DOSAGE UNIFORMITY OF RAINFALL SIMULATOR DEPENDING ON NOZZLE TYPE AND PRESSURE

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Abstract. Water erosion and its symptoms represent a worldwide problem. In the Czech Republic conditions are at risk by water erosion more than in half of the agricultural land. A rainfall simulator is a promising method of measuring of erosion values such as infiltration rate, surface runoff and amount of washed off soil. At the Department of Agricultural Machines (Czech University of Life Sciences Prague) the rainfall simulator for the mentioned measurements has been developed. For the operation of the rainfall simulator it is necessary to know the progress of the surface dose of the rainfall simulator for individual nozzles. Three types of nozzles were selected. Two of the nozzles have a circular spray pattern and the third has a square spray pattern. Firstly, the flow through the nozzles was measured for different operating pressures. Secondly, the surface dose of water per unit area was measured. The measurements showed the lack of the nozzle with the square spray pattern. The correlation between precision in the surface dose and operating pressure was also observed.

Keywords: rainfall simulator, dosage, nozzles.

Introduction

Water erosion is a worldwide problem. Every year, water erosion causes destruction or damage to vast areas of agricultural land [1]. Agricultural land in the Czech Republic is largely exposed to the risk of water erosion due to habitat and agrotechnical reasons. Janeček stated that more than half of the agricultural land in the Czech Republic is threatened by water erosion [2].

Losses of soil most threaten the agriculture and the forestry because this loss is permanent. The affected soil is only in very exceptional cases returned to the original site. During intense rainfall the upper part of the soil is taken away and exposes the less fertile layers of soil – subsoil. For example, the loss in 5-15 mm of the topsoil layer can reduce crop yields by up to 15-30 % [3].

There are three basic models to determine the threat of the soil – empirical, conceptual and physically based models. Empirical models are based on observations and statistical nature. Nowadays, the universal equation for calculating the long-term loss of soil erosion in the Czech Republic – USLE (Universal Soil Loss Equation) is used. This equation was originally compiled for the conditions of the USA. The equation calculates washes off multiplied by the six factors that affect its value [4]. Loss of soil is determined by the so-called unitary plot of length 22.13 m with a slope of 9 % and the surface is cultivated like fallow land in the direction of the slope. The disadvantage of this equation is its inability to estimate the amount of sediment in the catchment area. In the 90s this equation had been verified, updated and revised, this led to a new equation RUSLE (Revised Universal Soil Loss Equation).

The intensity and process of water erosion can be most accurately determined at exactly defined drainage areas that have a certain slope and are able to capture surface water run-off and washed off soil particles. The advantage of this mentioned method is relatively quick and easy data collection [5]. For these surfaces it is possible to use for measurement the natural rainfall, which is time consuming. The second option is to use the rainfall simulator. Rainfall simulators have common characteristics in portability, mobile sources of water, bounded test area, spraying mechanism of various types, which allows control of the applied water. In addition, as the device that concentrates rainfall and measures surface water runoff. The rainfall simulator should be cheap in production and in operating, it must be able to authentically imitate the natural rainfalls and it should be portable and ready to use in any conditions. Despite all the problems, the practice shows that the rainfall simulator is a very necessary tool to research the process of erosion, infiltration and rainfall-runoff relationships. The most commonly used rainfall simulator in the world is the portable rainfall simulator with scattering up to 1.5 m^2) [6].

To identify the characteristics of the rainfall simulator it is vital to know the process of the scatter for different types of nozzles. For this reason, experimental measurements were performed to determine the surface dose for each individual nozzle (total of 3 selected models) at different working pressure. Simulated rainfall intensity and kinetic energy of raindrops are regulated by changing the spraying pressure [7].

Materials and methods

Between 2012 and 2013 an entirely new rainfall simulator was constructed at the Department of Agricultural Machines (Czech University of Life Sciences Prague – CULS). The concept of the simulator (Fig. 1) is partially different from the above-described design. The simulator has a modular design, being accepted that most of the technological parts are placed on the chassis of the car trailer. The rainfall simulator is designed as universal. It is used to measure erosion values such as surface water or soil runoff, or for monitoring of the infiltration processes.

Fig. 1. **Rainfall simulator**

The pump can draw water from the tank or, after turning the valve, from an external source. The pump draws water into the switchboard. The switchboard has a control valve which serves for setting the pressure. The water is then guided into hoses with a diameter of 0.5 inch. The hoses are wound up on the drum. The length of these hoses is always 30 m. The hoses are provided with couplings at the ends for connection to the nozzle frame (with total number of four nozzle frames). Each nozzle frame is equipped with a selected pair of nozzles (always only one nozzle operates) and also a pressure gauge to check the set pressure. Measuring the nozzle frame allows continuous adjustment of the nozzle height above the soil surface (eventually vegetation). It is possible to measure very high vegetation (eg., grown maize).

The measurement is related to three types of nozzles with surface scattering. The first part of the measurements was to determine the flow of water through the nozzle. All water from the nozzle was collected in a container for a set period of time (one minute) and then weighed by Kern scales. Water flow through the nozzles was designed for working pressures in the range of 0.4-1.2 bar. The second part of the measurement was the measurement of surface doses in different locations of the spray pattern. From the irrigated area the area of the square shaped 1x1 m was chosen. The water was collected into square bowls with a side 14.2 cm, which were marked with numbers 1-7 in the horizontal section and the letters A to G in the vertical section. The bowls were placed side by side in a grid of 7x7 pieces.

The height of the nozzle above the edge of the bowls was exactly one meter. The measurement was carried out again at a pressure of from 0.4 to 1.2 bar. After the pump starts it was followed by measurements for a given period of time (depending on the type of the nozzle 1-3 minutes). After that weighing of all the bowls on the laboratory scale Kern with accuracy of 0.01 was done. After resetting the settings of bowls a new measurement began. The same pressure was measured total of 3 times to be able to statistically process the output data. Subsequently, the values were converted to the intensity of rainfall in $mm \cdot h^{-1}$.

Results and discussion

A graph showing the dependence of the flow through the nozzle on the working pressure is shown in Fig. 2. For all selected nozzles a very strong linear relationship in the measured section 0.4-1.2 bar was found. However, the progress of linearity in terms of changes in the water flow is not the same for all nozzles. The greatest dependence was detected for the nozzle Lechler 460.888.30.CG with a circular scattering in the case of pressure.

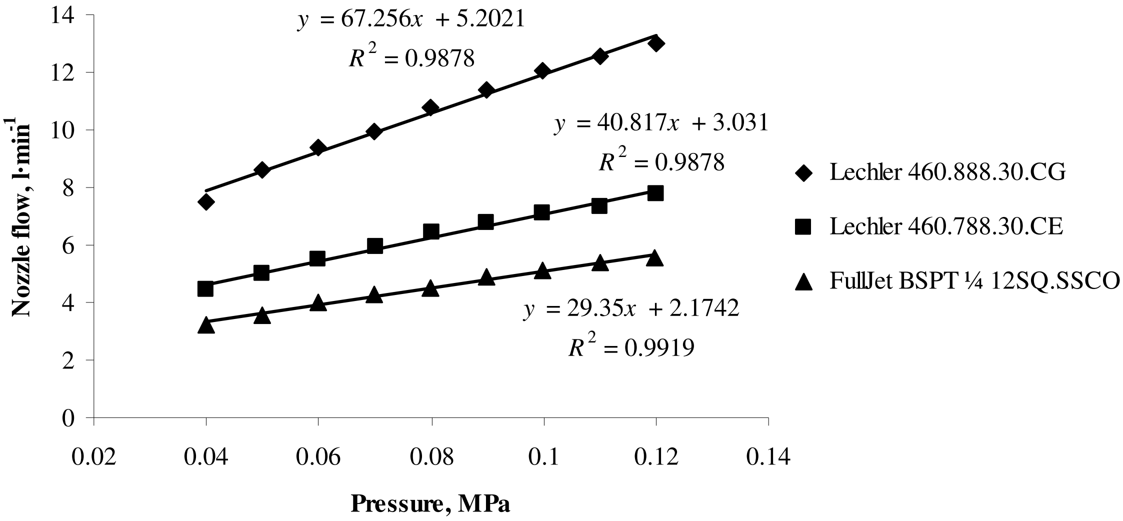

Fig. 2. **Measurement of water nozzle flow**

Fig. 3 shows the progression of the surface dose for the nozzle Lechler 460.788.30.CE. It shows the progression of the working pressures of 0.6 and 1 bar. This nozzle showed the smallest variance of the measured values in both cases of working pressures from all of the measured nozzles. Also, this nozzle is most suitable for the rainfall simulator in terms of uniformity of the scattering dose. However, there is an obvious dependence of the scattering dose on the position towards its centre. The nozzle in areas under its centre has a higher value than towards the edge of its scattering pattern.

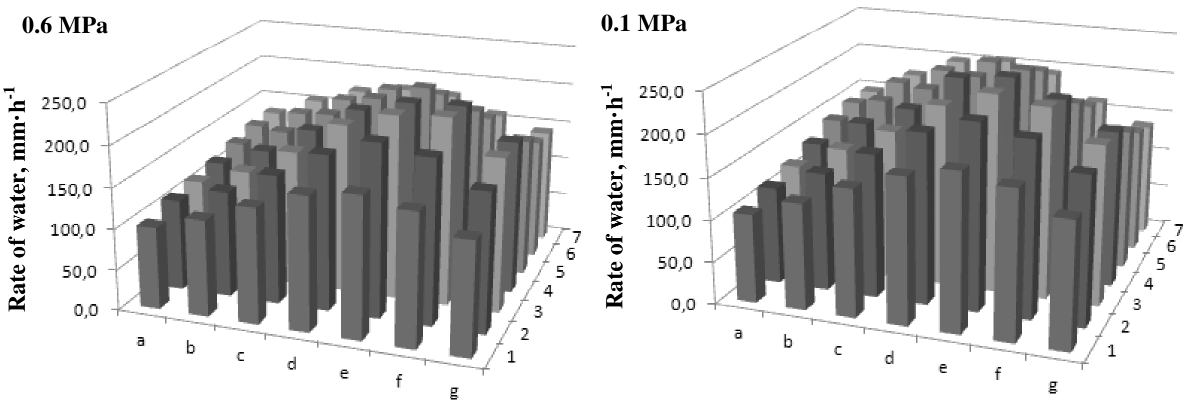

Fig. 3. **Progression of surface unevenness of the nozzle Lechler 460.788.30.CE**

Fig. 4 shows the progression of the surface dose for the second nozzle with a circular shape 460.888.30.CG. This nozzle also showed similar non-uniformity values as the previous nozzle for square grid measurement. However, the surface dose is due to flow through the nozzle incomparably greater than the previous nozzle. The values of non-uniformity are similar to the second nozzle with a circular pattern. Even for this nozzle there is increased tendency of the surface dose toward the centre of the scattering pattern as in the first case. Also in this case it was demonstrated that increased operating pressure positively affects the uniformity of dosage. For this measurement it has not been clearly shown whether improved accuracy of the dose is connected with increasing pressure.

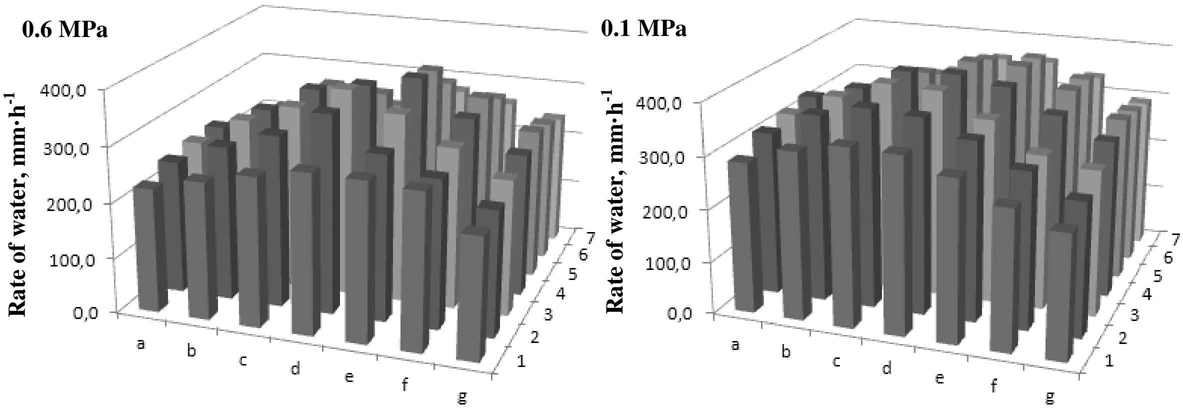

Fig. 4. **Progression of surface unevenness of the nozzle Lechler 460.888.30.CG**

Fig. 5 shows the measurement progression for FullJet BSPT ¼ 12SQ.ssco. This nozzle has according to the manufacturer's a square shape of the spray pattern. Many rainfall simulators utilize this type of nozzle to create a rectangular shape measurement using a serial arrangement of these nozzles. However, from our measurement a large non-uniformity area of the dose for this nozzle was detected. The non-uniformity of the dose far exceeded the measured nozzle with a circular pattern. Variations in this case are much higher for all measured pressures. Nevertheless, with increasing pressure the non-uniformity of dosage decreases slightly.

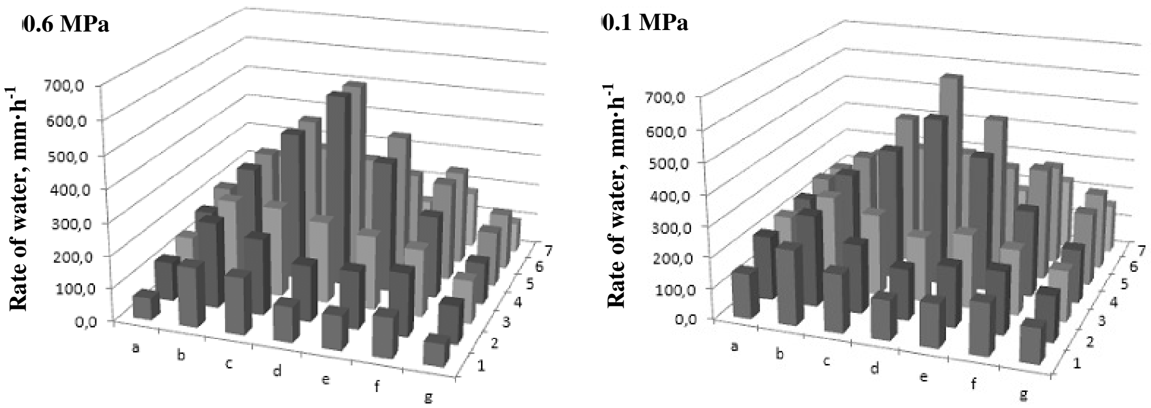

Fig. 5. **Progression of surface unevenness of the nozzle FullJet BSPT ¼ 12SQ.ssco**

Conclusions

The measurements showed the importance of the choice of the nozzle in terms of the amount of the applied dose of fluid during usage of the rainfall simulator. It has been proven that the nozzles have a linear dependence of the water flow on the working pressure regardless of the shape of the deflector. It was also proven that the accuracy of dose per unit area is influenced by the shape of a nozzle deflector. The nozzles with circular pattern showed more precise uniformity of dosage for the selected measurement conditions. For most of the nozzles the influence of the set pressure on the non-uniformity of the dosage was demonstrated.

Acknowledgments

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