ANNALS OF THE POLISH ASSOCIATION
OF AGRICULTURAL AND AGRIBUSINESS ECONOMISTS

received: 01.12.2020
acceptance: 19.12.2020
published: 22.12.2020
JEL codes: Q12, D24

Annals PAAAE • 2020 • Vol. XXII • No. (4)

DOI: 10.5604/01.3001.0014.6032

**MARIUSZ MACIEJCZAK, TADEUSZ FILIPIAK**

Warsaw University of Life Sciences – SGGW, Poland

# ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS OF THE POTATO AND ITS BENEFICIAL MICROORGANISM INTERACTIONS[1]

Key words: potatoes, sustainable production, plant – microbiome interaction, interaction effects, innovation effectiveness

ABSTRACT. The primary objective of this paper was to identify the economic, social and environmental impacts of plants and their beneficial microorganism interactions. As a plant example, the potato (*Solanum tuberosum*) has been chosen due to its worldwide nutritional and economic importance. Based on a systematic literature review, high importance effects were identified. From an economic point of view these were an increase in plant immunity and yield along with cost reductions and a reduction of abiotic and biotic stresses. From a social point of view, the importance of healthier food, a cleaner environment and resistant ecosystem were identified. From an environmental perspective, the effects of the increase of soil fertility and biodiversity as well as bioremediation opportunities were found to be important. The cross impact analysis of the identified effects indicate the primary importance of the economic effects, however their occurrence is determined by social effects, while the environmental ones are in a supporting position. It is argued, therefore, that the successful implementation of innovative products and technologies in potato production based on the plant – beneficial microorganism interactions will require economic empirical evidence and will be driven by social tension.

## INTRODUCTION

The current challenges of highly scaled needs of the growing human population require more food and renewable resources for industry purposes. The primary source is agriculture, which is being significantly intensified to fulfill increasing demands. As a consequence of such actions, there is also rising negative pressure on the basic production resources of agriculture coming from the natural environment, especially climate and soil

[1] This paper is based on the results of the project "potatoMETAbiome" – Harnessing potato-microbiome interactions for the development of sustainable breeding and production strategies. The financing of this project by ERA-NET Cofund on the Sustainable Crop Production programme through the Polish National Centre for Research and Development (NCBiR) is acknowledged.

[Bruinsma 2003]. Additionally, the gradual limitations of production capacities, due to degradation and pollution, also directly lead to unfavorable socio-economic conditions of development. As argued by Bazyli Czyżewski [2017], such trade mill requires significant changes and shifts from the industrialization of agriculture to its more sustainable development, which should be an important part of a wider change of the current socio-economic system.

Agricultural production, as a primary sector of the economy, cannot be treated in a mechanistic way anymore, in which industrial optimization is applied to natural processes [Maciejczak 2018]. Such an approach, in the last century, resulted in significant degradation not only of the environment, but also in the limitations on the strength of natural processes that underpin the functioning of agriculture. Therefore, under the paradigm of sustainable development, both researchers and practitioners are looking for new alternative solutions that will not only lead to the protection and enhancement of environmental resources aimed at agricultural production but also to the restitution of natural processes marginalized by intensification practices. Gabrielle Berg et al. [2020], stressed that these processes were developed by nature on the path of evolution and were intended to enable adaptation to new and emerging threats. As highlighted by Lynn Margulis and René Fester [1991], a great example of such a mechanism is symbiosis. Thanks to symbiosis, it is possible for weaker species to coexist. By cooperating, they are able to generate positive synergy effects and create a strong ecological unit (holobiont) that is able to survive and develop [Sánchez-Cañizares et al. 2017]. In countless cases in nature, symbiosis occurs between a plant or animal organism and useful microorganisms (i.e. bacterias, fungis, etc.). Both humans, animals and plants have a natural microbiome whose role has well been recognized in the past, although not fully researched. Today, beneficial microorganisms are being studied more and more extensively and thoroughly by many scientists, representing both basic and applied sciences and are being increasingly recognized by practitioners.

The literature on plant-microbiome interactions provide many examples, both theoretical and empirical, confirming the important scientific and practical role of beneficial microorganisms in agricultural production, particularly in plant production [Kocira et al. 2020]. In the vast majority of studies, the focus is laid, however, on identifying strains of individual microorganisms and how they interact with relevant crop varieties or even their genomes, in search of botanic or agronomic benefits. From a practical point of view, these benefits, in turn, further translate into economic, social and environmental benefits. However, the literature on the subject lacks consistent studies to confirm these benefits or mention the threats, especially from a sustainable point of view. In particular, economic and social effects are elements of causal analyses and are merely mentioned when discussing the results of environmental or agronomic research. Thus, there is a need to consistently look at these effects and identify the economic, social and environmental impacts of plants and their beneficial microorganism interactions in particular.

## OBJECTIVES AND METHODS

The primary objective of this paper is to identify the economic, social and environmental impacts of plants and their beneficial microorganism interactions. As a plant example, the potato (*Solanum tuberosum*) has been chosen due to its nutritional and economic importance. Rubí Raymundo et al. [2017], indicated that, after rice and wheat, the potato is the third most important food crop, with total global crop production exceeding 300 million metric tonnes.

Firstly, the literature review was performed in order to identify the effects of potato – microbiome interactions as an example of the agroecological model of agriculture. The systematic literature review method was applied as proposed by Yu Xiao and Maria Watson [2017]. Desk research covered scientific publications indexed in the Web of Science, Scopus and Google Scholar as well as Researchgate databases. The following main key-words were applied: plant, potato, microbiome, microorganisms and effects. After the first screening, based on titles and key words, more than 1200 papers were selected. The abstract evaluation allowed to select as many as 320 publications, out of which, after full text reviews, less than 100 were used for analysis. The inclusion criteria related to the potato and applied research. Secondly, the identified effects were analyzed by experts in order to show their cross – impacts. 5 experts, whom were chosen based on expertise, were chosen: 2 farmers growing the potato, 1 scientist specializing in agronomy, 1 scientist specializing in agricultural economics and 1 potato processor. They met on-line in November 2020 for focus group exercise. Based on its outcome, cross-impact analysis was performed using methodological guidelines of Alka Parashar et al. [1997]. Finally, primary data were collected using the direct survey approach, in order to identify general opinions of farmers applying preparations strengthening potato-microbiome interactions. The survey was conducted among Polish farmers using the CATI method based on randomized sampling in October-November 2020. As a result, 83 responses were obtained, of which 9 questionnaires were rejected due to incompleteness, thus 74 opinions were included in the analyzes. For this purpose, the MS Excel 2010 analysis package for descriptive statistics was used.

## RESULTS AND DISCUSSION

Agroecology is recognized as an alternative model of agriculture that applies systemic thinking and local adaptation. This model uses autonomous mechanisms of plant and animal resilience. It also includes the material cycle closure, production technologies, human ecology and the natural aspect [Maciejczak 2018]. Based on a systematic literature review, the effects of the potato and its beneficial microorganism interactions in different agronomic strategies were identified in economic, social and environmental perspectives (Table 1). Firstly, from an economic perspective, the following six effects were highlighted: an increase in plant immunity, an increase in yield, a decrease of production costs, a reduction of pathogens, drought resistance and limitation of weeds. Analysis of the impacts' strengths showed the high importance of the increase in plant immunity and yield. Secondly, the following three effects from the social perspective were shown: healthier

Table 1. Effects of the potato and its beneficial microorganism interactions in different agronomic strategies

| Perspective/Effects | Authors, year of publication | Strength of impact |
|---|---|---|
| Economic | | |
| Plant immunity increase | Wang et al. 2019<br>Berg et al. 2020<br>Bhanumati et al. 2019<br>Motaher et al. 2017 | +++ |
| Yield increase | Wang et al. 2019<br>Nyiraneza et al. 2015<br>Bernett et al. 2015<br>Hijri 2016<br>Jeanne et al. 2019<br>Kowalska 2016. | +++ |
| Production cost decrease | Dyrdahl-Young et al. 2020<br>Srinivasarao et al. 2017 | + |
| Reduction of pathogens | Farhana et al. 2018<br>Kepler et al. 2017<br>Finkel et al. 2017<br>Kannojia et al. 2017 | ++ |
| Drought resistance | Sindhu et al. 2017<br>Srinivasarao et al. 2017 | ++ |
| Limitation of weeds | Trognitz et al. 2015 | + |
| Social | | |
| Healthier food | Qiua et al. 2019<br>Obidiegwu et al. 2015<br>Barnett et al. 2015 | ++ |
| Cleaner environment | Morrissey et al. 2004<br>Berg et al. 2020 | +++ |
| Resistant ecosystem | Srinivasarao et al. 2017 | + |
| Environmental | | |
| Soil fertility increase | Ajar Nath et al. 2017<br>Motaher et al. 2017<br>Muzaffer and Eşitken 2017 | +++ |
| Biodiversity increase | Morrissey et al. 2004 | ++ |
| Soil bioremediation | Thomashow et al. 2019<br>Godheja et al. 2017 | + |

+++ quite important; ++ on average important; + less important

Source: own research based on a systematic literature review

food, a cleaner environment and a resistant ecosystem. From this perspective, a cleaner environment and healthier food were recognized as those with the highest importance. Finally, from an environmental perspective, an additional three effects were mentioned: a soil fertility increase, a biodiversity increase and soil bioremediation. From these effects, the soil fertility increase was identified as important.

The analyzed scientific achievements mostly reported the ways and conditions in which beneficial microorganisms cooperate with the cultivation plant as well as the results of such actions. The primary effect of the potato – microbiome interaction is the strengthening of the plant's immune system [Berg et al. 2020, Wang et al. 2019, Bhanumati et al. 2019]. Plants become more resistant and receive additional protection against biotic and abiotic stresses. As a result of such action, potatoes were able to grow and provide higher yield [Jeanne et al. 2019, Nyiraneza et al. 2015]. However, there is seldom empirical evidence on the real measurable yield increase [Bernett et al. 2015]. Jolanta Kowalska [2016] reports several-percent yield increases. Similarly, from an economic point of view there are vague reports about the production cost decrease [Dyrdahl-Young et al. 2020, Srinivasarao et al. 2017]. The literature review has confirmed that the potato – microbiome interactions can significantly impact the reduction of stress situations through a reduction of a biotic stress resulting from pathogens attacking the plant [Farhana et al. 2018, Kepler et al. 2017, Finkel et al. 2017] or an abiotic stress occurring with drought [Sindhu et al. 2017, Srinivasarao et al. 2017] or nutrient reduction due to competition with weeds [Trognitz et al. 2015].

From a social perspective, interactions between the potato and its microbiome led to the fulfillment of growing needs for healthier food [Qiua et al. 2019, Barnett et al. 2015, Obidiegwu et al. 2015] as well as a cleaner environment [Morrissey et al. 2004, Berg et al. 2020]. Although the literature also mentions the importance of the resistant ecosystem [Srinivasarao et al. 2017], consumer studies did not confirm that empirically.

The environmental perspective is addressed in a large body of research confirming the positive effects of the potato – microbiome interrelation on a soil fertility increase [Ajar Nath et al. 2017, Motaher et al. 2017, Muzaffer, Eşitken 2017] as well as an increase in biodiversity, especially soil communes [Morrissey et al. 2004]. Research also shows that such an interaction can be used for the purpose of soil bioremediation [Thomashow et al. 2019, Godheja et al. 2017].

The further performed cross impact analysis was aimed at measuring the relation between identified effects of potato-microbiome interactions. It was assumed to identify how the growth of one effect interacts with the growth of another, how strong the mutual influence is and how far it affects the outcome of others (Figure 1).

The analysis allowed to identify three groups of effects: determinants, supporting and of key importance. The effects of key importance that highly impact and accordingly are impacted by other effects are: the increase of plant immunity, the increase of soil fertility, the increase of yield and the decrease of production costs. The identified key-effects are primarily important from an economic point of view. Increased plant immunity and soil fertility results in the strengthening of plant condition, which increases its productivity – higher yields and also reduces production costs, mainly concerning fertilization. The effects that to a larger extent impact the other one, however, at the same time, are themselves not very susceptible to such an impact, are mostly socially oriented. These are effects

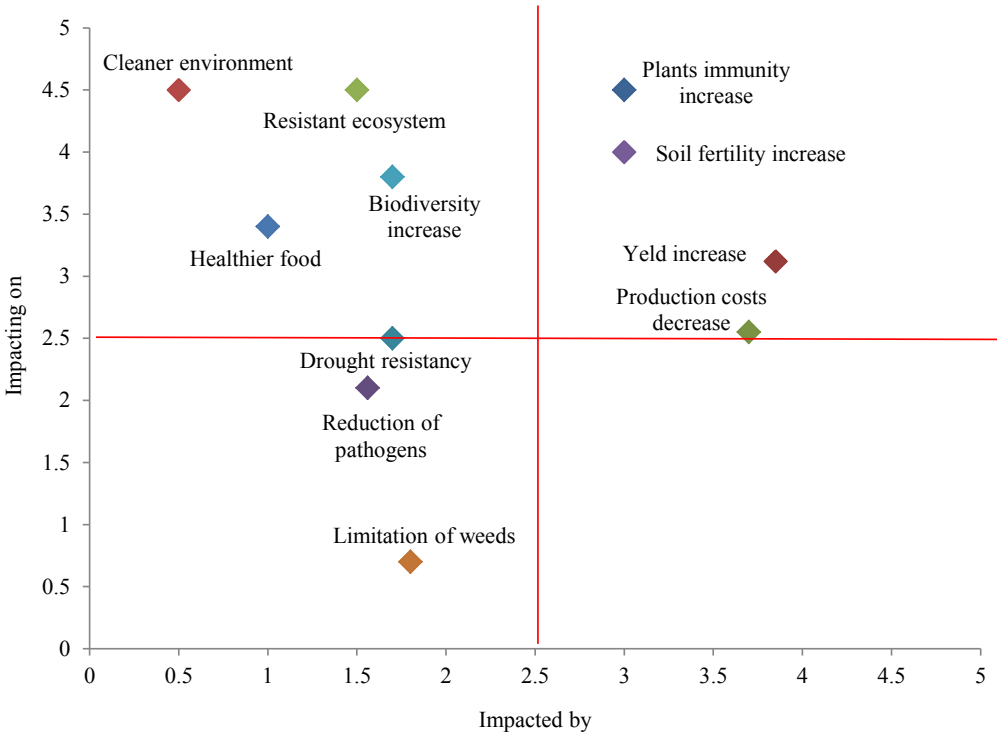


Figure 1. Cross-impact analysis of the effects of the potato and its beneficial microorganism interactions

Source: own research based on focus group results

appreciated by the society that determine the actions of farmers. To such determinants one could include: a cleaner environment, a resistant ecosystem and healthier food. To the supporting effects, that to a lesser degree are impacted and impact other ones, include those of environmental character that allow for the reduction of plant stresses, both abiotic (drought) and biotic (pathogens and weeds).

Summarizing the results of the cross-impact analyses, it can be concluded that the introduction of practices that increase the interactions of the potato and its microbiome is conditional on the achievement of measurable economic effects, which are directly related to factors of a social nature. Social effects are determining the need of such practices. Environmental effects, on the other hand, are side effects and support the achievement of necessary economic effects.

The results of the cross impact analysis are supported by the opinions of Polish farmers (Figure 2). The most important benefit, they reported from the use of biological preparations activating the potato microbiome, was the general improvement of plant conditions for better yielding. Out of 5 points, this effect was assessed, on average, to be 4.27. That can be recognized as high recognition of this agronomic practice. Accordingly, plant strengthening against unfavorable growth conditions, such as abiotic and biotic stresses,

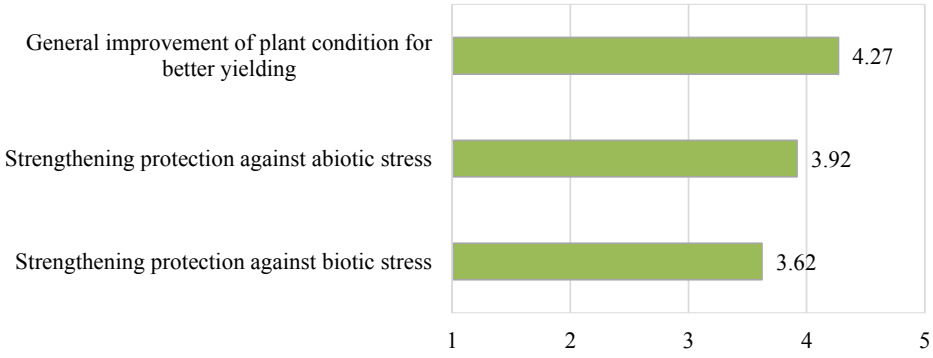


Figure 2. Obtained benefits from the use of biological preparations activating the potato microbiome in the opinion of Polish farmers (N = 74)
Source: own research based on the survey results

have been assessed, on average, to be 3.92 and 3.62, respectively. That also shows that, for farmers, the environmental results support the economic effects.

The obtained results show that the model of agroecological agriculture and its agronomic practices aimed to increase potato – microbiome interactions should be considered a technological innovation. The recommendation that resulted from this study indicates that, while undertaking measures aiming to implement such innovations to farms, one needs to remember about a sufficient level of information, firstly concerning possible economic effects. These effects are most important for farmers whose actions are determined by the opinions and tensions of society. This information, however, should be based on empirically obtained evidence. Therefore, there is a need for further socio-economic research on plant – microbiome interactions and their effects in order to raise the awareness of producers and consumers.

## CONCLUSIONS

The conducted research showed that, to conduct agricultural activity, there is a real alternative path which would lead to a more sustainable use of environmental resources. This is the agroecology model of agriculture. Although considered an innovation, this model's primary objective is to re-integrate the lost ties between human activities and natural processes. The idea is to utilize naturally occurring mechanisms to strengthen agricultural production and make it more sustainable, especially by reducing negative tension on the environment and through strengthening social and economic performance.

The analyzed mechanism of symbiosis between the cultivated plant - the potato and its naturally occurring beneficial microorganisms - proved to be successful interactions which can be used to address sustainability needs. On the basis of scientific interdisciplinary literature, a set of coherent effects of such interactions have been identified. Such effects occur in economic, social and environmental dimensions. Further analyses lead to the

conclusion about the cross impact of these effects, which is primarily oriented at the achievement of economic goals. However, to achieve them, socially oriented effects are utilized as driving forces and the role of environmental effects is of a supporting nature. Farmers, while deciding to implement the innovative agronomic method of strengthening the plant – microbiome interaction, look for tangible economic results. The researched potato growers from Poland have confirmed that they have achieved such results to a high degree.

Potato-microbiome interactions fulfill the requirements for sustainable agricultural production. For one, agronomic practices can also be used at the farm as a strategic approach to produce food in a more naturally-oriented way. Such production should be supported by policy options for agriculture and rural areas. Similar actions need to be taken to convince consumers about the benefits this kind of production has, not only for their health but also in a broader context. In order to convince policymakers and consumers, knowledge and information about this type of production should be spread to eliminate the asymmetry of information and build trust. Mutual trust and confidence in the advantages of this type of production will allow it to be spread, as was the case with organic production.

This study highlighted the importance of the utilization of plant – microbiome interactions as an innovative agricultural practice. In order to strengthen the diffusion of this innovation, further studies need to be conducted to eliminate the asymmetry of information between scientists studying natural processes and farmers waiting for tangible economic and market effects.

## BIBLIOGRAPHY

Ajar Nath Yadav, Verma Priyanka, Kour Divjot, Rana Kusam Lata, Kumar Vinod, Singh Bhanumati, Chauahan Vinay Singh, T.C.K. Sugitha, Saxena Anil Kumar, Dhaliwal Singh Harcharan. 2017. Plant microbiomes and its beneficial multifunctional, plant growth promoting attributes. *International Journal of Environmental Sciences & Natural Resources* 3 (1): 1-8. DOI: 10.19080/IJESNR.2017.03.555601.

Barnett Brittany A., David G. Holm, Jeffery W. Koym, Robert G. Wilson, Daniel K. Manter. 2015. Site and clone effects on the potato root-associated core microbiome and its relationship to tuber yield and nutrients. *American Journal of Potato Research* 92: 1-9. DOI 10.1007/s12230-014-9405-9.

Berg Gabrielle, Daria Rybakova, Doreen Fischer, Tomislav Cernava, Marie-Christine Vergès Champomier, et al. 2020. Microbiome definition re-visited: old concepts and new challenges. Microbiome 8: 103. DOI: 1186/s40168-020-00875-0.

Bhanumati Singh, Chauahan Vinay Singh, T.C.K. Sugitha, Kumar Saxena Anil, Singh Dhaliwal Harcharan. 2017. Plant microbiomes and its beneficial multifunctional, plant growth promoting attributes. *International Journal of Environmental Sciences & Natural Resources* 3 (1): 1-8. DOI: 10.19080/IJESNR.2017.03.555601.

Bruinsma Jelle. 2003. *Agriculture and the environment: changing pressures, solutions and trade-offs. world agriculture: towards 2015/2030: an FAO Study* (1st ed.). Earthscan. DOI: 10.4324/9781315083858.

Czyżewski Bazyli. 2017. Market treadmill in European agriculture. Warsaw: PWN.

Dyrdahl-Young Ruhiyyih, Emilie Cole, Marisol Quintanilla Tornel, Richard Weldon, Peter Di Gennaro. 2020. Economic assessment of nematode biological control agents in a potato production model. *Nematology* 1-9. DOI: 10.1163 / 15685411-00003339.

Farhana Syed Ab Rahmana Sharifah, Eugenie Singha, Corné M.J. Pieterseb, Peer M. Schenk. 2018. Emerging microbial biocontrol strategies for plant pathogens. *Plant Science* 267: 102-111.

Finkel Omri M., Gabriel Castrillo, Herrera Sur Paredes, Salas Isai Gonzalez, Jeffery L. Dangl. 2017. Understanding and exploiting plant beneficial microbes. *Current Opinion in Plant Biology* 38:155-163. DOI: 10.1016/j.pbi.2017.04.018.

Godheja Jai, Sudhir K. Shekhar. Dinesh R. Modi. 2017. Bacterial rhizoremediation of petroleum hydrocarbons (PHC). [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., 495-519. DOI: 10.1007/978-981-10-6593-4_20.

Hijri Mohamed. 2016. Analysis of a large dataset of mycorrhiza inoculation field trials on potato shows highly significant increases in yield. *Mycorrhiza* 26: 209-214. DOI 10.1007/s00572-015-0661-4.

Jeanne Thomas, Serge-E´tienne Parent, Richard Hogue. 2019. Using a soil bacterial species balance index to estimate potato crop productivity. *PLOS ONE* 14 (3): e0214089. DOI: 10.1371/journal.pone.0214089.

Kannojia Pooja, P.K. Sharma, Abhijeet K. Kashyap, Nazia Manzar, Udai B. Singh, Kamal Chaudhary, Deepti Malviya, Shailendra Singh, Sushil K. Sharma. 2017. Microbe-Mediated Biotic Stress Management in Plants. [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., 627-648. DOI: 10.1007/978-981-10-6593-4_26.

Kepler Ryan M., Jude E. Maul, Stephen A. Rehner. 2017. Managing the plant microbiome for biocontrol fungi: examples from Hypocreales. *Current Opinion in Microbiology* 37: 48-53. DOI: org/10.1016/j.mib.2017.03.006.

Kocira Sławomir, Agnieszka Szparaga, Patryk Hara, Krzysztof Treder, Pavol Findura, Petr Bartoš, Martin Filip. 2020. Biochemical and economical effect of application biostimulants containing seaweed extracts and amino acids as an element of agroecological management of bean cultivation. *Scientific Reports* 10: 17759. DOI: 10.1038/s41598-020-74959-0.

Kowalska Jolanta. 2016. Wpływ nawożenia oraz biostymulatorów mikrobilogicznych na zdrowotność i plonowanie ziemniaka w systemie ekologicznym (Effect of fertilization and microbiological bio-stimulators on healthiness and yield of organic potato). *Progress in Plant Protection* 56: 230-235. DOI: 10.14199/ppp-2016-039.

Maciejczak Mariusz 2018. Non-industrial sustainable intensification of agriculture. [In] *From the research on socially-sustainable agriculture (48). Multi-Annual Programme 2015-2019*, eds. Mariola Kwasek, Józef Zegar, 29-53. Warsaw: Institute of Agricultural and Food Economics National Research Institute.

Margulis Lynn, René Fester. 1991. *Symbiosis as a source of evolutionary innovation*. *Speciation and morphogenesis*. Cambridge, US: MIT Press.

Morrissey John P., J. Maxwell Dow, G. Louise Mark, Fergal O'Gara. 2004. Are microbes at the root of a solution to world food production? *EMBO Reports* 5 (10): 922-926. DOI: 10.1038/sj.embor.7400263.

Motaher Hossain M., Farjana Sultana, Shaikhul Islam. 2017. Plant Growth-Promoting Fungi (PGPF): phytostimulation and induced systemic resistance. [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., 135-181. DOI: 10.1007/978-981-10-6593-4_6.

Muzaffer İpek, Ahmet Eşitken. 2017. The actions of PGPR on micronutrient availability in soil and plant under calcareous soil conditions: an evaluation over fe nutrition. [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., 81-100. DOI: 10.1007/978-981-10-6593-4_4.

Nyiraneza Judith, Peters D. Rick, Rodd A. Vernon, Grimmett Mark G., Jiang Yefang. 2015. Improving productivity of managed potato cropping systems in Eastern Canada: crop rotation and nitrogen source effects. *Agronomy Journal* 107 (4): 1447-1457. DOI: 10.2134/agronj14.0430.

Obidiegwu Jude E., Glenn J. Bryan, Hamlyn G. Jones, Ankush Prashar. 2015. Coping with drought: stress and adaptive responses in potato and perspectives for improvement. *Frontiers in Plant Sciences* 6: 542. DOI: 10.3389/fpls.2015.00542.

Parashar Alka, Rakesh Paliwal, P. Rambabu. 1997. Utility of fuzzy cross-impact simulation in environmental assessment. *Environmental Impact Assessment Review* 17 (6): 427-447. DOI: 10.1016/S0195-9255(97)00046-2.

Qiua Zhiguang, Eleonora Egidia, Hongwei Liua, Simranjit Kaur, Brajesh K. Singh. 2019. New frontiers in agriculture productivity: Optimised microbial inoculants and in situ microbiome engineering. *Biotechnology Advances* 37 (6): 107371. DOI: 10.1016/j.biotechadv.2019.03.010.

Raymundo Rubí, Senthold Asseng, Richard Robertson, Athanasios Petsakos, Gerrit Hoogenboom, Roberto Quiroz, Guy Hareau, Joost Wolf. 2018. Climate change impact on global potato production. *European Journal of Agronomy* 100: 87-98. DOI: 10.1016/j.eja.2017.11.008.

Sánchez-Cañizares Carmen, Beatriz Jorrín, Philip Poole, Andrzej Tkacz. 2017. Understanding the holobiont: the interdependence of plants and their microbiome. Current Opinion in Microbiology, 38: 188-196. DOI: 10.1016/j.mib.2017.07.001.

Sindhu Satyavir S., Anju Sehrawat, Ruchi Sharma, Anupma Dahiya, Aakanksha Khandelwal. 2017. Below ground microbial crosstalk and rhizosphere biology. [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., 695-752. DOI: 10.1007/978-981-10-6593-4_29.

Srinivasarao Ch., M. Manjunath. 2017. Potential of beneficial bacteria as ecofriendly options for chemical-free alternative agriculture. [In] *Plant-microbe interactions in agro-ecological perspectives*, eds. D.P. Singh et al., . DOI: 10.1007/978-981-10-6593-4_19.

Thomashow Linda S., Melissa K. LeTourneau, Youn-Sig Kwak, David M. Weller. 2019. The soil-borne legacy in the age of the holobiont. *Microbial Biotechnology* 12: 51-54. DOI: 10.1111/1751-7915.13325.

Trognitz Friederike, Evelyn Hackl, Siegrid Widhalm, Angela Sessitsch. 2016. The role of plant –microbiome interactions in weed establishment and control. *FEMS Microbiology Ecology* 92: 138. DOI: 10.1093/femsec/fiw138.

Wang Zhenshuo, Yan Li, Lubo Zhuang, Yue Yu, Jia Liu, Lixia Zhang, Zhenjiang Gao, Yufeng Wu, Wa Gao, Guo-Chun Ding, Qi Wang. 2019. a rhizosphere-derived consortium of *Bacillus subtilis* and *Trichoderma harzianum* suppresses common scab of potato and increases yield. *Computational and Structural Biotechnology Journal* 17: 645-653. DOI: 10.1016/j.csbj.2019.05.003.

Xiao Yu, Maria Watson. 2017. Guidance on conducting a systematic literature review. *Journal of Planning Education and Research* 39 (1): 93-112. DOI: 10.1177/0739456X17723971.

***

# EKONOMICZNE, SPOŁECZNE I ŚRODOWISKOWE EFEKTY INTERAKCJI ZIEMNIAKA Z JEGO POŻYTECZNYMI MIKROORGANIZMAMI

Słowa kluczowe: ziemniaki, zrównoważona produkcja, interakcja roślina – mikrobiom, efekty interakcji, skuteczność innowacji

ABSTRAKT

Głównym celem artykułu jest identyfikacja ekonomicznych, społecznych i środowiskowych efektów interakcji pomiędzy roślinami uprawnymi i ich pożytecznymi mikroorganizmami. Analizy przeprowadzono na przykładzie ziemniaka ze względu na jego odżywcze i ekonomiczne znaczenie na świecie. Na podstawie systematycznego przeglądu literatury zidentyfikowano efekty interakcji o dużym znaczeniu. Z ekonomicznego punktu widzenia były to wzrost odporności oraz plonów roślin wraz z redukcją kosztów i zmniejszeniem stresu abiotycznego i biotycznego. Z społecznego punktu widzenia wskazano na znaczenie produkcji zdrowszej żywności oraz efekty czystszego środowiska i odpornego ekosystemu. W perspektywie środowiskowej uznano za istotne skutki wzrostu żyzności i różnorodności biologicznej gleb oraz możliwości bioremediacji. Analiza wzajemnych oddziaływań zidentyfikowanych efektów wskazała na pierwszorzędne znaczenie czynników ekonomicznych, jednak ich występowanie jest uzależnione od występowania efektów społecznych. Efekty środowiskowe jedynie wspierają te procesy. Stwierdzono, że skuteczne wdrożenie innowacyjnych produktów i technologii w produkcji ziemniaka opartych na interakcji rośliny i jej pożytecznych mikroorganizmów wymaga wykazania na potrzeby rolników empirycznych efektów ekonomicznych, a będzie warunkowane w znacznym stopniu potrzebami społecznymi.

AUTHORS

MARIUSZ MACIEJCZAK, DR HAB. PROF. WULS
ORCID: 0000-0002-0630-5628
Warsaw University of Life Sciences – SGGW
Faculty of Economic Sciences
Institute of Economics and Finance
166 Nowoursynowska St., 02-787 Warsaw, Poland

TADEUSZ FILIPIAK, PHD
ORCID: 0000-0002-9397-7595
Warsaw University of Life Sciences – SGGW
Faculty of Economic Sciences
Institute of Economics and Finance
166 Nowoursynowska St., 02-787 Warsaw, Poland