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THE ROLE OF BIOLOGICAL KNOWLEDGE IN THE DEVELOPMENT OF SUSTAINABLE BIOECONOMY – CASE OF POTATO AND ITS BENEFICIAL MICROORGANISMS INTERACTIONS[1]

Key words: sustainable bioeconomy, knowledge as production factor, plant – microbiome interaction, potato, innovation diffusion

ABSTRACT. The primary objective of this paper was threefold. Firstly, the importance and impact of knowledge factors in the economy were reviewed. Secondly, the role of innovations in biological sciences was identified and the role of biological knowledge in the development of bioeconomy was assessed. Finally, the case of potato (*Solanum tuberosum*) and its beneficial microorganisms interactions, as an example of the knowledge-based innovations in agricultural production in Poland, was presented. Based on the systematic literature review high importance of knowledge factor, considered as the main resource, in the development of economic systems was identified. It is argued that knowledge is a specific resource, not subject to the same laws as the other production factors (land, labor, and capital). Unlike other resources, which are exhausted when used, knowledge can be shared and thrive through its use. From the inception of the bioeconomy concept the knowledge, a part of technology, and renewable biological resources was considered as primary driver. As bioeconomy is assuming the development of an economic system that is sustainable and climate-neutral, especially biological knowledge is crucial in its growth. The diffusion of biological knowledge-based innovations in agricultural production can be achieved by using beneficial microorganisms and their interactions with arable crops. Their interactions with potatoes show positive effects and the diffusion of such innovations in Poland is mostly conditioned by the experiences of farmers, which should be strengthened through network facilitation.

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

INTRODUCTION

The reliance on knowledge, information, and highly-skilled labor is a principle of the knowledge-based economy [Baum et al. 2009]. Kwee Keong Choong and Patrick W. Leung [2021] argue that there is needed a new theoretical and practical perspective of applying technological advances that consume the human understanding of the nature of physical or biological processes to accelerate the explosion of novel product or process solutions that will become drives of the sustainable growth.

Knowledge, in economic terms, is primarily treated in two ways – it is considered as information and as assets [OECD 2005]. In the first approach, knowledge is treated as information that can be processed and used to make rational economic decisions [Sadowska 2019]. In the second approach, it is an economic good that can be privately owned and can be traded on the market as a commodity [Hadad 2017]. Therefore the economists treat knowledge as a resource that is needed to generate profit. According to this view, each enterprise operates on the basis of its knowledge – "the company as a storehouse of knowledge" [Moser, Moyer 1993]. The mainstream economic theories assume that people make economic decisions as if they knew all the facts that could actually influence those decisions (mechanistic approach, absolute certainty) [Szarzec 2002]. On contrary the heterodox schools claim that the knowledge of individuals about economic phenomena cannot be combined into one compact set, it is impossible to aggregate it. Knowledge does not appear in concentrated form, but as crumbs of incomplete and often contradictory information [Becker 1976, Solek 2014].

Therefore, as stated by Stan J. Metcalfe and Ronnie Ramlogan [2005] due to great heterogeneity and the unlimited connections of information flow the development of knowledge-based economy has certain boundaries, which understating shows knowledge driven-systems that is open-ended and has an evolutionary nature of towards complex adaptivity.

OBJECTIVES AND METHODS

The primary objective of this paper was threefold. Firstly, the importance and impact of knowledge factors in the economy were reviewed. Secondly, the role of innovations in biological sciences was identified and the role of biological knowledge in the development of bioeconomy was assessed. Finally, the case of potato (*Solanum tuberosum*) and its beneficial microorganisms interactions, as an example of the biological knowledge-based innovations in agricultural production in Poland, was presented. As a the example the potato (*Solanum tuberosum*) has been chosen due to its nutritional and economic importance.

Rubí Raymundo et al. [2018] indicated that after rice and wheat the potato is the third most important food crop, with the global total crop production exceeded 300 million tons.

The literature review was performed in order to identify the effects of potato – microbiome interactions as the example of the agroecological model of agriculture. There was applied the systematic literature review method as proposed by Yu Xiao and Maria Watson [2017]. The desk research covered scientific publications indexed in the Web of Science, Scopus and Google Scholar and Researchgate databases. There were applied main key-words: potato, microbiome, microorganisms, results, effects, economics. After the first screening based on the titles and key words more than 480 papers were selected. The abstract evaluation allowed to select as much as 140 publications, out of which, after full text reviews, less than 50 were used for analysis. The inclusion criteria were related to potato and the type of research that was applied based. The exclusion criteria were related to the empirical nature of the research conducted and convergence with the subject of the article. Additionally, the primary data were collected using direct survey approach, in order to identify general opinion 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

IMPORTANCE OF KNOWLEDGE

As Peter Drucker argued [1999] the basic economic resources understood as the factors of production are no longer capital, nor land, nor labor, this is the knowledge. He stressed that unlike most resources which are depleted when used, knowledge can be shared and actually thrive through its use. Also Mariusz Strojny [2000] showed that knowledge is a specific resource not subject to the same laws as the other production factors. It is characterized by the following features: domination, inexhaustibility, simultaneity, non-linearity.

Following the heterodox approach, as highlighted by the Austrian economic school [see Kacperski 2009] the starting point for subjectivist considerations about human action and knowledge is the perception that a person is making efforts to achieve a designated goal, to which assigns a certain weight. This weight depends on the psychological feelings and decisions of a given person at a given moment – and it may change at any time, depending from the circumstances. Because man cannot achieve all goals at once in unison with the value assigned to them, he arranges them on a hierarchical, subjective scale that allows to

decide on the legitimacy and sequence of taking individual actions. To achieve each goal, appropriate measures are necessary. Therefore there are attributed to these means different utilities, depending on the assessment of their usefulness in achieving the desired result and on the value he has attached to that result. Therefore, in this context, the subjective value determines the subjective utility of the measure.

As claimed by the Jesus Huerta de Soto [2014] in an evolutionary process involving countless people throughout history – each of whom has unique, subjective knowledge, experience feelings and goals. Thus certain patterns of behavior are slowly emerging that make it easier for people to live in a given society. They appear by duplicating the best – that is, those that allow for the most effective achievement in a given society certain goals – behaviors practiced by the most creative individuals at a given time. So these patterns do not arise in one moment, devised by some genius – but in a long-term, spontaneous and unconscious verification process of competitors behavior by trial and error. Thanks to this process, they gradually consolidate and spread those behaviors that best coordinate mismatches in society. As they are reproduced by the people who were encouraged by the successful pioneers of these behaviors. In this way, it is implied in each stage of the formation of these institutions a significant portion of the unique knowledge of people who have successfully applied new (or only modified) patterns [Lenihan et al. 2019].

With regard to agricultural sector one can observe that there is taking place a shift from resource-intensive and labor-intensive economy to knowledge-based economy and further to network economy [Maciejczak 2018]. With this sense it is important to stress out that knowledge, embodied in people (as "human capital") and technology, has always been critical to economic development [Takácsné-György, Takács 2022]. Knowledge-based economies use knowledge as a production factor to produce knowledge-based products and services. The concept of the knowledge-based economy is related to the theory of endogenous growth – certain production factors determine growth as a result of the processes of accumulation of, for example, knowledge capital [Ben-David, Loewy 2000].

BIOLOGICAL KNOWLEDGE BASED BIOECONOMY

Knowledge-based economy constitutes the basis of development, not only of developed economies but also of the economic development in general, also in less developed countries, which is heading towards greater dependence on knowledge. This indicates the growing importance of not only the practical application of knowledge and skills acquired through it, but also the growing need for easy access to them. As stated by OECD [2005] "the knowledge based economy is based directly on creation, treated as production, and further transfer, i.e. distribution and practical use of knowledge and information". The greatest example of biological knowledge based sector is bioeconomy. Bioeconomy can

be referred as the part of the economy that uses biological knowledge for commercial and industrial purposes and to improve human well-being [Enriquez, Martinez 2002]. Within the concept the special role is played with the knowledge related to the plants' microbiome.

As bioeconomy is assuming the development of an economic system that is sustainable and climate-neutral, especially biological knowledge is crucial in its growth. The diffusion of biological knowledge-based innovations in agricultural production can be achieved by using beneficial microorganisms and their interactions with arable crops. The literature on plant-microbiome interactions provide many examples, both theoretical and empirical, confirming the scientifically and practically important 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.

The importance of biological knowledge and innovations based on it in agriculture can be also seen in the practical implementations i.e. in strategic policy papers. One of the examples is the National Bioeconomy Strategy for Germany [BMEL 2020]. In this strategic document there is highlighted the importance of the biological knowledge that should be used in synergy with the advanced technology in use of biological resources to create the sustainable and climate-neutral economy. Special attention is paid on the biological processes in the ecosystem contexts that could deliver novel production models. The importance of microorganisms in the agricultural plant and animal production and further in food and non-food processing has been noted. The scenario-based analysis conducted by Sören Richter et al. [2022] showed that microorganisms utilization in novel products or processes could create significant production capacities. Accordingly Christopher Voigt [2020] reviewing already existing on the market products being developed based on synthetic biology confirmed the importance and market potential of microorganisms applications, not only in agriculture sector.

Based on the interviews among 74 farmers being potato producers in Poland there were identified sources of knowledge of these farmers about the biological preparations used in potatoes cultivation (Figure 1). The most important source was Internet. It was mentioned by 71,6% of respondents. The second important source was professional press, mentioned by 20,4%. On further places there were mentioned advisers from extension services – 4,1% as well as other farmers – 2,1% and traders 1,4%. The results show that the codified knowledge from media is most often used by farmers. They use it due to its ease of access and universality. Hence the important role of education through the media and the dissemination of good practices and knowledge in this way.

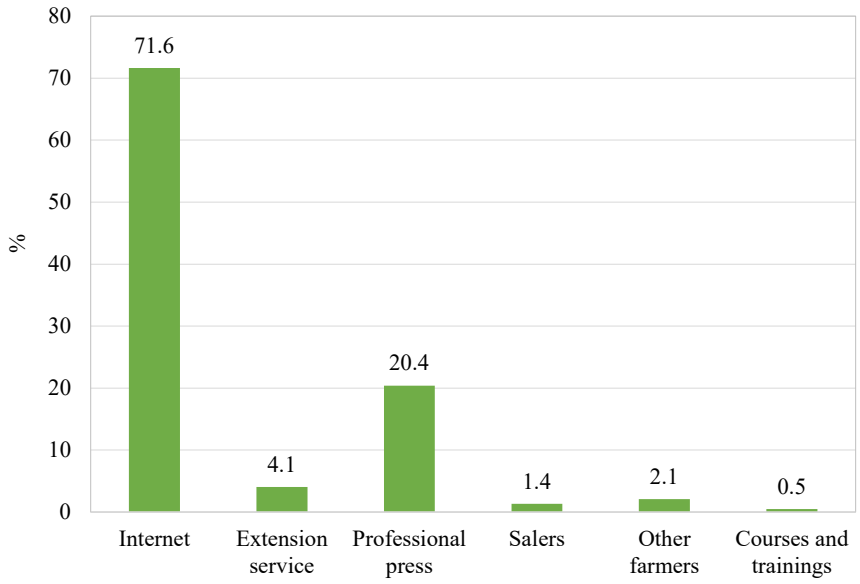

Figure 1. Sources of knowledge of farmers about the biological preparations used in potatoes cultivation

Source: own research

To determine what factors influence the use of knowledge in order to cultivate potatoes in a sustainable way, a linear regression analysis was performed. The source of knowledge about biological cultivation was assumed as the independent variable, while the dependent variables were socio-economic factors characterizing the farmer. The influence of knowledge factors on decisions about growing potatoes in a sustainable way is presented on Table 1.

One can learn from the analysis of the results of the regression that with ca. 60% of the model predictability that most important predictor of the application of biological knowledge in potato cultivation is the knowledge of the farmer resulted from his so-far experience on the farm (49%). The advancement of the experience comes naturally from the age of the farmer. This factor's importance has been assessed on 42%. Several authors, including Sandra Šumane et al. [2018] and Natasha Pauli et al. [2016] also pay an attention on the primary role of the experience-based knowledge in the development of the farms. Surprisingly the formal education of the farmer is not as much important. That is in line in the research of i.a. René Díaz-Pichardo et al. [2012], whom however emphasize the role of entrepreneurial and organizational competency in farmers. This can refer to the fact that general level of education allows to constantly search for new

Table 1. The influence of knowledge factors on decisions about growing potatoes in a sustainable way

Factors	Coefficients	Standard deviations	t Stat	p-value	Lower 95%	Upper 95%
Incept	0.87	0.85	1.03	0.31	-0.82	2.56
Age	0.42	0.19	2.35	0.02	0.07	0.81
Education	0.14	0.23	0.18	0.66	-0.42	0.50
Yers of work in agriculture	0.49	0.11	0.54	0.59	-0.17	0.29
Other farmers	0.24	0.21	2.06	0.04	0.01	0.86
Regression statistics						
Multiple R	0.67					
R square	0.59					
Adjusted R	0.47					
St. Dev.	0.50					
Observations	74					

Source: own research

knowledge that further is expressed in entrepreneurial competencies. As it was indicated in Figure 1, the knowledge is freely and easy available on constant basis. Not surprisingly farmers exchange the knowledge, thus this one acquired form other farmers plays also some importance, which was assessed on 24%.

Recent literature, however, has emphasized the role and importance of new forms of knowledge. The research on alternative approaches has focused on the role of networks as innovation systems formed by interactions between heterogeneous actors [Wood et al. 2014]. There are several types of networks that could be used to strengthen the knowledge exchange. In the presented study there is highlighted the raw information exchange among the farmers that use biological preparations in potato cultivation. Nonetheless, Sue Oreszczyn et al. [2010] suggest that farmers engage of networks that from the organizational point of view are weak, but accordingly are string from the relatively stable network of other communities or networks of practice they interact with. In this respect one needs to agree with Marcus Taylor and Suhas Bhasme [2018] about the role of networking of farmers activities and knowledge acquisition both horizontally to community members and vertically through linkages with extension agents, research institutions and private sector interests to strengthen the effectiveness of agricultural knowledge transfer.

CONCLUSIONS

The conducted research showed that the knowledge is a key factor in the development of the bioeconomy. Knowledge plays a significant role in the implementation of sustainable potato production strategies in the researched farms. The potato-microbiome interactions fulfills the requirements for biological knowledge-based bioeconomy. As a one of production agronomic practice can be also used at the farm as an strategic approach to produce food in more naturally oriented way. Such production should be supported by the policy options for agriculture and rural areas. Similar actions need to be taken to ensure the life-long learning of farmers, which predominantly should include the use of specialized media, such as Internet. In order to convince the policymakers and the farmers about the importance of biological knowledge-based agricultural strategies the knowledge and information about this type of production should be spread that will eliminate the asymmetry of information and build the trust. This can be done by strengthening of the networks of agricultural knowledge exchange between farmers.

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ROLA WIEDZY BIOLOGICZNEJ W ROZWOJU ZRÓWNOWAŻONEJ BIOGOSPODARKI NA PRZYKŁADZIE ZIEMNIAKA I JEGO INTERAKCJI Z POŻYTECZNYMI MIKROORGANIZMAMI

Słowa kluczowe: zrównoważona biogospodarka, wiedza jako czynnik produkcji, interakcja roślina – mikrobiom, ziemniak, dyfuzja innowacji

ABSTRAKT

Głównym celem artykułu jest przedstawienie i ocena roli wiedzy biologicznej w rozwoju zrównoważonej biogospodarki. Dokonano przeglądu znaczenia, roli i oddziaływań czynnika wiedzy w gospodarce. Zidentyfikowano innowacje powstałe przy wykorzystaniu nauk biologicznych i dzięki temu dokonano oceny roli wiedzy biologicznej w rozwoju biogospodarki. Na przykładzie ziemniaka (*Solanum tuberosum*) i jego korzystnych oddziaływań z pożytecznymi mikroorganizmami przedstawiono znaczenie innowacji opartych na wiedzy biologicznej w produkcji rolniczej w Polsce. Na podstawie przeglądu literatury stwierdzono, że czynnik wiedzy, który należy uznać jako jeden z głównych czynników wytwórczych, ma duże znaczenie w rozwoju systemów ekonomicznych. Stwierdzono, że wiedza jest specyficznym zasobem, niepodlegającym tym samym prawom, co inne czynniki produkcji (ziemia, praca i kapitał). W przeciwieństwie do innych zasobów, które wyczerpują się, gdy są używane, wiedza może być dzielona i rozwijać się dzięki jej użyciu. Podkreślono, że od początku rozwoju koncepcji biogospodarki za jej główną siłę napędową, poza technologią i odnawialnymi zasobami biologicznymi, uważano właśnie wiedzę. Ponieważ biogospodarka zakłada rozwój systemu gospodarczego, który jest zrównoważony i neutralny dla klimatu, szczególnie wiedza biologiczna ma kluczowe znaczenie dla jego rozwoju. Rozpowszechnienie w produkcji rolniczej innowacji opartych na wiedzy biologicznej, można osiągnąć dzięki wykorzystaniu pożytecznych mikroorganizmów i ich interakcji z roślinami uprawnymi. Ich interakcje z ziemniakami wykazują pozytywne efekty, a dyfuzja takich innowacji w Polsce uwarunkowana jest przede wszystkim doświadczeniami rolników, które należy wzmacniać przez wzmocnienie działań sieciowych.

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