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SHORT COMMUNICATION: GUTTATION OF OAT AND WHEAT AND THE RESULTS OF ITS COMPARISON WITH THE YIELD

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ABSTRACT. The present paper aims to give an overview of results collected in the Estonian Crop Research Institute related to the comparison between guttation and yield in grain crop cereals. The objects of research were oat variety 'Eugen' and wheat 'Manu', which went through the stages of germinating their seeds (*in vitro*), set them by sprouts down into the soil, and the emergence of sprouts under conditions of a hydrothermostat. Since transpiration in a hydrothermostat at an air temperature of 23 °C, and an extremely high value of air relative humidity was limited, therefore, due to this, the plant sprouts have begun to exude guttation fluid. As result, we have found that the amount of isolated gutted fluid correlates significantly with the grain yields of field trials indicators. The comparison between relative guttation and relative yield was described by a straightforward relationship. The entire experiment took about one week, and the first results of droplet prints on filter paper can be obtained after 60 hours. This was the novelty of our approach which provides the prerequisites for both increasing the reliability of conclusions regarding the yield obtained and its forecast.

Introduction

It is well known that during guttation fluid is released from the hydathode of the plant seedling (cereal) always if the amount of moisture becomes higher than its release during evaporation through the plant seedling (Barrs, 1966; Tumanov, Chiruk, 2012; Jauneau *et al.*, 2020). It should be noted that all this was known for a long time (Shardakov, 1928; Logvenkov, 1993).

In Estonia, the guttation method has used for the first time in the Estonian Research Institute of Agriculture and Land Improvement (Reppo, 1977).

The first time in Estonia was found a practical application how to use better this phenomenon in agricultural research (Kuht, Reintam, 2001; Nugis, Kuht, 2013; Nugis *et al.*, 2020). When it comes to determining the relationship between guttation and yield, then in earlier periods this problem was not the priority. Although the authors have long noted (Goatley, Lewis, 1966; Dieffenbach *et al.*, 1980; Tumanov, Chiruk, 2012) that the guttation fluid secreted by the sprout can be a good indicator as it quickly reacts to any changes in the soil conditions. In addition, an important question is at what physical state of the soil can be achieved in experiments with guttation the expected result. Here the problem rests on the assessment of soil compaction (Nugis *et al.*, 2020) and the assessment of water's biohydrological constants (Reppo, 1980). In the first case, the guttation plant responds by the amount of released guttation fluid to the bulk density of the soil, and in the second case, to its water content.

Nevertheless, it seems to us that such a simple and operational method is far from exhausting the possibilities of studying the soil. Production capability and containing both useful and negative chemical elements in the soil, as well as various harmful toxins that affect not only the health of the soil but also the quality of agricultural products.

A distinctive feature of these studies is that laboratory experiments were carried out in the course of field experiments of the Estonian Crop Research Institute (Edesi *et al.*, 2016; Kangor *et al.*, 2017).

In general, the problem of guttation can be approached with varying elaboration. We have chosen the easiest and most understandable way for the farmer, how to have an idea of the upcoming expected yield even before sowing already.

Material and Methods

The laboratory experiments were carried out (2015–2016) in the Saku Sector laboratory of the Estonian Crop Research Institute (ECRI). Work were supported by PhD L. Edesi (ECRI, seeds of 'Eugen'), and MSc T. Kangor (ECRI, seeds of 'Manu') from whose experimental fields soil samples were taken and seeds of the same crops were obtained. It should be noted that we did not determined plant yield and we have used some data from L. Edesi and T. Kangor.

The first stage of laboratory tests was germinating of seeds of the spring wheat (variety 'Manu') and oat (variety 'Eugen') at a temperature of 23 °C in a special thermostat TPS-3 for germinating seeds. At the same time, the thermostat for germinating seeds was previously converted into a hydrothermostat where all the free parts of the shelves were occupied under the containers with water. Due to this, a setting in the hydrothermostat where the relative humidity of the air was more than 90%, was created.

The germination process usually takes 24 hours. After that, the germinated seeds, five pieces per cylinder (270 cm^3 in volume; 6.4 cm in diameter and 8.4 cm in height) were introduced into the soil with three replicates of downward directed shoots (Nugis, Kuht, 2013). For this, a special stencil was used. Previously, the hole in the soil of the cylinder at a depth of 7 mm for wheat and 12 mm for oat were made.

The appearance of the first shoots in the cylinders with water drops on them, *i.e.* the guttation fluid could be seen after 48 hours. For fixing the guttation fluid, we are specially prepared 2x6 cm pieces of filter paper by which we have collected water droplets from the surface of the sprouts. Since the leaves of the filter paper were pre-treated with a 5% solution of copper sulphite and were well dried the water droplets were distinguishable on them. To facilitate the processing of the areas, the splotch on the filter paper (drop trace) had to be drawn around with a pen (Fig. 1).

Guttation fluid was collected three times a day every five hours. In total, it was possible to fix the guttation fluid on filter paper also once and the next day after which the collection ended. Since the roots of the plant had already reached the bottom of the cylinder and the results of collecting the guttation fluid turned out to be implausible. The processing of guttation fluid splotch on filter paper was carried out digitally by using the Foxit PDF Reader 8.3. Whereby which with the help of the corresponding blot areas (cm^2) were determined. The amount of guttation fluid was estimated with the help of the corresponding blot areas.

When recalculating areas in the values of relative units, we took the largest area as a unit and all other areas were calculated relative to this largest area. At the same time, it should be noted that a distinctive feature of this technique is that when receiving data on the harvest, we could not take into account copyright protection, claim their result. Therefore, we also presented the yield data in relative units. For example, the highest splotch value of guttation fluid on the filter paper, which was set at one relative unit, was 2.21 cm^2, and the yield was 5330 kg ha^{-1}, respectively (Fig. 2).

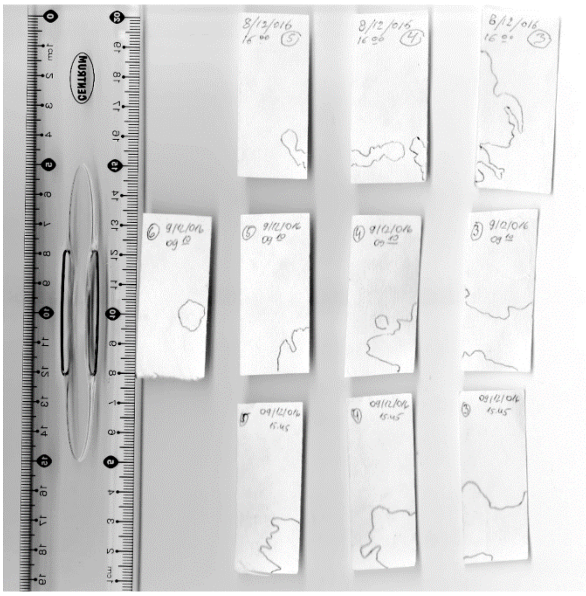

Figure 1. Example of splotch (drop trace) of guttation fluid on filter paper

What were the experimental treatments and in what soil and climatic conditions the field experiments were carried out for us, in this case, did not matter. The main thing for us was to carry out laboratory experiments on guttation with identical soils and with identical seeds.

The statistical estimation of data of the areas of a splotch of the guttation fluid and corresponding yield has been carried out by Student T-test at 0.05 significance level. The least significant difference (LSD) test as of right was used. In addition, the correlation coefficient (r) was calculated through the coefficient of determination (R^2) taking from it the square root.

Results and Discussion

The results of laboratory experiments on guttation with a variety of oat 'Eugen' are shown in Figure 2, and for spring wheat 'Manu' in Figure 3. Based on the above principles of treatments regarding the details of field experiments it can be seen that as different variants of experiments and different soil and climatic conditions did not have a significant outside influence on the relationship between guttation and yield. At the same time, attention is drawn to the rather high value of the coefficient of correlation (r).

According to the interaction between guttation and yield are shown in Figure 3, a strictly linear relationship with a very high coefficient of correlation (r) draws attention.

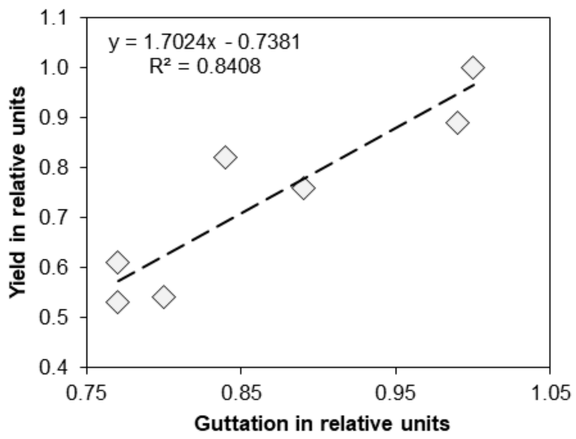

Figure 2. Results of guttation and comparison with the yield for variety 'Eugen' oat

Note: For relative yield $LSD_{0.05}$ = 0.17; for relative guttation $LSD_{0.05}$ = 0.09. Soil bulk density in the cylinder during laboratory tests was 1.15 ± 0.02 Mg m^{3-1} and water content was 23.0 ± 1.8%(kg kg^{-1}). The correlation coefficient r = 0.92

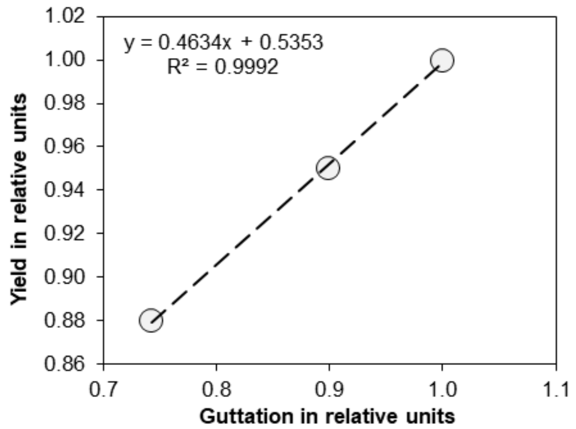

Figure 3. Results of guttation and comparison with the yield for variety 'Manu' spring wheat

Note: For relative yield $LSD_{0.05}$ = 0.32; for relative guttation $LSD_{0.05}$ = 0.15. Soil bulk density in the cylinder during laboratory tests 1.15 ± 0.02 Mg m^{3-1} and water content 19.8 ± 0.6%(kg kg^{-1}). The correlation coefficient r = 0.995

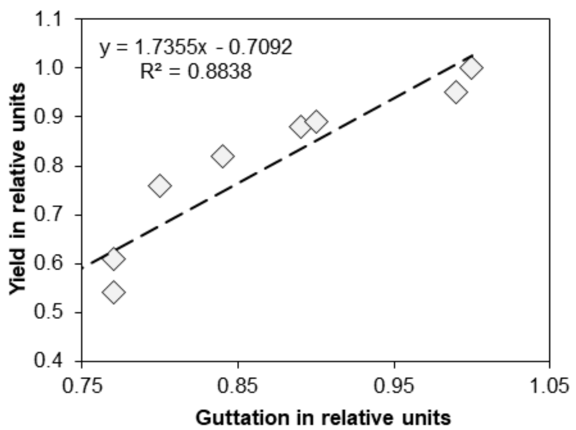

Figure 4. Results of guttation and comparison with the yield for oat (variety 'Eugen') and spring wheat (variety 'Manu') as a total

Note: for relative yield $LSD_{0.05}$ = 0.25; for relative guttation $LSD_{0.05}$ = 0.14. Soil bulk density in the cylinder during laboratory tests was 1.15 ± 0.02 Mg m^{3-1} and water content was 23.0 ± 1.8% (kg kg^{-1}) and 19.8 ± 0.6% (kg kg^{-1}). The correlation coefficient was r = 0.94.

Since for both types of cereals, the above results (Figs. 2, 3) of the soil physical properties did not differ significantly, therefore, it will be possible to combine the results obtained as a whole (Fig. 4).

Based on the obtained graph (Fig. 4), it can be emphasized that in the presence of various variants of experiments as well as different types of cereals, not to mention their different varieties, a rather close relationship was obtained between the guttation of seed sprouts and their final yield obtained during field experiments.

When analyzing the works of other authors (Goatley, Lewis, 1966; Dieffenbach *et al.*, 1980; Singh, Singh, 2013), none of them, except (Singh, 2014), with the thoroughness and depth of their study, did not establish the relationship between guttation and yield. Singh (2014) emphasizes the relationship between guttation and biological yield. One cannot but agree with this, but in our case, we claimed the results that are closer to the real practical situation of current agriculture.

If we restrict ourselves without using the guttation method only on the results of field experiments (at least 3-year data are required), then due to difficult weather conditions, harvests, depending on the various variants of experiments, cannot always give a reliable result. Since in laboratory experiments all the variants of the experiments under consideration are in the same conditions, it is quite clear that here the results will naturally be more reliable.

Also noteworthy is the fact that the possibilities of using the guttation method are far from being exhausted. A good example can be the studies of the authors (Goatley, Lewis, 1966; Singh, 2014) who, for the main cereals such as wheat, oat, barley and rye, set in a drop of isolated guttation fluid many chemical elements, such as amino acid, asparagine, pyridoxine *etc*., and to say nothing of pesticides. Such an example prompted us to think (Curtis, 1944) why not use the guttation method, in addition to our studies, as an indicator for assessing glyphosate residues in the soil. If by analogy, in a dairy farm, the feed was not of high quality, then this immediately affects the quality of milk. In our case is analogical, the clean (without glyphosates) of the isolated drop of guttation fluid on the sprout of grain crops provide prompt information about the cleanliness of the soil.

Finally, we can focus on the fact that based on our research and the examples given, we can be convinced of what many opportunities we could have if we use the guttation method in agricultural science and practice.

Conclusion

The present research has revealed the results of guttation and comparison with the yield when using 'Eugen' variety of oat and 'Manu' variety of spring wheat. This relationship for both, *i.e.* oat and spring wheat, has a strictly linear relationship with a sufficiently high coefficient of correlation (r). At the same time, when used with oat during field experiments, various experimental treatments and soil conditions did not have any significant effect on the specified relationship.

When considering the specified relationship for oat and spring wheat together, a similar linear relationship was obtained, which is the basis for the conclusion that many varieties and types of cereals do not provide a basis for confirming the relationship between guttation and yield will not have a linear relationship.

The guttation method has not lost its significance now and is a valid method for predicting the yield.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

EN 60%, JK 40% − study of the concept and design;
EN 65%, JK 35% − data collection;
EN 65%, JK 35% − analysis and interpretation of data;
EN 75%, JK 25% − writing a manuscript;
EN 55%, JK 45% − critical revision and approval of the final manuscript.

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