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Quality of operation of bauer rainstar 90/300 reel sprinkling machines in agrocoop imel sa agricultural company

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S u m m a r y. The paper aimed at evaluation of the results of sprinkling uniformity measurements for four reel Bauer Rainstar 90/300 sprinkling machines, realized during three years on the lands of agricultural company Agrocoop, Imeľ. The sprinkling rate uniformity was evaluated with the use of general indexes for irrigation technique work quality. Value of the uniformity coefficient was determined according to STN ISO 7749-2 Standard. There were used from 30 to 70 measuring cups, spaced by 1 to 2 m. Particular sprinkling rate values ranged from 0.41 mm to 49.16 mm, while average values ranged from 15.19 to 31.60 mm. Satisfactory values of sprinkling uniformity coefficients CU according to Frieling-haus and Růžička criterion (more than 70 %) were obtained for three sprinkling machines during sprinkling without overlapping (CU_{Z1}=72.72%, CU_{Z3}=73.32%, CU_{Z4}=73.23%). The requirements of Klement and Heinige criterion (CU more than 80%) were satisfied for three sprinkling machines (Z1, Z2, Z4), only when overlapping was introduced. None of the investigated sprinkling machines satisfied the requirements of STN ISO 7749-2 Standard (CU above 90%), even when overlapping was applied.

The lowest value of variance coefficient was found for sprinkling machine Z3 (33.29 %), while the highest value for sprinkling machine Z2 (41.31 %); the sprinkling overlapping was found as an effective factor.

K e y w o r d s : quality of operation, sprinkling, coefficient of sprinkling uniformity CU.

INTRODUCTION

Setting of sprinkling rate values is the first step towards determination of sprinkling uniformity. Therefore, the well-known methods are used that are common in the evaluation of operational quality of irrigation technology.

The applied measuring methods depend on kind of devices used: sprinkling machines with spaced sprinklers, machines with hoses of wide pivot angle or sprinkling machines with reel devices [9,4].

Sprinkling was executed upon decrease in the actual soil moisture content under conditions of hydrolimit value and reduced access to water. Such conditions call not only for soil moisture monitoring but also for controlling of tractors' traction properties in the field [17,19,15,2,78].

During sprinkling, the reel sprinkling machines with sprinklers move continuously along the field. In practice, the sprinkling rate measured on elementary surfaces does not consider the effect of other input factors (sprinkler model, jet diameter, water pressure, sprinkle sector, speed of movement, spacing of sprinklers) [9].

The sprinkling quality is regarded from the viewpoint of correct intensity and uniformity. The sprinkling intensity means the water amount in mm supplied in time unit. The sprinkling uniformity depends on the correct functioning of sprinklers and, particularly, on correct selection of sprinkler jet, water pressure in the flow line and appropriate selection of spacing and reach of the next sprinkler position [11].

PURPOSE AND METHODS

The aim of the presented paper was to evaluate the results of sprinkling uniformity measurements for four Bauer Rainstar 90/300 reel sprinkling machines Z1, Z2, Z3, Z4.

The practical measurements were executed during three years in the agricultural company Agrocoop a.s., Imeľ, situated in the southest Slovakia in Komárno region, with rather flat fields of slope ranging from 0 - 2°.

The company uses 30 reel sprinkling machines of model Bauer Rainstar 90/300 (Fig.1); four of them were randomly selected.

Specifications

- Hose diameter and length 90 mm / 300 m
- Maximal belt length 340 m
- Flow rate 17 – 65 $m^3.h^{-1}$
- Connecting pressure 0,35 – 1 MPa
- Jet size 16 – 30 mm
- Weight with hose and water 3270 kg
- Weight with hose and without water 1850 kg
- Total length with stand 5350 mm
- Maximal width at greatest spacing 2050 mm
- Total height 3060 mm

The sprinkling machine was equipped with the sprinkler SR-101 of jet diameter 20 mm. The sprinkling machine was controlled with microcomputer Ecostar 4000. The sprinkling uniformity evaluation was carried out on a parcel of land with potato crop.

Fig. 1. Sprinkling machine Bauer Rainstar 90/300 TX Plus Ecostar 4000 with sprinkler SR101

The sprinkling equipment was controlled with buttons on the panel. The system was equipped with sprinkling belt length detector, electronic panel, winding speed detector, solar collector and detector of electric energy source connector. Ecostar 4000 has four lines' display and it shows the settings of machine working parameters. They are: winding speed, time to the end of sprinkling, length of the moved out hose, prior irrigation (irrigation at the beginning before the start of stand movement) and after irrigation (irrigation at the end of irrigation after the stop of stand movement). The irrigation rate, or more precisely the winding speed, can be adjusted during sprinkling to obtain the so called variable sprinkling rate within one pass of machine.

The most advanced method for sprinkling uniformity evaluation involves application of uniformity coefficient CU, according to CHRISTIANSEN (1942) in [18]:

$$CU = 100.\left[1 - \frac{\sum_{i=1}^{n}|h_i - h_m|}{n.h_m}\right], \quad (1)$$

where: h_i – rainfall height on elementary surfaces (mm),

h_m – average rainfall height on the examined surface (mm),

n – number of elementary surfaces making up the sprinkled surface, equal in size (pc),

$\sum_{i=1}^{n}|h_i - h_m|$ – absolute sum of variance of average rainfall.

Measurements of sprinkling uniformity is evaluated according to STN ISO 7749-2 Standard for the reel sprinkling machines and must be performed on a flat ground (maximal gradient 1%). The winding velocity cannot exceed 1.5 $m.s^{-1}$ during investigations; overlapping values of 4, 8 and 16 m are applied in determination of the uniformity coefficient CU (%).

Fig. 2. Spacing of measuring cups in one radius, position of irrigators (rainfall cups, sprinkler, sprinkler movement direction)

RESULTS AND DISCUSSION

The layout of practical measurements is presented in Fig. 2, while the input values for work quality evaluation of the selected reel sprinkling machines together with calculated values of uniformity coefficient according to Christiansen CU are listed in Table 1. As it is evident from the results, the highest value was found for the reel sprinkling machine Z3 and the lowest one for the machine Z2.

Many experiments aimed at investigating the connection between irrigation irregularity and crop. [1,12] independently came to conclusion that plants were equal with respect to sprinkling irregularity. Frielinghaus [3] confirmed it and found the Christiansen uniformity coefficient value equal to 70% as satisfactory one. The measurement accuracy is negatively affected by wind activity, pressure variation in the distributing main and the like [20].

Table 1. Sprinkling uniformity, overlapping = 0

Sprinkling machine	Cups spacing, m	Aver. Vi, mm	Sum Vi, ml	Sum Vi, mm	CU, %
Z 1	1	15.19	10383	1063.46	72.72
Z 2	1	23.77	14158	1450.10	67.57
Z 3	2	24.18	7082	725.36	73.32
Z 4	2	31.60	9256	948.03	73.23

It was found out that 75% of investigated sprinkling machines achieved the satisfactory uniformity. Therefore, there is a need for further investigations to determine the ways for increasing the uniformity coefficient CU. One of them is overlapping with the next sprinkling belt, for example. The values of sprinkling uniformity coefficient CU at covering of 4, 8 and 16 m are presented in Table 2 together with work quality performance according to Frielinghaus. The CU values increased at the increased overlapping for sprinkling machines Z1, Z2 and Z4, while for Z3 it increased only for overlapping value of 4 m, and then decreased at bigger overlapping values. The minimal values of outer cups rainfall increase after application of overlapping and so does the uniformity coefficient value.

Růžička [1996] found out that sprinkling uniformity is maintained at sprinkling uniformity coefficient of 70%. [6] consider the value CU = 80 % as good uniformity, while TNV 754307 Standard recommends the uniformity coefficient value according to Christiansen as CU = 90 % for cross uniformity. The Standard recommends also that 80 % of surface should be sprinkled within the range from 0.85 to 1.15 of the average rate at wind velocity of 2 $m.s^{-1}$.

Klementová and Heinig [6] requirements were achieved only after the introduction of overlapping and only for three sprinkling machines; the recommendations of TNV 754307 Standard [16] (CU higher than 90%) were failed without and with application of overlapping.

Table 2. Sprinkling uniformity with overlapping, Bauer Rainstar 90/300

Serial number	*Overlapping, m*	*Sprinkling uniformity CU, %*			
		Z1	*Z2*	*Z3*	*Z4*
1	0	72.72	67.57	73.32	73.23
2	4	76.79	74.06	76.27	83.50
3	8	83.68	81.89	73.45	88.39
4	16	84.15	83.04	71.32	83.89

One of the first researchers who began to evaluate the sprinkling uniformity was [13]; he followed the rule in sprinkling uniformity evaluation that the maximal intensity of sprinkling should not exceed the double value of minimal one, with the exception of outside zone. He developed isograms (the lines like rainfall heights) on the basis of rainfall heights measurements in the rainfall cups, and he evaluated visually the uniformity as very good, good, satisfactory and bad [9].

The descriptive statistics was introduced to Table 3 for the investigated sprinkling machines Z1, Z2, Z3 and Z4. The average irrigation rate was not equal, but it ranged from 15.19 to 31.60 mm. The measuring cups

Table 3. Descriptive statistics, measurements 2010, sprinkling machine 1, Bauer Rainstar 90/300

Parameter	**Value**			
	Sprinkling machine 1	**Sprinkling machine 2**	**Sprinkling machine 3**	**Sprinkling machine 4**
Average value, mm	15.19	23.77	24.18	31.60
Divergence max – min, mm	23.15	37.69	31.75	48.34
Minimum, mm	1.84	0.41	7.17	0.82
Maximum, mm	24.99	38.10	38.92	49.16
Sum, mm	1063.46	1450.10	725.36	948.03
Number, pc.	70	61	30	30
Level of reliability (95.0%)	1.3	2.51	3.01	4.35
Variance coefficient, %	35.94	41.31	33.29	36.84

number amounted to 30, 61 or 70 pc.. Values of particular irrigation rates ranged from 0.41 mm to 49.16 mm. The lowest value of variance coefficient was found for sprinkling machine Z3 (33.29 %) and the highest one for sprinkling machine Z2 (41.31 %).

The graphical evaluation of results for particular reel sprinkling machines Z1, Z2, Z3 and Z4 is presented in Fig. 3.

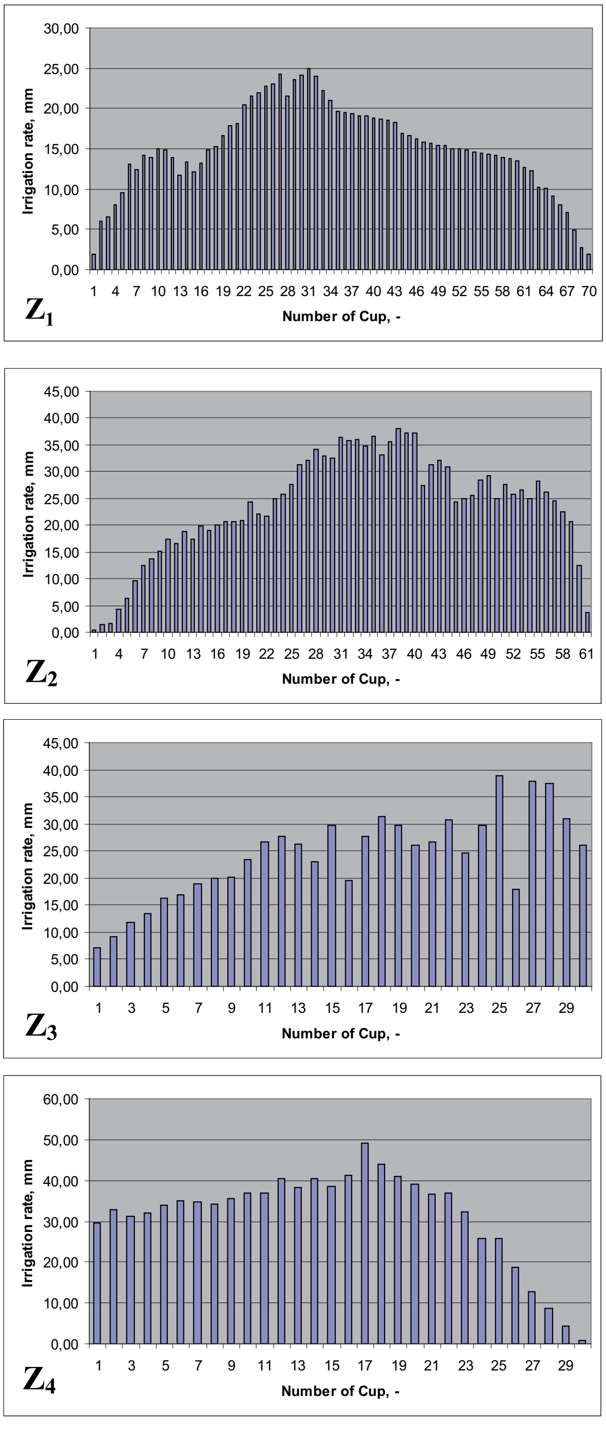

Fig. 3. Irrigation rate, overlapping 0, sprinkling machines Z1, Z2, Z3 and Z4

CONCLUSIONS

The presented article was focused on the work quality evaluation of four reel sprinkling machines in agricultural company Agrocoop Imeľ, a.s. The method of Christiansen (STN ISO 7749-2 [14]. Standard, 1999) was applied for evaluation. Its value is affected by a series of external factors like: the shape of sprinkling curve, spacing and the wind effect. One can find on the basis of [10,3] recommendations (the sprinkling uniformity coefficient value over 70 %), that the three reel sprinkling machines met the conditions. The requirements were fulfilled with application of overlapping for all the examined reel sprinkling machines. However, the use of overlapping is effective only to a limited degree, because an increase in overlapping decreases the effective output of reel sprinkling machines. As a result, the time and economic items increase; this may point out at the need for optimization of effective spacing of the sprinklers.

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OCENA JAKOŚCI PRACY DESZCZOWNI SZPULOWEJ BAUER RAINSTAR 90/300 W PRZEDSIĘBIORSTWIE ROLNICZYM AGROCOOP IMEL SA

S t r e s z c z e n i e . Celem badań było przeprowadzenie analizy równomierności opadu deszczowni szpulowych Bauer Rainstar 90/300. Pomiary równomierności opadu przeprowadzono na polach uprawnych przedsiębiorstwa rolniczego Agrocoop, Imel SA na Słowacji. Badania prowadzono w ciągu 3 sezonów agrotechnicznych. Obiektem badań były cztery deszczownie szpulowe Z1, Z2, Z3, i Z4. Współczynnik równomierności opadu był określany według normy STN ISO 7749-2. Liczba używanych kubków pomiarowych, które rozstawiano w odległości do 1 do 2 m, wynosiła od 30 do 70.
Wartości poszczególnych średnich dawek polewowych były w zakresie od 15,19 do 31,60 mm. Zadawalające wartości współczynników równomierności opadu według kryterium Frielinghausa i Růžički (CU powyżej 70%) uzyskano dla trzech deszczowni przy deszczowaniu bez zakładu (CU_{Z1} = 72,72%, CU_{Z3} = 73,32% i Cu_{Z4} = 73,23%).
Wymagania według kryterium Klementovej i Heiniga (wartość współczynnika CU powyżej 80% CU) spełnione były dopiero po zastosowaniu zakładów i to tylko w przypadku trzech deszczowni Z1, Z2 i Z4.
Wymaganiom według normy STN ISO 7749-2, według której współczynnik równomierności opadu powinien mieć wartość powyżej 90%, nie odpowiadały wartości CU uzyskane dla żadnej z badanych deszczowni, nawet po zastosowaniu zakładów. Najniższą wartość współczynnika wariancji uzyskano dla deszczowni Z3 - 33,29%, a najwyższą wartość dla deszczowni Z2 – 41,31%.

S ł o w a k l u c z o w e : jakość pracy deszczowni, deszczowanie, współczynnik równomierności opadu CU.