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## **REVIEW**

**of doctoral thesis of Ms Kalisa Amarsingh Bogati, MSc,  
entitled "The impact of simulated drought on changes in microbial  
biodiversity and soil biological activity".**

The doctoral thesis submitted for evaluation by Ms Kalisa Amarsingh Bogati was carried out at the Faculty of Biological and Veterinary Sciences, Department of Environmental Microbiology and Biotechnology, Nicolaus Copernicus University in Torun, Poland. The Supervisor of this doctoral thesis was prof. dr hab. Maciej Walczak, Nicolaus Copernicus University, Torun-Poland and Foreign supervisor: Prof. Ali Boularbah Université Cadi Ayyad, Marrakech, Morocco. The review of the doctoral dissertation was prepared at the request of prof. dr hab. Justyna Rogalska - Dean of the Faculty of Biological and Veterinary Sciences, Nicolaus Copernicus University, Torun-Poland.

### **1. General comments and relevance of the research topic undertaken**

The research problem of the doctoral dissertation is primarily an analysis of the functional and structural diversity of soil microorganisms in response to variable conditions of aeration caused by simulated drought. This subject is important for several reasons. The soil environment is considered the richest habitat of various microorganisms. They create multi-species communities that, as a community, are responsible for the functionality of a given environment. Their number, activity and diversity, both structural and functional, directly affect soil fertility. The variety of microbiological consortia depends on many environmental factors. Oxygen availability and soil moisture are distinguished among them. Natural soil moisture changes related to, among others with the cyclicity of the seasons and rainfall, they directly affect the metabolism of microorganisms. However, the appearance of a long-term lack of water in the areas affects the biological activity of soils.

In the literature, the problem of drought and the impact of variable conditions of soil moisture on the quality of the soil environment has not yet been widely described. Currently, in Polish and foreign literature, you can find a number of studies regarding physicochemical and biological changes in the soil in the conditions of drought, while there is no data on the dynamics of changes in individual groups of microorganisms and monitoring the dynamics of their functions in the conditions of drought, as well as character and symmetry these changes. As the most important element of the news of the scientific dissertation, I consider the use of modern analytical methods, including metabolic profiling and new generation sequencing in the quality of the soil environment in conditions of variable soil moisture, including drought.

Soil is a habitat for a variety of organisms and should not pose a threat to human health or the state of the environment (biodiversity). The loss of soil biodiversity is often caused by changing soil moisture, including long-lasting droughts or floods. I therefore consider all attempts to undertake research into the impact of simulated drought on changes in microbial to be very valuable and necessary in today's world. The topic of the doctoral thesis of MSc Kalisa Amarsingh Bogati is in line with this trend.

The contribution of bacteria to soil fertility and health is well known, as soil microorganisms play a major role in mineralization of organic matter, making nutrients available to plants, forming soil humus, reducing pathogens and much more. Furthermore, this dissertation also fits into the so-called European Biodiversity Strategy. In the above context, the problematic of the evaluated doctoral thesis **has a utilitarian and practical significance due to the** possibilities of implementing the achieved research results into practice. The reviewed dissertation is based on both modern laboratory methods and experimental experiences involving plants. It is also noteworthy that the reviewed dissertation clearly and professionally presents the research results as a result of a reliable conduct of experiments.

The dissertation presented above deals with important and topical issues related to the protection of the soil environment and, based on the results obtained, I highly appreciate the relevance and topicality of the research topic undertaken.

## 2. Formal evaluation of the dissertation

The reviewed doctoral dissertation is in the form of a thematically coherent collection of articles published in scientific journals, in accordance with the Act on Academic Degrees and Academic Title and Degrees and Title in Art of 14 March 2003, Article 13 (Dz. U. Nr 65, poz. 595, as amended), the Regulation of the Minister of Science and Higher Education of 19 January 2018 on the detailed procedure and conditions for conducting activities in doctoral dissertation proceedings, in habilitation proceedings and in proceedings for the conferment of the title of professor (Dz. U, item 261).

The dissertation comprises three publications, two of which are original research papers and one review article. This collection is a concise discussion of the research results contained in the following publications:

1. **Bogati, K., & Walczak, M.** (2022). Review- The impact of drought stress on soil microbial community, enzyme activities and plants. *Agronomy* 12(1):189. doi: <https://doi.org/10.3390/agronomy12010189>. [IF: 3.949; MNiSW: 100].
2. **Bogati, K.A., Golińska, P., Sewerniak, P., Burkowska-But, A., Walczak, M.** (2023). Deciphering the Impact of Induced Drought in Agriculture Soils: Changes in Microbial Community Structure, Enzymatic and Metabolic Diversity. *Agronomy* 2023, 13, 1417. doi: <https://doi.org/10.3390/agronomy13051417>. [IF: 3.949; MNiSW: 100]. **Bogati, K.A., Sewerniak, P., Walczak, M.** (2023). Effect of changes in soil moisture on agriculture soils: response of microbial community, enzymatic and physiological diversity. *Ecological Questions*, 34(3). doi: <https://doi.org/10.12775/EQ.2023.043>. [IF: 0.312; MNiSW: 20].

The publications appended to the dissertation were preceded by a paper containing the following structure: Abstract, List of publications and abbreviations, Introduction, Hypotheses, Aims, Research Objectives, References, Discussion, Conclusions. The dissertation also includes the following appendices: Copies of publications, Co-authors' statements and List of other activities of the PhD student (Preface).

The total Impact Factor of the publications constituting the set of articles according to the year of publication is **8.21**, while the number of points according to the MEiN list is **220**. These are therefore good indices and prove that the original creative publications constitute a significant and enough valuable part of the PhD thesis. All papers are co-

authored, and the Doctoral Student is the first author in four of them. The Candidate's contribution to their creation was 80%. This demonstrates the Doctoral Candidate's scientific maturity and confirms her key role at all stages of the dissertation. Her contribution to these publications included soil sampling, analyses of literature, writing-original draft preparation, writing-review and editing, visualization, physico-chemical and microbiological determinations, statistical processing of the research results and preparation of the manuscripts. It is particularly noteworthy that the research results forming the basis of the PhD thesis have appeared in print in good journals such as *Agronomy* and *Ecological Questions*. An good addition to the original creative work is a publication on a review of the impact of drought stress on soil microbial community, enzyme activities and plants. Statements of substantive and percentage contribution of the PhD student and co-authors of the publication were included in the documentation. The statements show that the contribution of the PhD student was significant, both in the execution of the experimental part and in the elaboration and interpretation of the results.

### **3. Substantive evaluation of the dissertation**

The first chapter of the dissertation, entitled "Introduction", is a five-page description of the subject matter, introducing the reader to the scope of the research conducted. The doctoral student precisely presents the most important issues concerning biological methods of protect soil biodiversity and biological activity against drought. Then, the Author precisely states the purpose and hypothesis of her research. The next chapter of the dissertation is the clearly stated aim of the work. In my opinion, the aim of the research and the research hypotheses were correctly planned and in the course of the research the Doctoral Student obtained results that provide answers to them.

The next chapter of the dissertation is 'Research Hypotheses', in which the PhD student presents the three main and rightly stated research hypotheses. The verification of the research hypothesis was based on the logically related subsequent stages of the research, adequate to the adopted aim of the dissertation. The next chapter "Research objectives" includes a description of the three research objectives that were used in the presented publications that make up the dissertation. Particularly noteworthy is the appropriate selection of modern research methods and techniques, i.e. next-generation sequencing,

metabolic profiling and physical and chemical analyses of soil samples. The following chapters present a list of literature and statements of the authors of the publication.

In the chapter "Conclusion", the PhD student describes in a synthetic way the research results presented in the individual publications included in the dissertation. The results of the research are very well justified and compared with data from the literature. The description of the results highlights the coherence of the individual publications included in the dissertation. In a short summary, the PhD student presents the most important results of her research, which include:

- prolonged drought of 8 weeks has a deleterious effect on the growth and activity of the soil microbial abundance and taxonomic diversity.
- the soil water regime strongly modified the activities of enzymes, leading to a slowing-down and /or affecting the nutrient cycles. Clay-rich soil was more resistant to suppression of soil enzymatic activity during soil water deficiency, whereas sandy soil resulted in significant soil enzyme inhibition.
- drought induced substantial shifts in the metabolic potential of microbial communities in investigated soils. The use of most of the carbon substrates were strongly inhibited by water deficit conditions.

In concluding the substantive evaluation of the dissertation, I conclude that the publications comprising the dissertation were prepared on the basis of a good research design. They were good adapted to the requirements of the journals. All studies have been methodologically correct. The research results are original. They have been correctly statistically processed and well-illustrated. They bring new values to soil microbiology and thus extend the knowledge of biology and biodiversity. The PhD student has demonstrated that she has the general theoretical knowledge to properly evaluate the obtained research results. Ms Kalisa Amarsingh Bogati also proved that she has the ability to synthetically describe the research problem presented in the set of publications, which she entitled "*The impact of simulated drought on changes in microbial biodiversity and soil biological activity*".

### 3.1. Main achievements

Well-designed experiments, an original research concept and a wide range of precise and modern research methods, as well as adequate preparation by the PhD student, made it possible to achieve many valuable and valuable results.

- prolonged drought of 8 weeks has a deleterious effect on the growth and activity of the soil microbial abundance and taxonomic diversity,
- the soil water regime strongly modified the activities of enzymes, leading to a slowing-down and /or affecting the nutrient cycles. Clay-rich soil was more resistant to suppression of soil enzymatic activity during soil water deficiency, whereas sandy soil resulted in significant soil enzyme inhibition,
- drought induced substantial shifts in the metabolic potential of microbial communities in investigated soils. The use of most of the carbon substrates were strongly inhibited by water deficit conditions.

Four soils were chosen for experience differing in fundamentally physicochemical parameters, including organic carbon content. At this point, I would like to ask a PhD student or did the organic carbon content have an impact on the differentiation of microorganisms in the conditions of drought? Have you managed to indicate these types of bacteria and fungi that were drought resistant? What should be done practically to protect soil and biodiversity against the effects of drought?

### 4. Conclusion

In summary, the presented dissertation is an original solution to a scientific problem and demonstrates the extensive theoretical knowledge of Ms Kalisa Amarsingh Bogati, MSc. At the same time, it is **comprehensive and practical study** of the impact of simulated drought on changes in microbial biodiversity and soil biological activity. The doctoral student has demonstrated that she has knowledge in the above-mentioned topic, as well as the ability to plan and properly carry out methodological research related to the above-mentioned topic. In my opinion, the formulated research problem has been achieved. Reading the original scientific publications included in it makes a good impression. The scientific and research technique used by the Doctoral Student is broad, and the results obtained made it possible to achieve the aim of the dissertation assumed at the beginning.

The dissertation does not raise any formal or substantive objections. A very well thought-out research plan and the selection of appropriate research methods, including modern research methods from the field of molecular biology and the assessment of metabolic diversity of soils, deserve appreciation.

In the light of the above assessment, the dissertation meets the current substantive and formal requirements, which are set out in Article 13 of the Act on Academic Degrees and Titles of 14 March 2003 (Journal of Laws No. 65, item 595, as amended). I therefore request the Commission of the Faculty of Biological and Veterinary Sciences, Nicolaus Copernicus University, Torun-Poland to admit Ms Kalisa Amarsingh Bogati, MSc to the next stages of the doctoral proceedings.

A handwritten signature in blue ink, appearing to read 'Anna Gałazka'.

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