broad bean, spring barley with red clover, winter wheat, and winter rye. The plants studied were grown in a six-field crop rotation system. Rainfalls under the plants were measured at 0700 a.m., the same time as at the standard meteorological station, with the help of a gutter rain gauge of our own design. A single rain gauge has the shape of a gutter 4 cm x 50 cm. It is made of polished stainless steel. Water from the gauge was collected in covered glass jars. There were 10 rain gauges placed in each of the studied experimental fields. For statistical analysis average values of total rainfall from all 10 rain gauges were taken. The measurements under plant covers were related to the measurements in the open space taken at the same time with the use of Hellman's rain gauge.

The number of observations was different in successive years of the study. It depended, among other things, on the frequency of atmospheric precipitation and it is characterized by the following values: under broad bean from 42 to 79 days, under spring barley - 51 to 77 days, under winter wheat - 92 to 97 days, and under winter rye - 91 to 97 days. During four years of the experiment 510 measurements were conducted from which 82 were taken under broad bean, 112 under spring barley, 162 under winter wheat and 154 under winter rye.

Analysis of the results on rainfall interception was based on the mean values while their distribution was characterized by the coefficients of skewness. The coefficients of relative variability and the correlation coefficients were also calculated. All the data have been classified by applying distributing series.

The problem discussed in this paper is fairly difficult as the measurement of the amount of rainfall water intercepted by plants is not always sufficiently representative [1]. The paper does not include the runoff of water over plants which is a feature of a majority of interception models [4]. The water runoff over plants is, in the opinion of some authors, of low significance, especially when the amount of precipitation increases.

RESULTS AND DISCUSSION

The amount of rainfall water intercepted by plants is a variable feature, dependent on many factors that have been mentioned earlier. At the beginning of the discussion we present the mean values of interception under the plants in the successive years of the study.

Comparison of the results presented in Table 1 allows us to evaluate the range of changes of interception in the particular years of the experiment. The largest differences were recorded under spring barley - 23.3 %, slightly smaller under winter rye - 16.2 %, considerably smaller under winter wheat - 5.6 %, and the smallest under broad bean - 2.4 %. Total values of interception under cereals indicate that the highest amounts of water remained in the canopy of winter wheat, a little less in spring barley, and the least in winter rye. Thus, these results support those of the earlier experiments on this phenomenon [6].

Table 1. Mean values of rainfall interception (in %) in stands of cultivated plants in the years 1987-1990

Plant	Years			
	1987	1988	1989	1990
Broad bean	34.4	-	34.6	32.2
Spring barley	46.5	22.4	34.4	29.4
Winter wheat	37.4	31.8	35.3	33.8
Winter rye	30.1	35.4	38.6	22.4

The coefficients of variability given in Table 2 indicate a great fluctuation in the interception. The greatest variability was observed in the canopy of winter rye, which is proved by both the highest and lowest value of the coefficient, while the lowest variability of interception was noticed in the case of spring barley. The highest range between extreme values of the coefficients was stated for winter wheat - 14.2 %, the lowest one for broad bean - 9.8 %.

Table 2. Coefficients of variability of rainfall interception in stands of cultivated plants - extreme values (1987-1990)

Plant	Coefficients of variability (%)
Broad bean	41.3 - 51.1
Spring barley	34.3 - 45.3
Winter wheat	39.7 - 54.0
Winter rye	43.0 - 54.6

To obtain more information on the distribution of the interception values the coefficients of skewness were calculated. Table 3 presents the extreme values chosen from the experimental data.

Table 3. Coefficients of skewness characterizing the distribution of the amount of rainfall interception in stands of cultivated plants - extreme values (1987-1990)

Plant	Coefficients of skewness
Broad bean	0.71 - 1.10
Spring barley	0.11 - 1.47
Winter wheat	0.31 - 0.84
Winter rye	0.29 - 0.70

The coefficients of skewness for barley showed the widest range: 1.36. The remaining values of the coefficients were two or three times lower than those for barley. Positive values of the skewness coefficients also prove that among the data analysed high values were prevalent which means that, in particular, rainy days were more often the situation when the amount of water intercepted by plants constituted a significant part of the rainfall. To confirm the above observations Table 4 has been elaborated where all the cases of interception in our experiment, i.e., 510, are classified into class ranges of 10 % each.

As can be seen in Table 4, only in the class range from 0 to 10 % is there no adequate interception value under broad bean and spring barley, while for the other two crops all the class ranges are occupied. The distribution of data in Table 4 is clearly asymmetrical in all cases because the largest

Table 4. Number of cases of rainfall interception in stands of cultivated plants in range classes (1987-1990)

Range classes	Plants			
	Broad bean	Spring barley	Winter wheat	Winter rye
0 - 10	-	-	5	1
10 - 20	6	3	14	17
20 - 30	12	23	21	24
30 - 40	21	24	38	33
40 - 50	14	21	31	35
50 - 60	13	9	16	12
60 - 70	4	15	16	15
70 - 80	2	4	13	9
80 - 90	5	6	3	3
90 - 100	5	7	5	5
Total	82	112	162	154

number of cases in the distributing series concerning the interception under broad bean, spring barley and winter wheat occurred in the fourth range class, i.e., from 30 to 40 % with the exception of winter rye where the largest number occurred in a higher class, namely from 40 to 50 %. A slow decrease of frequency in successive class ranges and even sometimes a slightly increased number of cases in final classes for cereals (80-90, 90-100 %) gives a good illustration of our earlier statements concerning the positive values of the coefficient of skewness as characterizing data distribution in the analysed sample.

Another problem we attempted to solve while elaborating the data presented concerns the correlation between the total amount of atmospheric precipitation measured in free spaces and in stands of the plants studied. In view of other results high values of interception should be expected along with a decrease in rainfall amounts. Kołodziej *et al.* [6] found that rainfalls up to 3 mm intensity were almost completely captured by plants. Pasierski [8] also proved, for the Wrocław region, that the highest values of interception can be found with rainfalls as high as 5 mm intensity. It is worth stressing that some authors studying the interception in forest stands have found that the permeability of tree crowns depends not only on the amount of rainfall but also on its duration; the longer the rainfall the lower the values of interception [2,7].

In Table 5 the coefficients of correlation between the amount of rainfall and the values of interception are given.

Table 5. Coefficients of correlation between the amount of atmospheric precipitation and rainfall interception in stands of cultivated plants - extreme values

Plant	Correlation coefficients	
Broad bean	-0.61** (1989)	-0.41 (1990)
Spring barley	-0.69** (1987)	-0.47* (1988)
Winter wheat	-0.57** (1989)	-0.34* (1988)
Winter rye	-0.57** (1987)	-0.39* (1989)

Significance level: *P=0.05; **P=0.01.

As in earlier tables the extreme values are presented. One can notice that all the coefficients of correlation are negative. This proves that in the material examined there is a typical phenomenon of a simultaneous decrease in interception with an increase in total amount of rainfall on free spaces. Thus our results collaborate the results of previously cited authors [6,8]. The results of Hoyningen-Huene [5] are noteworthy here. He stated that these dependencies clearly show a non-linear character. In our own experiment the lowest correlation between the analysed values was found under winter wheat and winter rye, while the highest was under spring barley. Moreover, in the case of barley these coefficients were the highest both for maximum and minimal values. Hence, these results partly collaborate the results presented by Pasierski [8], who found that in the canopy of spring barley, at the stage of wax maturity, only 39 % of rainfall reaches the surface ground. Thus, the interception is equal to 61 %. The highest values of interception, equal to 100 %, were noticed when the amount of rainfall was the lowest, i.e., at the limit of measurability that is, with rainfalls of about 0.1 mm.

For better illustration of the material discussed we present some observations with the lowest values of interception. From the entire experimental materials only one case from each year of the study has been selected. The results given in Table 6 concern spring barley.

Table 6. Selected examples of the lowest values of rainfall interception in stands of spring barley (1987-1990)

Date	Rainfall (mm)	Interception (%)	Plant height (cm)
28.07.1987	20.6	20.9	95
01.06.1988	4.7	17.0	20
03.06.1989	3.3	21.1	32
25.05.1990	5.5	14.5	18

In all the cases, except the first one, the plants' height was not too high and probably due to this fact the interception was low. The role of plants' height and density in the process of interception has been many times stressed by various authors [5,6,8]. In the first example, representing the year 1987, the plants were relatively high but in that year the rainfall was also high.

In summary we may say that our observation on the negative correlation between the amount of rainfall on free spaces and the value of interception has been confirmed.

CONCLUSIONS

Some conclusions resulting from the analysis of the experimental materials demand special attention. The highest mean values of interception in the period studied were noticed under spring barley, while the lowest were under winter rye. The coefficients characterizing the relative variability of interception changed to the greatest extent under winter wheat and to the least extent under broad bean. The widest range of changes of the coefficients of skewness was found in the case of interception under spring barley. For this plant the highest values of the negative correlation coefficients between the amount of rainfall on free spaces and the value measured at the bottom of the plants' stand were also found. In the case of winter wheat a negative correlation was found as well; however, it was the lowest. In the material analysed one can find that, as a rule, lower values of interception correspond to higher amounts of rainfall. Thus our earlier observations on this phenomenon have been confirmed. Another observation, partly connected with the former one, is the positive skewness of distributions of the interception values in the analysed sample. A distinct advantage of higher values of interception was found; in some cases those values reached 100 %.

The results obtained confirm beyond doubt the necessity of taking into account the value of interception of rainfall while elaborating the water balance within arable fields. For a better understanding of the problems discussed here, further research is obviously still needed.

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INTERCEPCJA OPADÓW ATMOSFERYCZNYCH W ŁANACH ROŚLIN UPRAWNYCH

Badania intercepcji opadów atmosferycznych w łanach roślin uprawnych prowadzono w Obserwatorium Agrometeorologicznym w Felinie koło Lublina (51°14'N, 22°38' E) w latach 1987-1990. Badaniami objęto żyto ozime, pszenicę ozimą, jęczmień jary i bobik. Pomiary intercepcji wykonywano przy pomocy deszczomierzy własnej konstrukcji, o wymiarach 4 x 50 cm (powierzchnia 200 cm^2), czyli takiej samej jak w deszczomierzach Hellmanna. Deszczomierze te w liczbie po 10 sztuk umieszczono na dnie badanych łanów roślin. Średnia wartość intercepcji opadowej wahała się od około 22,4 % w życie ozimym do 46,5 % w jęczmieniu jarym. Wartość intercepcji zależała od wysokości roślin, zwartości łanu i przede wszystkim od wysokości opadów atmosferycznych. Istotną rolę odgrywały również fazy rozwojowe roślin, gdyż od nich zależała powierzchnia łodyg i liści, na których zatrzymywała się woda opadowa. Typowe było zmniejszanie się intercepcji wraz ze wzrostem liści przy opadach o małej wysokości. Stwierdzono również, że podczas opadów o dużej wysokości wyniki w serii 10 powtórzeń pomiarów intercepcji różnicowały się w mniejszym stopniu.