THE INFLUENCE OF NOZZLE TYPE AND PRESSURE ON THE DOSAGE UNIFORMITY OF RAINFALL SIMULATOR

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Abstract

Water erosion and its symptoms represent worldwide problem. In the Czech Republic conditions is at risk by water erosion more than 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) has been developed the rainfall simulator for mentioned measurements. For the operation of rainfall simulator is necessary to know the progress of surface dose of rainfall simulator for individual nozzles. The aim of this measurement was to compare the dependence of fluid pressure to the uniformity of dispersion nozzles during the simulated rainfall. Three types of nozzles were selected. The two of nozzles have 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 for nozzle with square spray pattern. The correlation between precision in surface dose and operating pressure was also observed. The measurements took place in laboratory conditions. The nozzle Lechler 460.788.30.CE with circular spray pattern showed the smallest scatter of measured values of all measured nozzles. It is therefore the most suitable nozzle for use of simulator rain.

Key words: dosage, nozzles, rainfall simulator.

INTRODUCTION

Water erosion is a problem of global significance. Water erosion causes destruction or damage to enormous areas of agricultural land every year (MORGAN, 2005). Agricultural land in the Czech Republic is largely exposed to the risk of water erosion on grounds of habitat, but as well agro technology. More than half of agricultural land is endangered by water erosion in the Czech Republic (JANEČEK, 2005).

Due to water erosion the soil is depleted of its most fertile part – topsoil. The physical and chemical properties of the Earth's surface are deteriorating, the content of nutrients and humus in the soil reduce, and the thickness of the soil profile decreases. 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. For example, the loss in 5-15 mm of topsoil layer can reduce crop yields by up to 15 - 30% (TRUMAN ET AL., 2005).

Intensity and process of water erosion can be most accurately determine 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 (NOVÁK, 2011). 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 concentrate rainfall and measuring 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 very necessary tools to research the process of erosion, infiltration and rainfall-runoff relationships. The most commonly used rainfall simulator in the world is portable rainfall simulator with scattering up to 1.5 m^2 (SCHINDEWOLF, SCHMIDT, 2012).

To identify the characteristics of rainfall simulator 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 is regulated by changing the spraying pressure (KOVAŘÍČEK ET AL., 2008).

NOVÁK ET AL., (2014) also measured the uniformity of the dose surface of nozzles for different shapes of the deflector. He concluded that nozzles with circular spray pattern have the smallest uniformity of dose of dispersion. Thus the aim of this measurement was to compare the dependence of fluid pressure to the uniformity of dispersion nozzles during the simulated rainfall.

Fig. 1. – The nozzles with circular spray pattern

MATERIALS AND METHODS

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

Fig. 2. – Rainfall simulator

The pump can draw water from the tank or, after turning the valve, from an external source. The pump draws water into switchboard. Switchboard has a control valve which serves for setting the pressure. The water is then guided into hoses with a diameter of ½ 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 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 0.04 – 0.12 MPa. The second part of the measurement was the measurement of surface doses in different locations of the spray pattern. From the irrigated area was chosen the area of square shaped 1 x 1 m. 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. 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 0.04 to 0.12 MPa. After pump starts was followed by measurements for a given period of time (depending on the type of nozzle 1-3 minutes). After that was done weighing of all the bowls on the laboratory scale Kern with accuracy of 0.01. 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·h^{-1}.

RESULTS AND DISCUSSION

A graph showing the dependence of the flow through the nozzle on the working pressure is shown in Fig. 3. For all selected nozzle was found a very strong linear relationship in the measured section 0.04 – 0.12 MPa. However, the progress of linearity in terms of changes in 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. The R^2shows the size dependency of pressure on the resulting water flow. The flow increases with the increasing pressure.

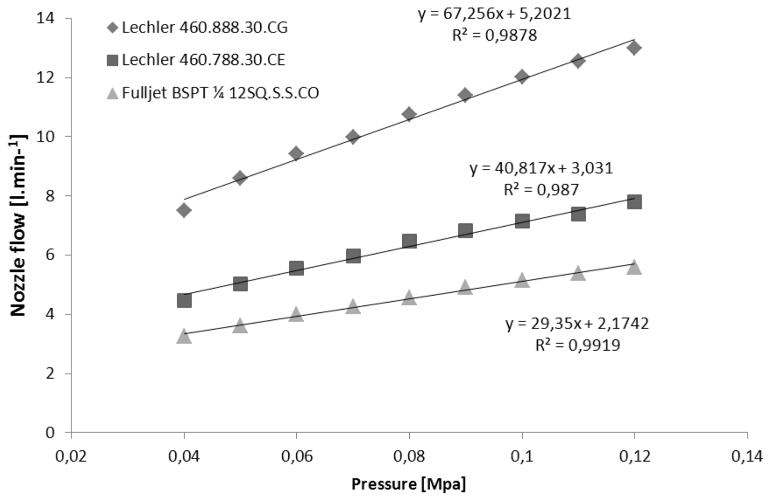

Fig. 3. – Measurement of water nozzle flow

Fig. 4 shows the progression of the surface dose for the nozzle Lechler 460.788.30.CE. It shows the progression of the working pressures of 0.05 and 0.11 MPa. This nozzle showed the smallest variance of measured values in both cases working pressures from all of measured nozzles. Also, this nozzle is most suitable for rainfall simulator in terms of uniformity of the scattering dose. However, there is a obvious dependence of scattering dose on the position towards to its centre. The nozzle in areas under its center has a higher value than towards the edge of its scattering pattern.

Fig. 5 shows the progression of the surface dose for a second nozzle with a circular shape 460.888.30.CG. This nozzle also showed similar non-uniformity values as previous nozzle for square grid measurement. However the surface dose is due to flow through the nozzle incomparably greater than previous nozzle. The values of non-uniformity are similar to the second nozzle with a circular pattern. Even for this nozzle is increased tendency surface dose toward the centre of the scattering pattern as in the first case. Also in this case it was demonstrated that increased the operating pressure positively affects the uniformity of dosage. For this measurement has not been clearly shown whether improved accuracy of the dose is connected with increasing pressure.

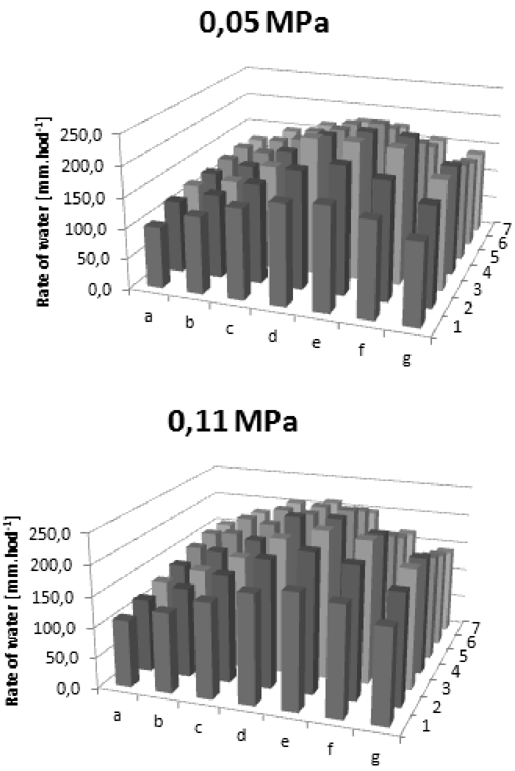

Fig. 4. – The progression of surface unevenness of the nozzle Lechler 460.788.30.CE

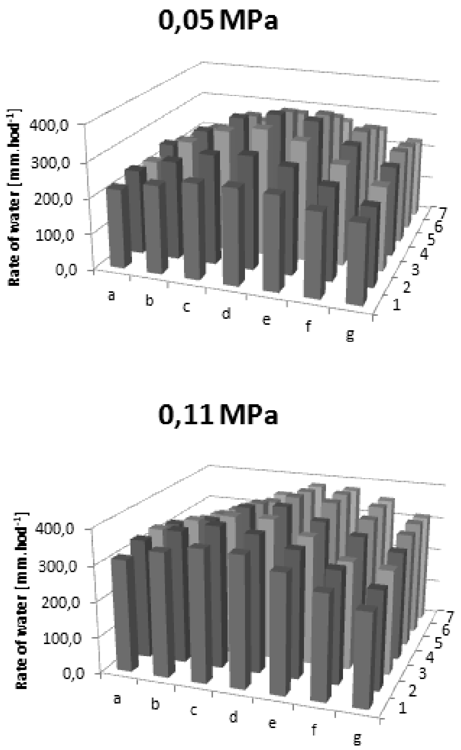

Fig. 5. – The progression of surface unevenness of the nozzle Lechler 460.888.30.CG

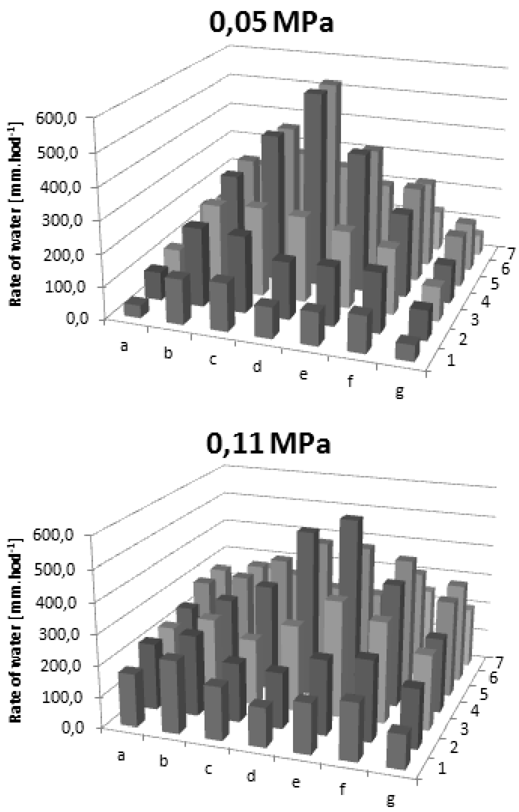

Fig. 6. – The progression of surface unevenness of the nozzle FullJet BSPT ¼ 12SQ.ssco

Fig. 6 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 was detected large non-uniformity area of the dose for this nozzle. The non-uniformity of dose far exceeded both 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.

It is obvious from the graphs above that the nozzles with circular spray pattern of deflector have a more uniform splashing than the nozzles with a square shape. NOVAK ET AL. (2014) also points out that the circular nozzles have better uniformity than square nozzles.

CONCLUSIONS

From the measured values, which were converted into the graphs above, show great difficulty in simulating rain. 100% uniform spray cannot be reached at the given dimension. It has been proven that the nozzles have a linear dependence of 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. Nozzles with circular pattern showed more precise uniformity of dosage, for the selected measurement conditions.

ACKNOWLEDGMENTS

Project is supported by the CULS Prague, Project No CIGA 20123006.

REFERENCES

1. MORGAN, R. P. C.: Soil erosion and conservation. 3rd Edition. Blackwell Publishing Company, Malden, USA, 2005: 304 p.
2. JANEČEK, M. ET AL.: Soil erosion protection. Prague: ISV publishing, 2005: 195 p.
3. TRUMANN, C.C., SHAW, J.N., REEVES, D.W.: Tillage efects on rainfall partitioning and sediment yield from an ultisol in central Alabama. Journal of Soil and Water conservation, vol. 60, 2005: pp. 89-98.
4. NOVÁK, P.: Evaluation of surface water runoff and soil loses in the cultivation maize crops. In The Fifth International Scientific Conference Rural Development in Global Changes 2011, Vol 5, Book 1 24.11.2011, Akademija, Kaunas District, Lithuania. Akademija, Kaunas District, Lithuania: Aleksandras Stulginskis University, 2011, pp. 405-411.
5. NOVÁK, P., CHYBA, J., KROULÍK, M., MAŠEK, K.: Dosage uniformity of rainfall simulator depending on nozzle type and pressure, Conference on Engineering for Rural Development 2014; Jelgava; pp. 69-73
6. SCHINDEWOLF, M., SCHMIDT, J.: Parameterization of the EROSION 2D/3D soil erosion model using a small-scale rainfall simulator and upstream runoff simulation, Catena, vol. 91, 2012, pp. 47-55.
7. KOVAŘÍČEK P., ŠINDELÁŘ R., HŮLA J., HONZÍK I.: Measurement of water infiltration in soil using the rain simulation method. Research in Agricultural Engineering, 54, 3: 2008: pp. 123-129.

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