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THE ECONOMIC EFFECTS OF APPLYING BENEFICIAL MICROORGANISMS IN VITICULTURAL PRODUCTION UNDER CLIMATE CHANGE CONDITIONS[1]

Key words: climate change, economic effects, beneficial microorganisms, viticultural production

ABSTRACT. The paper aimed to present the economic effects of applying beneficial microorganisms in viticultural production under climate change conditions. It was found that increasing climate change effects calls for a broad range of adaptation and mitigation strategies in agriculture, especially in viticultural production. One of them might be the innovative use of microorganisms that have the ability to interact with plants, and thus contribute to the prevention of stresses as well as respond to them, both abiotic – like drought and biotic – like pests. Based on the direct survey carried out in 2018 among experienced winegrowers from Germany, Italy and Poland, it was observed that there was a direct economic effect of the inoculation of beneficial microorganisms to the cultivation of resistant grape varieties. The majority of farmers think that such innovation in vineyards could reduce both the costs of protection and cultivation as well as increase direct benefits. Empirical evidence from the case study performed in 2018 in the Italian sustainable farm showed that such innovation, despite increasing the costs of irrigation and organic fertilization, also led to a significant reduction of artificial fertilizer and pesticide use, the costs of which predominated.

INTRODUCTION

Due to climate change effects increased incidences of abiotic and biotic stresses affecting productivity in principal crops all over the world are observed. The process is a continued trend with increasing strength, which in turn gives rise to the questions concerning its impact on the productivity of agricultural crops and human food security [Lobell, Gourdji 2012]. Thus, several authors [i.e. Lescot et al. 2014, Nelson et al. 2014, Grover et al. 2010] emphasized that a broad range of adaptations and mitigation strategies are required to cope with such impacts. However, there is a need to invent simple and low cost methods for the management of biotic and abiotic stresses, which can be used in

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various production systems both on a regional and global scale. More importantly, there is a need to provide a solution that will respond to the challenge of reducing short-term direct negative effects and limit or avoid negative externalities. So far, industrial intensification methods of using synthetic fertilisers and pesticides are no longer considered to be the only solution [Maciejczak, 2018].

A promising and realistic solution was recently highlighted in Nature Magazine by a group of scientists lead by Ricardo Cavicchioli. They stressed that Nature itself has developed mechanisms to combat extreme phenomena, counteracting them with equally significant forces. Such forces are invisible but very effective microorganisms. According to these authors, "microorganisms date back to the origin of life on Earth at least 3.8 billion years ago, and will likely exist well beyond any future extinction events" [Cavicchioli et al. 2019]. Microorganisms play a significant role primarily in carbon and nutrient cycles, thus in regulating climate change effects, too. Additionally, they are indispensable in animal (including human) and plant health. They can also be useful in responding to plant stresses, if we can exploit their extraordinary attributes. These attributes are related to omnipresence, high tolerance to extremities, genetic diversity as well as their superior interaction with crop plants [Grover et al. 2011].

Grapevine is one of the most profitable crops yielding berries, wine products and derivatives. Currently, regions where viticulture is present are located in selected geographical areas worldwide. As mentioned by Mariusz Maciejczak and Jakub Mikiciuk [2019] some of these zones, due to climate change, will not be appropriate for such production, and instead new ones will become appropriate. José Mirás-Avalos and Diego Intrigliolo [2017] argue that regardless of the location, production is and increasingly will be affected by abiotic stresses such drought, frost or hail. Grapevines are and will be more and more frequently and strongly exposed to various biotic stresses resulting from infections by fungi, bacteria, viruses, phytoplasma and insects [Laimer et al. 2009]. The occurrence of abiotic and biotic stresses already generate significant economic losses in viticulture around the world. As reported by Marc Fuchs [2006], in France, fanleaf disease causes 1.5 billion US dollars of annual losses to the grapevine industry despite implementing prophylactic activities and certification systems. In 2005 the disease affected 540,000 ha (approximately 60% of the total grapevine area in France), with damaging effects in many vineyards. Moreover, according to Giovani Martelli [2003], the grapevine is one of the crops most often infected by viruses with at least 55 species belonging to 20 different genera. On other hand, it needs to be noted that conventional grapevine production is one of the most pesticide consuming agricultural systems [Provost, Pedneault 2016]. For instance, viticulture in France occupies approximately 3% of the total area devoted to agriculture and consumes nearly 20% of total pesticides [Delière et al. 2014]. The intensive application of pesticides generates the buildup of pest resistance and has a negative impact on other organisms including fauna, plants as well as microbiota [Hildebrandt et al. 2008, Komárek et al. 2010].

Therefore, the reduction of pesticides in grape production and the higher deployment of beneficial microorganisms to control pathogen diseases has become highly valuable [Gilbert et al. 2014]. In this context, success in organic and sustainable viticulture is largely connected with implementing a production system that reduces the incidence of disease and consequently minimizes the use of pesticides, for instance copper-based fungicides, without compromising crop productivity [Sivcev et al. 2010].

The above shows that the vineyard should be considered as a complex adaptive system where every resource is optimized to keep a biodiversity contributing to minimizing the influence of biotic and abiotic stresses. Such grape production systems differ from conventional crop production and may also have an impact on the quality of grapes and quality of wine. However, there is limited research reporting the economic impact of the implementation of beneficial microorganisms on viticultural production.

RESEARCH MATERIALS AND METHODS

The aim of the research was threefold. Firstly, based on the literature, it aims to review evidence concerning the economic impact of the implementation of beneficial microorganisms on vineyard production. Secondly, based on interviews with winegrowers, the research aims to make an attempt to assess the potential impact of the implementation of beneficial microorganisms on vineyard production effects. Finally, using the case study method, the impact of vineyard management and grape production is presented.

For the purposes of this research, growers were asked to determine the potential impact of microorganisms on grapevine cultivation. The research, conducted in the 4th quarter of 2018, was directed to wine producers with broad knowledge and experience in grapevine cultivation. Respondents were randomly selected to represent various wine producers from different regions of Europe. Two main methods of data collection were used: CATI (the computer assisted telephone interview) and CAWI (the computer assisted Web interview). Wine producers were asked to estimate the impact of beneficial microorganisms on resistant varieties of grapes in order to strengthen the natural resistance of plants against diseases, pests or unfavorable climate conditions. The research, based on a short questionnaire (closed questions with the additional opportunity to provide an opinion), was fully anonymous. Below, the presented data were collected from Germany (18 answers), Italy (15 answers) and Poland (14 answers). Among 47 interviewed farmers, the majority (35 farmers, i.e. 74%) were males and 26% (12 farmers) were females. The average age of men was 47 and women 42. Most respondents (85%, i.e. 40 farmers) have a higher education and have been growing grapes for more than 10 years (68%, i.e. 32 farmers).

The case study was based on a direct interview with managers of a vineyard that for over 15 years has been managed with sustainable methods of production aimed at increasing natural mechanisms of resistence to biotic and abiotic stresses. For over 3 years, in this farm, there are practices used to increase the role of beneficial microorganisms for plant protection. The resistant varieties were inoculated with beneficial microorganisms. The farm is located in the Italian region of Veneto, in the province of Treviso. Research was conducted in the 4th quarter of 2018.

RESEARCH RESULTS

The application of microbial ecology in agriculture presents an opportunity to revolutionize grapevine cultivation by microorganisms that can improve soil quality and hence, crop productivity. Bacteria and fungi exist in complex connections with plants and have crucial roles in shaping the quality and composition of the soil as well as promoting the productivity and health of the plant itself [Gilbert et al. 2014]. The plant microbiome has direct and indirect relationships with the grapevine to prevent the activity of pathogens through the competition for space, the production of hydrolytic enzymes, nutrients, antibiosis, the inhibition of pathogen produced enzymes or toxins, as well as through the systemic induction of plant defense mechanisms. A large group of plant associated microbes live in the soil surrounding the roots or inside the roots themselves. However, microorganisms colonizing the root can migrate through the plant to aerial tissues, internally and/or externally [Mastretta et al. 2006, Compant et al. 2011]. Numerous microbes have multiple metabolic activities that strengthen plant health by stimulating growth or suppressing pathogens causing disease [Berg 2009]. The microorganisms associated with grapes, not isolated from the rest of the grapevine niche and roots, may be the primary source of colonization and transmission of microbes through the grapevine. Moreover, it may be essential to obtain favorable organoleptic wine characteristics that are sought after [Barata et al. 2012].

Differences in soil microbiological composition could also result in different responses in the plant itself by triggering the expression of diverse compounds or activating defense mechanisms that could potentially modulate the activity and quantity of other microorganisms associated with the plant [Berg 2009, Gilbert et al. 2014]. Carsten Thies and Teja Tscharntke [1999] highlighted that increasing the presence of beneficial organisms that preserve antagonist organisms under control contributes to maintaining a balance between the main crop and other organisms. Conversely, large numbers of natural enemies are frequently noted in response to low pesticide application. The key elements that contribute to the success of this approach are based on three elements: appropriate management availability of resources by improving soil structure, controlling crop variety and attractiveness as well as improving biological diversity to constant grapevine pathogens and preventing disease. Additionally, Robert Pool [1995] also reported that differences in soil quality and the presence of cover crop have an impact on production and economical aspects.

Viticulture, based on beneficial organisms, aims at minimizing the use of approved pesticides by adopting diverse practices that promote biodiversity within the grape production system. Conversely, the optimal selection of grape varieties is beneficial to effectively manage fungal disease and reduce cultivation costs [Pedneault, Provost 2016]. Increasing the attendance of beneficial microorganisms that maintain pathogens under control contributes to preserving a balance between the crop and other organisms [Thies, Tscharntke 1999].

To reduce economic losses caused by disease, growers inoculate plants with potential beneficial microorganisms as the biological control for grapevine pathogens [Compant et al. 2011]. Microbes are probably associated with different plant tissues and could have an impact on the flavor and productivity of grapes, and finally the taste of the wine. Furthermore, bacteria and fungi, particularly lactic acid bacteria and yeast, improve wine fermentation processes and flavor [Leveau, Tech 2011].

Many *Vitis vinifera* varieties have a low to high susceptibility to disease, especially fungal, that lead to high production costs as well as economic losses [Fuller et al. 2014]. In Italy, the annual cost for the management of downy mildew on a conventional vineyard mainly ranges from 8 to 16 million euros per year depending on disease intensity [Salinari et al. 2006]. Growers highlighted that, in medium intensity of the disease, at least 12 treatments per season are required for *Vitis vinifera*. According to Jacques Rousseau et al. [2013], the application of fungus resistant grape varieties in six different European countries contributed to reducing fungicide treatments in organic vineyards from 73% to 82% depending on the intensity of the disease. Karine Pedneault and Caroline Provost [2016] estimate that cultivating disease resistant cultivars could cut production costs by up to 50 % in French viticulture. Cost savings from growing resistant vines in comparison to conventional ones differ widely depending on the types of grapes being produced. Kate Fuller et al., [2014] reported that total annual economies can range from 177 US dollars per acre, in the case of traditional tray dried raisin production, to 287 US dollars per acre for table grapes in California. In organic management, diseases like botrytis, downy mildew, powdery mildew, black rot and anthracnose are mostly controlled using sulfur based fungicides, which, in conjunction with beneficial microorganisms, can bring significant savings for growers [Siegfried, Temperli 2008]. Moreover, even if copper based pesticides are necessary, they can be applied in a significant lower level, which, in the long term perspective, can be profitable for growers. Contrary to conventional pesticide practices, according to Carine Pedneault and Caroline Provost [2016], applying garlic powder suspension (marketed as Buran) by local growers, in Canada, efficiently suppresses and reduces the growth of powdery mildew in organic fungus resistant grapes.

Reducing agrochemicals in grapevine cultivation is very difficult due to changeable climate conditions but, according to anonymous growers that participated in the survey, the application of beneficial microorganisms can bring economic profits (Figure 1). As much as 83% of respondents are of the opinion that such applications could reduce the costs of protection. Only 4 farmers think that this might increase costs. On the contrary, 34% of respondents (16 farmers) presented the opinion that using beneficial microorganisms and resistant varieties will increase the costs of cultivation, while 42% (20 farmers) have the opposite opinion. There was relative agreement as to the opinion that such innovations in the vineyard might increase benefits, 34 farmers (72%) were of such an opinion, while only 3 farmers opposed, with 8 farmers having no idea on this topic.

In the opinions presented, additionally to the asked questions, 18 farmers (38%) paid attention to the fact that the potential usage of beneficial microbes, in the short term, can increase the costs of cultivation but, in the long term, can contribute to a decrease in cost protection. Growers are willing to apply microorganisms that can reduce the application of pesticides but underline that, according to changeable weather conditions, it will be difficult to significantly minimize this level. Furthermore, it is very difficult to estimate the precise costs of introducing beneficial microbes and profits that can be attained, which is also a limiting factor affecting vineyard cost management.

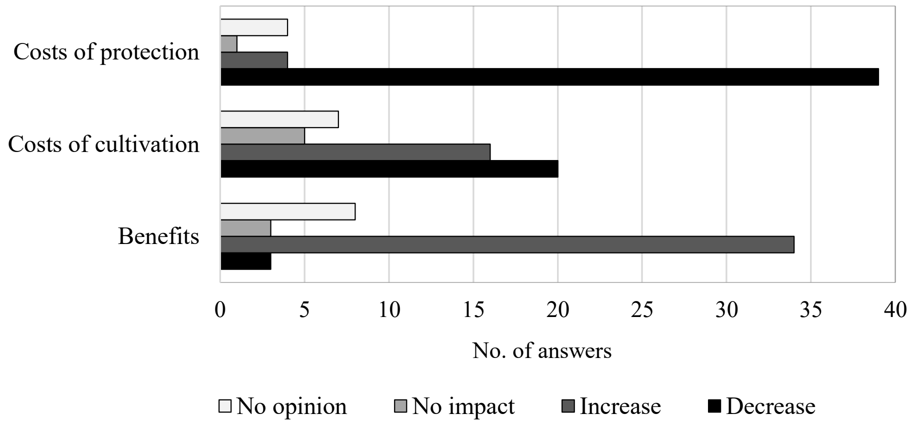

Figure 1. The opinion of farmers on the hypothetical situation when improvements in the farm are made by applying beneficial microorganisms to resistant varieties of grapes in order to strengthen the natural resistance of plants against diseases, pests or unfavourable climate conditions, assuming other conditions unchangeable.

Source: own elaboration

Table 1. The impact of using beneficial microorganisms in growing of resistant grape varieties on direct cultivation costs

Direct costs of viticultural production	No impact	Higher costs	Lower costs
Mechanical treatment before the beginning of the vegetation season	+		
Fertilization – N			+++
Fertilization – P			++
Fertilization – K			++
Fertilization – micro		+	
Organic fertilization		+++	
Mechanical treatment during the vegetation season		++	
Pruning and forming	+++		
Chemical protection against diseases			+++
Chemical protection against pests			+++
Irrigation		+++	
Shading	+		
Mechanical treatment after the vegetation season		+	

+ low impact, ++ medium impact, +++ strong impact

Source: own elaboration

Additional research in the Italian sustainable farm showed that using beneficial microorganisms in growing resistant grape varieties has a different impact on the direct costs of cultivation (Table 1).

In the researched farm, there was no impact reported on pruning and forming as well as shading costs. These are activities preformed before and during the vegetation season and are associated more with plantation management and obtaining good quality grapes.

The highest increase of costs was reported in the case of irrigation and organic fertilization. A medium increase of costs was also observed in the case of mechanical treatment during the vegetation season, which was associated with soil cultivation. Additionally, a small cost increase was found in the case of implementing additional activities associated with plant protection, fertilization with micro elements as well as mechanical treatment after the vegetation season. According to interviewed managers of the investigated farm, there are significant cost reductions while applying beneficial microorganisms to resistant vinegrape varieties. The highest reduction could be seen in the case of chemical protection against pests and diseases. A strong impact was also reported in the case of cost reductions of applying nitrogen. Additionaly, as a medium cost reduction, applications of other fertilizers were assessed.

CONCLUSIONS

Under the current climate change conditions, management strategies of vineyards based on synthetic means of production are cost intensive. Therefore, there is a necessity to develop uncomplicated and economical methods for the management of biotic and abiotic stresses, which can be applied on a short term basis. Microorganisms could play a meaningful role in this aspect, especially when considering their particular properties. The application of beneficial microorganisms over a long-term period can bring significant economic profit to winegrowers and reduce agrochemical input. This is part of the general trend of changing the agricultural development paradigm towards agrobiology. This leads to greater sustainability. This research confirmed that the inoculation of beneficial microorganisms to cultivating resistant grape varieties might have a beneficial effect on the economics of such production. Further research is however necessary in order to demonstrate the exact benefits and costs, including those related to externalities and market effects resulting from consumer perception.

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EFEKTY EKONOMICZNE ZASTOSOWANIA POŻYTECZNYCH MIKROORGANIZMÓW W UPRAWIE WINOROŚLI W WARUNKACH ZMIAN KLIMATU

Słowa kluczowe: zmiany klimatu, skutki ekonomiczne, pożyteczne mikroorganizmy, uprawa winorośli

ABSTRAKT

Celem artykułu jest przedstawienie efektów ekonomicznych zastosowania pożytecznych mikroorganizmów w uprawie winorośli w warunkach zmiany klimatu. Stwierdzono, że coraz intensywniejsze zmiany klimatu wymagają szerokiego zakresu dostosowań i strategii łagodzących ich skutki w rolnictwie, w szczególności w uprawie winorośli. Jednym z nich może być wykorzystanie pożytecznych mikroorganizmów, które dzięki zdolnościom do współdziałania z roślinami przyczyniają się do przeciwdziałania i zwalczania ich stresów, zarówno abiotycznych – takich jak susza, i biotycznych – takich jak szkodniki. Na podstawie badań ankietowych przeprowadzonych w 2018 roku wśród doświadczonych rolników z Polski, Niemiec i Włoch stwierdzono, że można zaobserwować bezpośredni efekt ekonomiczny wykorzystania pożytecznych mikroorganizmów w uprawie odpornych odmian winorośli. Większość rolników uważa, że takie innowacje w winnicy mogą zmniejszyć zarówno koszty ochrony, jak i koszty uprawy, a także zwiększyć bezpośrednie korzyści. Jednocześnie dowody empiryczne uzyskane ze studium przypadku przeprowadzonego w 2018 roku we włoskiej zrównoważonej winnicy wykazały, że takie innowacje, chociaż zwiększyły koszty nawadniania i nawożenia organicznego, doprowadziły również do znacznej redukcji użycia nawozów sztucznych i pestycydów, których koszty przeważały.

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