Advantages of Using the Biofertilizers in Ukrainian Agroecosystems

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Abstract

Amid growing problems of excessive application of chemical fertilizers, biofertilizers hold the potential to increase farmers' current agricultural productivity, while at the same time contributing to the soil's ability to produce more in the future. This article is part of a larger study conducted by the Université de Montréal in Ukraine with the support of Mitacs and Earth Alive Clean Technologies. The responses of user farmers and non-user farmers of biofertilizers, manufacturers or suppliers of biofertilizers, government officers and research scientists are captured to build understandings of how microbial products (biofertilizers) prove to be advantageous when applied in food crops. The agronomic advantage of biofertilizers compared to conventional chemical fertilizers is well proved biologically and in economic terms. The farmers surveyed showed interests in using biofertilizers in the future, however, both manufacturing and supply of biofertilizers are inadequate compared to the demand of microbial biofertilizers in the country. Yet, the farmers are concerned for supply of quality products have better effectiveness, longer shelf life and lesser costs.

Keywords: Biofertilizers; Biologicals; Fertilizers; Farmers' Preference; Soil Health

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INTRODUCTION

To accomplish high productivity of crops and soil, the unsustainable application of chemical fertilizers and plant protection chemicals have resulted in steady declines in soil and crop productivities the world over. Hence, agricultural practices need to evolve to sustainably meet the growing global demand for food without irreversibly damaging the world's natural resources (especially soil) while maintaining food security. Investing in sustainable agriculture is one of the most effective ways to simultaneously achieve the Sustainable Development Goals (SDGs) related to poverty and hunger, nutrition and health, education, economic and social growth, peace and security, and preserving the world's environment (Earth Alive, 2017). Amid growing problems of excessive application of chemical fertilizers, biofertilizers hold the potential to increase farmers' current agricultural productivity, while at the same time contributing to the soil's ability to produce more in the future. Several countries, such as Canada, Argentina, South Africa, Australia, USA, India and Brazil, have embraced these technologies. The list of potential commercial biofertilizer products that promise increased yield for the farmer continues to grow (Simiyu *et al.*, 2013).

A biofertilizer is a substance containing living microorganisms that are applied to seed, plant surfaces, or soil, and that colonize the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant (Weyens *et al.*, 2009; Xiang *et al.*, 2012). Some common agents in biofertilizers include *Rhizobium*, *Azotobacter*, *Azospirillum*, Phosphorus solubilizing bacteria (PSB) and *Mycorrhizae*. The microbial biofertilizers have been developed to recover the soil biology and sustainability of agroecosystems. The biofertilizers contribute to the soil's ability to produce more in the future (Arjjumend *et al*., 2017). The benefits of biofertilizers have been cited as cost-effective, providing up to 25-30% of chemical fertilizer equivalent of nitrogen, providing phosphorous and potassium, increasing water absorption and keeping soil biologically active (Arjjumend, Konstantia and Warrren, 2020). The agronomic potential of plant–microbial symbioses proceeds from the analysis of their ecological impacts, which have been best studied for N-fixing (Franche, Lindstrom and Elmerich, 2009). In the soil or rhizosphere, biofertilizers generate plant nutrients such as nitrogen and phosphorous through their activities or make them available to the plants (Rajendra, Singh and Sharma, 1998).

The biofertilizers market is segmented by microorganisms into rhizobium, azotobacter, azospirillum, blue-green algae, phosphate solubilizing bacteria, mycorrhiza, and other microorganisms, by technology type into carrier enriched biofertilizers, liquid biofertilizers, and other technology types, by application into seed treatment and soil treatment, and by crop type into cereals, legumes, fruits and vegetables, plantations, and others (Arjjumend, Konstantia and Warrren, 2020). Ukraine has limited production of biofertilizer products. As the Ukrainian economy generally declined beginning in 1991, many production units were shut down, and have not been restored (Stefanovska, Pidlisnyuk and Kaya, 2006). The existing poor status of biofertilizer production and distribution, which is largely government-sponsored, indicates that the country has huge gaps between demand and supply. In Ukraine, the majority of plant nutrients, including biofertilizers and organic fertilizers, are imported, especially from China.

This article is an outcome of a larger study conducted between September 2017 and February 2020 by the authors from the Faculté de droit, Université de Montréal with the financial support from Mitacs and Earth Alive Clean Technologies. Field data collection support was provided by Department of Environmental Law, Yaroslav Mudriy National Law University of Ukraine and by several community workers in their individual capacities. The present paper focuses on advantages of using biofertilizers vis-à-vis chemical fertilizers in Ukraine. Four different groups of respondents were surveyed between April 2018 and March 2019 using methods of semi-structured interviews, structured interviews, informal discussions, and observation. The responses of user farmers and non-user farmers of biofertilizers, manufacturers or suppliers of biofertilizers, and scientists are reviewed to build cases of how microbial products (biologicals) prove to be advantageous when applied in field crops. The agronomic advantage of biofertilizers compared to conventional chemical fertilizers is biologically and economically well proven. The respondent farmers have shown their preference of biofertilizers over chemical fertilizers and have expressed willingness to adopt biofertilizers to revive their soil biology and health along with better crop yields.

MATERIALS and METHODS

The present study was conducted in Ukraine to understand scientific advantages of using biofertilizers. Several types of respondents were interviewed and observations were made in the field, apart from reviewing the pertinent literature.

Sampling and Sample Techniques

Different four respondent groups were chosen to conduct the study: Group 1 – research and development (R&D) Scientists; Group 2 – Manufacturers and Suppliers; Group 3 – User & Non-User Farmers; and Group 4 – Government Officers. Group 1 involves respondents from R&D of biofertilizers and scientists conducting research on microbial agents. These scientists were important for the study because they had explained the microbiology, biotechnology, agrochemistry of the microbial biofertilizers. Group 2 respondents include those from the manufacturing, trade and supply chain of biologicals and agrochemicals. Group 3 respondents are the farmers/cultivators/growers using or not using the biofertilizers. These farmers are direct stakeholders of this study on biofertilizers. In absence of biologicals, they may be suffering from adverse effects of chemical fertilizers. Alternatively, in event of using biologicals in their farming practices, these respondents will have experiences and opinions about various aspects of biofertilizers. Group 4 respondents included government officers involved in policy/law implementation/enforcement, some of which was informally shared by the officers, as they cannot share such information in writing or formally.

Table 1 contains the total sample size of each of the respondent groups. Names of Ukrainian oblasts are also mentioned in Table 1 for all respondent groups. In Table 2, distribution of surveyed farmers or growers is highlighted. All the proposed participants (respondents) were first contacted through telephone and/or email in order to make an appointment. Following the pre-appointments, the participants were physically visited and interviewed or interacted with.

To augment data from each respondent group, various sampling techniques were used, as indicated in Table 1. All the farmers were divided into two major distinct categories: non-users of biologicals and users of biologicals. The composition of sampling of these farmers is illustrated in Table 2.

Table 1. All the farmers were divided into two major distinct categories: non-users of biologicals and users of biologicals.

Respondent Group	*Sample Size*	*Names of Oblasts*	*Sampling Method*	*Research Method*
G.1 R&D Scientists	11	Lviv, Kiev, Ivano-Frankivsk, Kharkiv, Chernihiv	Expert, Snowball	Informal discussion; Semi-structured interview
G.2 Manufacturers and Suppliers	8	Kharkiv region	Snowball, Purposive	Semi-structured interview; Structured interview
G.3 User & Non-User Farmers	36	Ivano-Frankivsk, Kharkiv, Sumy, Luhansk	Stratified random	Semi-structured interview; Structured interview; Observation
G.4 Government Officers	8	Lviv, Kiev, Ivano-Frankivsk, Kharkiv	Purposive, Expert	Informal discussion; Semi-structured interview

Table 2. Composition of Group 3 Respondents (Farmers)

Category of Farmers	*Kharkiv*	*Sumy*	*Ivano-Frankivsk*	*Luhansk*	*Total*
Non-Users of Biologicals	3	3	3	3	12
Users of Biologicals	6	6	6	6	24
Total	9	9	9	9	36

Methods of Data Collection

As mentioned in Table 1, different data collection methods were used to augment data from different respondent groups. For instance, information from Group 1 respondents (R&D scientists) was augmented using informal discussions and semi-structured interviews through applying questions as listed in Appendix 1. On the other hand, manufacturers/suppliers (Group 2 respondents) gave their responses in accordance with the questions as listed in Appendix 2.

The data gathering methods used were semi-structured and structured interviews (Table 1). The farmers (Group 3 respondents) were surveyed by employing structured interview, semi-structured interview and observation methods (Table 1). The questions for non-users of biologicals among Group 3 respondents are listed in Table 3, whereas the questions for users of biologicals among Group 3 respondents are listed in Table 4. Similarly, Group 4 respondents (government officers) were interacted with using informal discussion and semi-structured interviews (Table 1) for the questions listed in Appendix 3.

Certificat D'approbation Éthique (Ethical Approval Certificate) and its Compliance

The Multi-Faculty Committee on Research Ethics (*Comité plurifacultaire d'éthique de la recherche - CPER)* of Université de Montréal issued Ethical Approval Certificate (no. CPER-17-114-P) to the study project. During the field data collection from all four respondent groups, the conditions of the Ethics Certificate were fulfilled and complied with. In compliance of the Ethical Certificate, the Consent Form was presented to each of the individual respondents in Ukrainian. Depending on participant preference, the appropriate Consent Form was used and signed by both the respondent and field researcher. Before conducting the interview or discussion with the respondents/participants, each individual was told the objectives of the research through an Information Sheet containing what was expected from respondent, the benefit of sharing information, confidentiality details, and the participant's right to withdraw. After adequate explanations about the research and freely given consent of the respondent/participant, the desired information was augmented from the respondent/participant.

RESULTS

The information gathered from all the respondents has been analyzed and presented to build cases of how microbial products (biologicals) prove to be advantageous when applied in field crops. Sampling of 12 farmers (3 farmers in each of 4 oblasts) using chemical fertilizers was done in Ukraine and their responses were recorded on several parameters (Table 3). The questions were chiefly regarding the disadvantages of using chemical fertilizers and the impacts they observed on their agroecosystems and human health and domestic animals from chemical fertilizers used. Likewise, 24 farmers (3 farmers using biofertilizers and 3 using biopesticides or using both in each of 4 oblasts) in Ukraine were interviewed and their answers were recorded in Table 4.

1. Soil performance under chemical fertilizers

The respondent farmers using chemical fertilizers were asked for their views on how chemical fertilizers affect the soil, plants, ecosystem and human health (Table 3). Most of these farmers gave favorable views about chemical fertilizers by stating that the chemicals improve production as the plants need nutrition and crops cannot be grown without nutrition (Table 3). Respondent scientists and officers argued that mineral fertilizers replenish the availability of nutrients in soil and maintain fertility of soil. The suppliers/manufacturers articulated that the impact of chemical fertilizers on soil depends on the quantum of chemicals being used. According to farmers, if chemical fertilizer is used in the right proportion in accordance with moisture, it is harmless to soil (Table 3).

However, other respondent farmers narrated how chemical fertilizers deteriorate the conditions of the soil. These respondents observed that, after the introduction of mineral fertilizers, the intensity of the natural conversion of atmospheric nitrogen to the compounds that can be assimilated by plants is reduced (Table 3). The mineral salt solutions are harmful to soil microorganisms that form a layer on the fertile soil, and hence the formation of humus slows down (Table 3).

Another question posed to the respondent farmers was "how does the soil get affected after application of chemical fertilizers?" (Table 3). Ukrainian farmers using chemicals advocated in favour of the fertilizers, saying that the soil restores deficient nutrients once fertilizers are applied and that only excesses of mineral fertilizers cause harmful effects on soil (Table 3). These respondent farmers noted that they use chemicals in right quantities, hence negative effects are not visible (Table 3). According to them, soil is not affected if chemical fertilizer is applied wisely in appropriate quantity as the correct dosage of fertilizers minimize the ecological footprint on the soil (Table 3). However, some respondent farmers using chemical fertilizers shared their experiences that chemical fertilizers can increase the radioactive lead Pb (^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb), which causes accumulation of heavy metals in soil and plant bodies (Table 3). The influence of chemical fertilizers on atmospheric air and water is mainly due to excessive nitrogen release. Apparently, mineral fertilizers have a negative impact on plants and on the quality of products, as well as on organisms that use it, the farmers claimed (Table 3).

2. Health and ecological risks from chemical fertilizers

In Ukraine's four oblasts, respondent farmers using chemical fertilizers listed the common health effects of chemical fertilizers, especially on children and women (Table 3), including gastrointestinal problems, poisoning, vomiting, cancer (if residues persist), phlegm of the upper respiratory tract, rhinitis, laryngitis, bronchitis, and pneumoconiosis (Table 3). The respondent scientists explained that the enzyme system is poorly developed in children, making nitrates more dangerous for them, especially as nitrates and nitrites are carcinogens. Moreover, nitrozoamines, which have hepatotoxic properties, cause hepatitis. Some suppliers and surveyed farmers using chemical fertilizers highlighted that nitrites lead to chronic intoxication of the body, weaken the immune system, reduce mental and physical capacity, exhibit mutagenic and embryotoxic properties (Table 3). The respondent farmers using chemical fertilizers explained the ecological effects of chemical fertilizers (Table 3). They replied that chemicals take path in the human food chain. The mineral fertilizers accelerate leaching of calcium, magnesium, zinc and copper, from the soil, which affects the processes of photosynthesis and reduces the resistance of plants to diseases (Table 3). Mineral fertilizers lead to reducing soil porosity and granular aggregates and, finally, to acidification of the soil (Table 3).

Regarding the health effects of chemical fertilizers, Ukrainian farmers using biofertilizers and biopesticides suggested a list of associated sicknesses, such as asthma, skin diseases, gastrointestinal problems, toxicity among children, and miscarriages of pregnant women (Table 4). Some respondent farmers explained that mineral fertilizers are used everywhere in Ukraine and that no health issue is observed if fertilizer is used in appropriate quantity (Table 4). However, scientists, officers and other farmers explained that many chemical elements enter plants through biological processes, and that they are transformed into toxic elements. Nitrogenous fertilizers pose the greatest danger to humans and agroecosystems (Table 4).

Nitrates are especially dangerous for infants, because their enzyme base is imperfect, and recovery of methemoglobin into hemoglobin is slow (Table 4).

The question "Do you think that biofertilizers are safer compared to chemical fertilizers?" was addressed by farmers using biofertilizers and biopesticides (Table 4), who affirmed this observation. The respondent farmers reiterated that biofertilizers do not cause harm to the soil or plants (Table 4). Several respondent farmers also reported that biofertilizers remove ions of heavy metals from soil and clean the contaminated soil (Table 4).

The respondent farmers then described the comparative ecological advantage of biofertilizers, including that they are relatively safer to ecosystems as they trigger oxidation of soil (Table 4). Some of the respondents said that biofertilizers contribute to the neutralization of salts of heavy metals. These respondents compared chemical fertilizers by stating that chemicals store in soil and plant body, hence the mineral fertilizers need to be used as per strict technical prescriptions if used along with biofertilizers (Table 4).

3. Soil performance under biofertilizers

Respondent Ukrainian farmers using biofertilizers in crops were asked how the biofertilizers benefit the soil, plants, ecosystem and human health (Table 4). In the respondents' views, biofertilizers do not harm humans, plants or ecosystems. According to the surveyed government officers, biofertilizers benefit and enrich the soil as fertility increases. According to the farmers interviewed, biofertilizers stimulate plant growth and mobilize the minerals (e.g. N, Fl) to become accessible to plants and nourish soil (Table 4). The respondent manufacturers and scientists expressed their views that the chemicalization process of soil reduces because the biofertilizers are safer and have no negative impact on soil. Biofertilizers are also reported to increase plant and soil immunity while improving quality of produce (Table 4). The respondent farmers shared their observations that resistance to various diseases and to climatic variability increases following the application of microbial biofertilizers (Table 4). The farmers and government officers also explained how microorganisms deliver functions in the soil. They described that atmospheric nitrogen is fixed by microbes and transferred to plants, as microbes also synthesize a wide range of substances in soil (Table 4). According to respondent scientists, humus is increased several times because microbes of biofertilizers positively impact the enzymatic activity in the soil. Finally, the farmers indicated that biofertilizers solve salinity problems in the soil (Table 4).

The question of how the attributes of the soil change once biofertilizers are used was answered by the surveyed farmers using biofertilizers and biopesticides (Table 4). The respondent farmers expressed their views that the bacteria of biofertilizers stimulate root growth and solubilize the nutrients or minerals like phosphorus, which the plants easily digest. Plant root systems enlarge and are nourished because the microbes fix nutrients to make them accessible to plant roots (Table 4). The biofertilizers increase soil temperature by 2-5^{o}C which enhances root formation and germination of seeds. Fruiting, blooming, germination, and root formation are supported by the bacteria that feed on root secretions and release growth metabolites (Table 4). The rational use of biofertilizers contributes to obtaining environmentally friendly products, the accumulation of humus, reducing soil fatigue, improving soil structure and fertility (Table 4). According to the surveyed farmers using them, due to their biological properties, biofertilizers are absorbed by plants at a rate of almost 100 per cent, while the content of nitrates in farm produce remains minimal (Table 4).

The manufacturers/suppliers said that with prolonged use and strict application of biofertilizers, soil can improve. Farmers also stated that the bacteria feed on secretions of the root system in rhizosphere (Table 4). The respondent farmers using biofertilizers and respondent scientists articulated that biofertilizers work on a synergistic basis or on antagonism principles and, as a result, the fermentation process makes leaves and fruits of plants inedible to the pathogenic microbes.

Finally, plants becomes more resistant to pathogens, drought and frost (Table 4). The farmers disclosed an important fact that heavy metal ions are reduced from the acidic soil if microbial biofertilizers are applied (Table 4).

The same respondent farmers using biofertilizers in agriculture explained how soil becomes softer after the application of biofertilizers (Table 4). They replied that soil improves on application of biofertilizers because bacteria change the soil structure, texture, profile, fertility and productivity. The biofertilizers increase soil fertility, improve yield and quality of cultivated crops, and enhance humus formation (Table 4). These farmers also indicated that nitrogen, potassium and phosphorus are easily accessible to plants when biofertilizers are applied. Simultaneously, soil becomes resistant to fungal diseases, drought and other pathogens as biofertilizers reduce negative impacts of chemicals on soil fertility and reduce the residues by 60% (Table 4). Farmers and scientists highlighted that bacteria of the biofertilizers renew microbiocenosis of the soil, restoring the microenvironment balance of the soil. Using biofertilizers, soil becomes black, a favorable environment for growing vegetables (Table 4). A respondent farmer reiterated that biofertilizers are not efficient unless used with the chemical fertilizers (Table 4). This hints that mineral fertilizers and biofertilizers needs to be used simultaneously to get better results.

Table 3. Responses of Control Farmers/Growers (Non-Users of biofertilizers)

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
1. Soil performance under chemicals				
1.1. Do you think that chemical fertilizers affect the soil, plants, ecosystem and human health?	• Chemicals improve production • Chemical fertilizers are essential • Yes. All people talk about it	• Plants need nutrition. If chemical fertilizer is used in right proportion in accordance of moisture, it is harmless to soil. • Crops cannot be grown without chemical fertilizers	• Mineral fertilizers replenish the availability of nutrients in soil • Impact of fertilizers on soil depends on the quantum of chemicals being used • Fertilizers maintain fertility of soil	• After the introduction of mineral fertilizers, the intensity of the natural conversion of atmospheric nitrogen to the compounds that can assimilate plants is reduced. Mineral salt solutions are harmful to microorganisms that form the fertile soil layer; thus, the formation of humus is slowing down.
1.2. How does the soil get affected after application of chemical fertilizers?	• Soil is not affected if chemical fertilizer is applied wisely	• We use chemicals in right quantities. Hence negative	• Soil restores deficient nutrients once fertilizers are applied	• The fertilizers can increase the radioactive Pb which causes accumulation of heavy metals. The

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
	in appropriate quantity • Fertilizers are added more with no negative impact	effects are not visible • Excess of mineral fertilizers cause harmful effects on soil.	• Right doses of fertilizers minimize the ecological footprint on soil	influence of fertilizers on atmospheric air, water is mainly due to nitrogen formation. Mineral fertilizers have a negative impact on plants and on the quality of products, as well as on organisms that use it.
2. Investment & economic risks				
2.1. How much do/did you spend on buying chemical fertilizers and pesticides?	• UAH 6000 per ha • UAH 6000 per ha	• UAH 4500 per ha • UAH 4000 per ha	• UAH 4000 per ha • UAH 3000 per ha • UAH 4500 per ha	
2.2. Can you calculate the economic or investment risks of crop cultivation under chemicals if the crop fails due to nutrients' deficit, disease, pests, nematodes, insects, etc.?	• Huge sum	• A lot. Costs of labour, diesel, fertilizers, pesticides, tax, warehouse, transport, seed, traction, rent, etc.	• Costs of labour, equipments, repair works, diesel, fertilizers, pesticides, tax, warehouse, transport, seed, traction, rent, etc.	
3. Health and ecological risks				
3.1. What are the common health effects of chemical fertilizers? Specially on children and women.	• Gastrointestinal problems	• Excess cause poisoning, vomiting • Persisting residues can cause cancer	• Poisoning	• Phlegm of the upper respiratory tract, rhinitis, laryngitis, bronchitis, pneumoconiosis, etc.

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
				• In children, the enzyme system is poorly developed and nitrates for them are more dangerous. • Nitrates and nitrites are carcinogens. • Nitrozoamines, which have hepatotoxic properties, also cause hepatitis. • Nitrites lead to chronic intoxication of the body, weaken the immune system, reduce mental and physical capacity, exhibit mutagenic and embryotoxic properties.
3.2. Can you explain the ecological effects of chemical fertilizers?			• Chemicals take path in food chain	• Mineral fertilizers provoke leaching from the soil of calcium, magnesium, zinc, copper, manganese, etc. • Leaching affects the processes of photosynthesis, reduces the resistance of plants to diseases. • Mineral fertilizers lead to reducing soil porosity and granular aggregates. • Acidification of the soil.

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
4. Other qualitative information				
4.1. What is your preferred fertilizer?	• Ammonium Nitrate • Organic manure (not much available now because livestock farms are shutting down)	• Ammonium Nitrate • NPK • Organic fertilizers (livestock disappearing)	• Ammonium Nitrate • Nanjj Master • Complex fertilizer • Organic fertilizer	• Organic fertilizer
4.2. Do you want to use biofertilizers?	• No • Biofertilizers are ineffective in temperate non-irrigated zone	• They are ineffective • No • Expensive	• Expensive • No	• Yes
4.3. What drives you to use biofertilizers in future?	• Biofertilizer neither effective nor economic • Biofertilizers are ineffective	• They are expensive and ineffective	• Not effective	• They are not harmful
4.4.Which company/brand biofertilizer(s) do you like to use?				
5.Additional Questions				
5.1. Do you prefer locally made products or foreign products?	• Local • Both	• Local	• Local	• Local
5.2. Would you be willing to pay more for a foreign product than for a local product?	• Only if it is more effective	• No • Yes, if it is effective	• No	• Yes, if quality product
5.3. Scale 1-10: How willing are you to try a new/innovative product?	• 9 • 7 • 6	• 5 • 5	• 3 • 3 • 2	• 10

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
5.4. Which local or international organic certification do you trust?				• Organic

4. Soil-water regime under biofertilizers

Only a few farmers using biofertilizers gave a precise answer to the question "how many irrigations were required for a crop (e.g. wheat) grown without biofertilizer(s) usage?" (Table 4). Some farmers said that watering varies from 3250 m^3/ha to 4760 m^3/ha water on the fields, while other farmers responded that it needs to be 3 times a year. Corn, for instance, needs 70-80% moisture in the soil (Table 4). Some farmers replied that irrigation is not available in Ukraine and farmers depend on rains and weather. These farmers affirmed that biofertilizers reduce irrigation needs by 2 irrigations for a crop (e.g. wheat). Rain was said to be the main source of growing crops by the farmers, however, these farmers reiterated that moisture is built up in soil when biofertilizers are applied, as biofertilizers provide natural water permeability of the fertile layer of soil (Table 4).

How biofertilizers help in increasing the longevity of moisture in the soil after usage of biofertilizer(s) was explained by the respondent farmers (Table 4). The Ukrainian farmers using biofertilizers in their fields responded that moisture remains for longer in the soil and 40-70% of water is kept in rhizosphere once biofertilizers are applied (Table 4). They hinted that soil agglomerations are formed by bacterial activity in the soil making phosphates easily accessible to plants (Table 4). According to the respondent scientists and suppliers, biofertilizers synthesize biologically active substances by dissolving, for example, silicate and other substances including nitrogen, potassium and phosphorus. It humidifies soil layers while maintaining air and water permeability of soil layer (at least 60 cm deep). The farmers also reported that the coefficient of water consumption in crops such as sunflower is 450-570 (Table 4). The government officers stated that bacteria dissolve phosphorus in soil and increase the salt index level that regulates pH of the soil. It all supports plant growth.

The respondent farmers have explained how biofertilizers increase the water holding capacity of soil (Table 4). They revealed that biofertilizers help keep moisture in soil and transform microelements to be easily digestible by plants. Water needs are reduced considerably, the farmers reiterated (Table 4). The suppliers explained that biofertilizers work for 3-5 years longer than conventional mineral fertilizers. Biofertilizers also contribute to the aeration of the soil, water retention, filtration ability, and rate of cation exchange in the soil (Table 4). According to the respondent farmers using biofertilizers, bacteria recycle and dissolve intractable phosphorus in soil and make it accessible to the plants. Moreover, resistance to leaching of nutrients from the soil is built up if biofertilizers are added to the soil (Table 4). Two farmers stated that 80% of organic fertilizers wash out of the soil, whereas 15% of biofertilizers also wash out of the soil (Table 4). This reflects an understanding that microbial biofertilizers have far more durability and sustainability.

The respondent farmers have described how increased moisture content enhances nutrition intake by the plant roots (Table 4). They narrated that the bacteria of biofertilizers mobilize the accumulated phosphorus for the plant root, thereby increasing the fertility of soil and transforming nutrients to be easily absorbed by soil (Table 4). In words of respondent scientists and manufacturers/suppliers, certain bacteria strain dissolve ammonia, amino-silicate and release potassium and hard nitrogen. As a result, quality and size of grain (I & II grades) and straw improve. Potassium (30%) contained by bacteria is used by plants after death of bacteria if the biofertilizers are applied in crops/soil.

5. Comparative yield & characteristics of produce

The respondent Ukrainian farmers gave their feedback about the effect of biofertilizers on qualitative change in crop production following the use of biofertilizers. To the question "how do you measure the (comparative) crop productivities accruing after usage of biofertilizer(s)?", the farmers responded that they observed increase in yields and quality production of crops they grow (Table 4). A farmer pointed out that this increased yield and production is approximately 10% after using biofertilizers (Table 4). One respondent farmer reported this increase by 6.11 ton/ha of corn (Table 4). Some respondent farmers stated that they did not calculate the benefits accruing from using biofertilizers, while others opined that the size of the harvest depends on the density of productive stalk and mass of grain from one ear, and that biofertilizers boost all that (Table 4).

The traits of farm produce, such as taste, color, quantity, and shelf-life, may also change when using biofertilizers. Accordingly, the respondent farmers were asked "how is the farm produce (grains, fruits, tubers) different when biofertilizer(s) used?" (Table 4). According to these respondents, biofertilizers result in beneficial impacts on farm produce as the plants grow better in a number of aspects (Table 4). For example, use of *Bacillus amyloliquefaciens* increase yield by 10%. Likewise, *Actinomycetes* inhibit the growth of pathogens and stubble (Table 4). In fact, bacteria help the plants produce higher growth by mobilizing the vitamins, carotenes, proteins and increasing qualitative indicators of plants (Table 4). These farmers also confirmed that plant products get saturated color and better quality once biofertilizers are applied (Table 4).

Table 4. Responses of Farmers/Growers (Users of Biofertilizers)

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
1.Soil performance under biologicals				
1.1 Do you think that **biofertilizers** benefit the soil, plants, ecosystem and human health? In what way?	• Yes. They do not harm to human or plants or ecosystem. • Biofertilizers benefit the earth • Chemicalization of soil reduces • Biofertilizers are safer	• They increase plant immunity and yield quality • Air nitrogen is fixed by microbes and availed to plants • Quality of yield improves	• They make plant more resistant • Biofertilizers have no negative impact on soil • Microbes synthesize wide range of substances in soil and help plants	• Plant nutrition • Resistance to various diseases • Rresistance to unfavorable soil and climatic conditions. • They help to form healthy and strong plants

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
	• Soil fertility increases • They enrich soil with minerals and protect soil • Minerals (e.g. N, Fl) become accessible to plants • Inoculants are used	• Nutrients are made accessible to plants • Beneficial for soil • They increase soil immunity and minerals • They impact positively the enzymatic activity • They protect and nourish soil and plant	• Humus is increased several times • Immunity of the soil is increased • Soil fertility increases	• They solve salinity of the soil • They improve the properties of the soil • They transform, revive the exhausted earth, rocky, sandy, contaminated soil • They stimulate plant growth
1.2 May you describe the changed attributes of the soil once biofertilizers are used?	• Bacteria stimulate the root growth and solubilize the nutrients like phosphorus, which the plants easily digest. Pathogens are expelled out. • Root system enlarges • Plant becomes more resistant to drought and frost • They work on synergistic basis or on antagonism principles • Soil becomes more nutritious • They fix nutrients to make them accessible to plants	• With prolonged use and strict application methods, soil can improve • In rhizosphere, the bacteria feed on secretions of root system • Pathogens do not develop • Fermentation process makes leaves and fruits of plants inedible to the pathogenic microbes • They increase soil temperature by 2-5^{o}C which enhances root formation and germination • Biofertilizers make minerals	• Nutrients are absorbed in the soil in presence of bacteria • Roots are nourished and supported • Plant growth is stimulated • No harmful effects on plants and soil • Heavy metal ions are reduced from the acidic soil • Fruiting, blooming, germination are supported • They are not toxic •	• The rational use of bio-fertilizers contributes to obtaining environmentally friendly products, the accumulation of humus, reducing soil fatigue, improving soil structure and fertility • Biofertilizers, due to their biological properties, are absorbed by plants by almost 100%, while the content of nitrates in products is minimal

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
		accessible to plants • Bacteria feed on root secretions and release growth metabolites		
1.3 Has the soil become softer after application of biofertilizers? If yes, can you explain the reasons behind this?	• Yes. Soil improves on application of biofertilizers. • Biofertilizers are not efficient unless used with the chemical fertilizers • Soil becomes resistant to fungal diseases and drought • Soil indicators improve and fertility increases • Biofertilizers reduce negative impacts of chemicals on soil fertility and reduce the residues by 60% • Soil becomes stronger	• Bacterial change the soil structure • Bacteria colonize the soil and prevent pathogens • Soil becomes more nutritious • Bacteria renew microbiocenosis of the soil • Bacteria contribute to the productivity and fertility of soil	• Biopesticides are not used because they are less effective • In drought, bacteria do not work properly • Resistance of plants to disease and pests increases • Microenvironment balance of the soil is restored • Root system is supported • Humus formation is enhanced	• Yes • Soil becomes black soil, a favorable environment for growing vegetables • It increases soil fertility, improves yield and quality of cultivated crops • They do not change the composition of the soil and are safe for the environment and humans • Organic fertilizers are easily digested by crops. Nitrogen, potassium and phosphorus, in the composition of biofertilizers, are in an easily accessible form for plants

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
2. Soil-water regime under biologicals (especially biofertilizers)				
2.1 How many irrigations were required for a crop (e.g. wheat) grown <u>without</u> biofertilizer(s) usage? Crop-wise data	• Sprinkler watering. No count available • Drought resistant grains	• No irrigation	• It depends on weather conditions • No irrigation • Corn, for instance, needs 70-80% moisture. Level of moisture in soil depends on weather conditions. • Watering varies from 3250-4760 m^3/ha on the fields	• Rainfed agriculture • Irrigation 3 times a year
2.2 How many irrigations are required for a crop (e.g. wheat) grown <u>with</u> biofertilizer(s) usage? Crop-wise data	• Weather dependent • Rains dependent. 0-100 cm moisture in 2016 • Biofertilizers reduce irrigation needs by 2 times at least		• Moisture is built up when biofertilizers are applied • Biofertilizers provide natural water permeability of the fertile layer of soil • Watering 2-3 times less • 2 less watering	• 2 irrigations
2.3 Can you tell about the <u>longevity of moisture</u> in the soil before and after usage of biofertilizer(s)? If possible, crop-wise data	• Coefficient of water consumption in sunflower is 450-570		• Moisture remains for longer • Bacterial dissolve phosphorus in soil and increase salt index level that regulates pH	

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
2.4 How do biofertilizers help the soil in summer and dry season?	• Phosphates become solubilized • Soil agglomerations are formed by bacterial activity • Biofertilizers synthesize biologically active substances	• Accumulation of phosphorus is easily accessible to plants • 40-70% water is kept in root area	• Bacteria dissolve silicate and other substances including nitrogen, potassium and phosphorus • Microbes make a humidified layer on soil • Air and water permeability of soil layer is maintained (at least 60 cm deep)	• Biofertilizers retain moisture more
2.5 Can you explain how biofertilizers increase water holding capacity of soil?	• Biofertilizers help keep moisture in soil and they transform microelements into easily digestible to plants • Water needs are reduced considerably	• Bacteria need moisture, which is built in the soil	• Bacteria recycle and dissolve phosphorus in soil and make accessible to the plants • Bacterial fix the intractable phosphorus	• Resistance to leaching of nutrients from the soil • 80% of organic fertilizers are washed out of the soil • 15% of biofertilizers are washed out of the soil • Biofertilizer on the field will work for 3-5 years longer than conventional fertilizers • Biofertilizer contributes to the improvement of aeration of soil,

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
				water retention and filtration ability, increases the rate of cation exchange
2.6 May you describe how increased moisture content enhances nutrition intake by the plant roots?	• Biofertilizers increase fertility of soil and transform nutrients to be absorbed easily by soil • Soil fertility increases • Correlation of grain and straw matters • Quality and size of grain improve. Grains of I & II grade are produced	• Bacteria mobilize the accumulated phosphorus for the plant roots	• Moisture increases where microbes work • Certain bacteria strain dissolve ammonia, aminosilicate releasing potassium and hard nitrogen. 30% of potassium in ash of bacteria. • Potassium is used by plants after death of bacteria. • Minerals are also accumulated in soil.	
3. Comparative yield & characteristics of produce				
3.1 How do you measure the (comparative) crop productivities accruing after usage of biofertilizer(s)?	• Ammonium nitrate (34.4%) – 600 UAH/50 kg • Humate LF20, microelements 20l – 1550 UAH	• Size of the harvest depends on the density of productive stalk and a mass of grain from one ear • Seeds are treated with inoculants • Biofertilizer-caused profits are not calculated	• Pre-sowing treatment of seeds • Quality of crops improve • Productivity of winter wheat increases by 10% • 6.11 ton/ha of corn	

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
3.2 How is the farm produce (grains, fruits, tubers) different when biofertilizer(s) used? [taste, color, quantity, shelf-life, etc.]	• Organic products without nitrates • Treatment of seeds • Use of Bacillus amyloliquefaciens increase yield by 10%	• Stubble destruction • Thickness of production is measured • Actinomycetes inhibit the growth of pathogens	• Bacteria help the plants produce higher growth • They mobilize vitamins, carotenes, proteins and increase qualitative indicators of plants • Plants product get saturated color and better quality • Quality of product is improved • No impact on gustatory traits of corn	
4.Comparative investment & economic risks				
4.1 How much do/did you spend on buying chemical fertilizers and pesticides?	• UAH 130 per kg for processing of seed cereals • 2-3 times more • UAH 7500/ha • UAH 8500/ha	• UAH 8500-10000 per ha • 350 kg fertilizer per ha • 6800-10000 kg ammonium nitrate per ha • UAH 7000-9000 • Ammonium nitrate – UAH 6800 per ton • Unical – 314.8 UAH per litre • Total – UAH 7500 per ha	• UAH 5000-6000 per ha • UAH 8000 per ha • UAH 8000-9000 per ha • UAH 5000 per ha • UAH 8000 per ha	
4.2 How much do/did you spend on buying biofertilizers	• 1 kg per 5 ton seeds • Biofertilizers cost more than mineral fertilizers	• UAH 2000 • PMK – U – 1395 UAH/canister	• UAH 4000 per ha	

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
and biopesticides?	• Organic fertilizers no more available due to declining livestock	• Biospore – 1317.5 UAH per canister • Humate LF20 – 1550 UAH/ canister		
4.3 Can you calculate the economic or investment risks of crop cultivation under chemicals if the crop fails due to nutrients' deficit, disease, pests, nematodes, insects, etc.?	• Efficiency of biofertilizer directly depends on usage methods • Use of biofertilizers needs systematic and constant application	• When biologicals are used systematically and properly, the yield and production are higher • Dry soil lead to economic loss		
4.4 What investment or economic risks are involved if the crops grown by using biologicals?	• Biologicals are less effective. They need very careful usage methods • Biologicals do not work in dry soil. Hence inoculants are used	• Bacterial products do not work effectively if not used side by side mineral fertilizers and organic fertilizers		
4.5 Comparison of risks between both situations	• Any fertilizer needs proper and careful application methodology	• Bacteria may not survive for longer. Short shelf life is a risk.		
5. Comparative health and ecological risks				
5.1 What are the common health effects of	• Asthma among children	• Chemical fertilizers are necessary to	• Mineral fertilizers are used	• Many chemical elements enter the plant through

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
chemical fertilizers? Examples	• Skin diseases	grow cereal crops. Yet, they need to be used wisely. • Gastrointestinal problems • Toxins in children	everywhere in Ukraine • No health issue if fertilizer is used in appropriate quantity	biological processes • They are transformed into toxic elements • Nitrogenous fertilizers pose the greatest danger to humans • Nitrates are especially dangerous for infants, because their enzyme base is imperfect, and recovery of methemoglobin into hemoglobin is slow • Pregnant women have miscarriages
5.2 Do you think that biofertilizers are safer compared to chemical fertilizers?	• Impacts of chemicals reducing • Yes	• Yes • Farmers use mineral fertilizers recklessly	• Yes • They do not cause harm • They remove ions of heavy metals from soil	• They do not harm the soil
5.3 What is comparative ecological advantage of biofertilizers?	• Biofertilizers are relatively safe to ecosystems • Chemicals store in soil and plant body	• Bacterial form humus in the soil from available organic matter	• Mineral fertilizers need to be used as per technical prescriptions • They contribute to neutralization of salts of heavy metals • Biofertilizers trigger soil oxidation.	• To fertilize a certain plot, less mineral fertilizers are required

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
6.Other qualitative information about farmer's preferences				
6.1 What is preferred fertilizer?	• Ammonium nitrate • Unical			• Any fertilizer for soil replenishment
6.2 Is biofertilizer preferred over chemical fertilizer? Why?	• Both have pros and cons • Biofertilizers are preferred. But they are expensive and they give results after using 2-3 years of application. • Root system of plants is developed and immunity is enhanced	• Yes • Safe • Yes. They develop root system and increase immunity	• Soil is humidified • No chemical formation • Yes • Check degradation of soil	• Improvement of soil quality
6.3 Are chemical fertilizers and biofertilizer(s) used simultaneously?	• Yes • Effective if used simultaneously	• They work better if used together • Yes	• Yes	
6.4 What are perceived or recorded advantages of using biofertilizers?	• Biofertilizers are expensive • Soil fertility and immunity increased • Quality of soil and produce improve • Amount of chemicals is reduced after using biofertilizers	• Quality of wheat grade – 1 improves	• Yield increase • Quality improvement • Nitrogen and phosphorus sequestration	• High biological activity to susceptible species of pests • Manifest in the death of pests in subsequent phases of development • Selectivity of action • Safety for entomophagus and pollinating insects

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
				• Resistance to insects and pathogens • Resistance to biopreparations • Lack of phytotoxicity and effects on taste • Low waiting time • No risk of toxicity accumulation in the environment
6.5 What drives you to spend on biofertilizers?	• Biofertilizers reduce the impact of chemicals on soil, plants and human health • Stress resistance of plants increased • Better yields of sunflower	• They improve the quality of produce • Wheat yield increases by 80%	• Plants are strengthened • Resistance of plants is improved • Increase of yields • Qualitative products are obtained	• Yes, • Increasing the yield of agricultural products • Protecting the soil from harmful substances
6.6 Which company/brand biofertilizer(s) do you use or like to use?	• Agritema	• Baikal EM-1 • Ecolife Odessa • BIOLAND • Enzyme Agro • Bayer • Life Force Ukraine	• Life Force Ukraine • Humate K • PMK	• Biostimulator SVIT BINFIELD AGRO TECHNOLOGY
7.Additional Questions				
7.1 Do you prefer locally made products or foreign products (biofertilizers or biopesticides)?	• Local • Foreign	• Both • Local	• Both • Local	• Local

Questions	*Kharkiv*	*Luhansk*	*Sumi*	*Ivano-Frankivsk*
7.2 Would you be willing to pay more for a foreign product than for a local product?	• It depends on economic benefits • French products	• If effective, we can pay high price for foreign products too • We are satisfied with products of Life Force	• Local products have problems • Foreign product should be affordable and effective • Constant problems	• Yes • No
7.3 Scale 1-10: How willing are you to try a new/innovative product?	• 8 • 10 • 8 • 7 • 9 • 10	• 9 • 8 • 7 • 8 • 5 • 6	• 6 • 6 • 7 • 7 • 8 • 6	• 5 • 10 • 2 • 10
7.4 Which local or international organic certification do you trust?	• Both	• Local	• International	• ECO Control • EU Organic Bio
7.5 What soil amendment products do you currently use?	• Humate, N, K	• Biocomplex BTU • Agritema • Bayer • Humate, K, Na	• Enzim State Enterprise, BTU-Center Private Enterprise	
7.6 Are you experiencing problems with impoverished soil?	• No	• Soil in Ukraine is losing fertility very fast • Destruction of stubble • Soil fertility is decreasing	• Destruction of stubble	• Yes constantly

6. Comparative investment and economic risks

The respondent Ukrainian user farmers of chemical fertilizers were asked how much they spend on chemical fertilizers and pesticides (Table 3). Seven farmers gave the rough estimate of expenditures of an average UAH 457.15 per hectare (Table 3). From among 24 respondent farmers in Ukraine who use biofertilizers and biopesticides, 11 farmers gave figures of their expenditure on chemical fertilizers and pesticides. Their spending ranged from UAH 5000 to UAH 9250 per annum per hectare (with an average of UAH 7504 per annum per hectare) on chemicals (Table 4).

Some respondent farmers provided information slightly different than the question posed yet still informative. For instance, one respondent farmer said that UAH 130 were spent on processing seeds, while other farmers stated that 350 kg of chemical fertilizer was required (Table 4) and that 8400 kg ammonium nitrate per ha was needed. Similarly, one respondent farmer stated that the cost of unical was UAH 314.8 per litre, but did not provide the quantity used (Table 4). However, another respondent farmer suggested that chemical fertilizers cost 2-3 times more than biofertilizers or organic fertilizers (Table 4).

The respondent Ukrainian farmers using biofertilizers and biopesticides did not properly describe their expenditure on buying the biofertilizers and biopesticides (Table 4). Several respondent farmers said that biofertilizers cost more than mineral fertilizers, which is absolutely incorrect. It has been established that the per unit price of biofertilizer is quite higher than that of chemical fertilizer, but, expenditure per unit area of land is far less. One respondent farmer could not differentiate between biofertilizer and organic fertilizer, and hence said that organic fertilizers are no longer available due to declining livestock in Ukraine (Table 4). Another respondent farmer stated the price of biospore (UAH 1317.5 per canister), another stated the price of PMK–U (UAH 1395 per canister) and yet another stated the price of humate LF20 (UAH 1550 per canister). However, two respondent farmers indicated that UAH 2000 and 4000 per hectare per annum expenditure are needed to purchase biofertilizers and biopesticides, respectively (Table 4). This amount comes to an average of UAH 3000 per hectare per annum. Comparing the average spending on biologicals, this expenditure of UAH 3000 per annum on biofertilizers/biopesticides (Table 4) is far less than the respondent farmers' average expenditure of UAH 7504 on chemical fertilizers and pesticides.

Surveyed Ukrainian farmers using chemical fertilizers provided no exact calculation of the economic or investment risks of crop cultivation with chemicals if the crop fails due to nutrients' deficit, disease, pests, nematodes, or insects. (Table 3). The respondents replied using concepts such as 'huge sum and a lot' and referred to a number of costs, such as labour, diesel, fertilizers, pesticides, tax, warehouse, transport, seed, traction, rent, equipments, repair works, and fertilizers (Table 3). Like users of chemical fertilizers, the users of biofertilizers and biopesticides were also asked the question, "can you calculate the economic or investment risks of crop cultivation under chemicals if the crop fails due to nutrients' deficit, disease, pests, nematodes, insects, etc.?" The respondent Ukrainian farmers stated that the efficiency of biofertilizer directly depends on usage methods and usage needs systematic and constant application (Table 4). They also stated that, when biologicals are used systematically and properly, the yield and production are higher (Table 4).

The question "what investment or economic risks are involved if the crops are grown by using biologicals?" was answered by the respondent farmers using biofertilizers and biopesticides. The respondents opined that biologicals are less effective and do not work in dry soil (Table 4), hence inoculants are used by farmers. Several farmers further stated that bacterial products do not work effectively if not used side by side with mineral and organic fertilizers because they require very careful usage methods (Table 4). Moreover, they presented their views that bacteria may not survive for longer as its shelf life is short, which is risky (Table 4).

7. Farmers' preferences for fertilizers and biofertilizers

The respondent farmers who were users of chemicals fertilizers were asked for their preferences of using fertilizers and their potential preferences should biofertilizers be offered to them (Table 3). Similarly, respondent users of biofertilizers also expressed their preferences (Table 4). Usage of chemicals in crops indicates that most of the nutrients are nitrogen, phosphorus and potash. Ammonium nitrate, unical and complex fertilizer are reported as major sources of nitrogen (Table 3; Table 4). Micronutrients and calcium or magnesium attained least priority. However, organic manure and organic fertilizer are two reported sources of humus content for the soil (Table 3). According to government officers, however, not much humus is available in Ukraine now because livestock farms are shutting down and livestock are disappearing fast.

Through the question, "do you want to use biofertilizers?", the willingness of respondent farmers to use biofertilizers was understood. With the exception of 1-2 respondent farmers, respondents failed to demonstrate a firm willingness to use biofertilizers. Some respondents argued that biofertilizers are ineffective in temperate and non-irrigated zones, while others simply stated it was too expensive to use (Table 3). What would drive them to use biofertilizers in the future also generated negative responses by Ukrainian farmers using chemical fertilizers (Table 3). Their answers were the same – biofertilizers are neither effective nor economic. However, several respondent farmers argued that biofertilizers are not harmful and can be beneficial (Table 3).

The reasons for preferring biofertilizers over chemical fertilizers were explored with the respondent farmers using biofertilizers (Table 4). They responded that the root system of plants is developed, and immunity is enhanced, once biofertilizers are used (Table 4), and that the biofertilizers check the degradation of soil and improve quality of soil as well as plants (Table 4). Chemicalization of the soil does not take place. However, one respondent farmer expressed the view that both chemical fertilizer and biofertilizer are expensive and they give results after using 2-3 years of application (Table 4). The respondent farmers also confirmed that they use chemical fertilizers and biofertilizer(s) simultaneously (Table 4). Biofertilizers give effective results if used simultaneously (Table 4).

The respondent Ukrainian farmers using biofertilizers disclosed the perceived or recorded advantages of using biofertilizers (Table 4). According to the respondent farmers, soil fertility/quality and plant immunity/yield increased with improved quality of wheat grade-I (Table 4). They also reported that the amount of chemicals needed is reduced after using biofertilizers, which promote nitrogen and phosphorus sequestration. Moreover, plant protection functions are also delivered by biofertilizers, which trigger high biological activity to susceptible species of pests (Table 4). This manifests in the death of pests in subsequent phases of development, while ensuring safety for entomophagus and pollinating insects. After all, biofertilizers build resistance to insects and pathogens with lack of phytotoxicity and no risk of toxicity accumulation in the environment (Table 4).

The factors which drive respondent user farmers to purchase biofertilizers include their being economically cheaper, poison free, and ecologically safe. The farmers using biofertilizers suggested that plants are strengthened with increased resistance through using biofertilizers. Moreover, biofertilizers reduce the impact of chemicals on soil, plants and human health (Table 4). These respondent farmers stated that crops, like sunflower, produce better yields (80% increase) and better quality of grains, fruits and tubers, and forage (Table 4).

The surveyed farmers using biofertilizers provided the names of some manufacturers of biofertilizers which they prefer, including Agritema, Baikal EM-1, Ecolife Odessa, BIOLAND, Enzyme Agro, Bayer, Life Force Ukraine, Humate K, PMK, Biostimulator and SVIT Binfield Agro Technology (Table 4).

Potential preferences of respondent farmers regarding the use of local or foreign products (biofertilizers) were identified through interview questions. Most of the respondent farmers showed preferences for using local biofertilizers (Table 3). Only a few respondent farmers preferred both local and foreign made products (Table 3). Similarly, respondent user farmers of biofertilizers gave their preferences as to both local and international products (Table 4). However, many respondent farmers have shown no preference to pay more for a foreign product rather than for a local product (Table 3). Yet, majority of respondent farmers stated that they could pay more for foreign products if they are relatively more effective and their quality is better (Table 3). In the same fashion, respondent farmers using biofertilizers were asked the question, "would you be willing to pay more for a foreign product than for a local product?" There was a mixed response on this issue. The majority of respondent farmers using biofertilizers showed willingness to use a foreign product (Table 4), although many of them stated that this willingness was conditional. They expressed that preference for biofertilizers depends on economic benefits, effectiveness, affordability, and other qualitative traits (Table 4). One respondent farmer refused to accept foreign products due to satisfaction with products of Life Force company (Table 4).

The respondent farmers' willingness scale to try a new/innovative product was probed as well. Out of 12 surveyed farmers, 9 farmers opted to share their willingness on a total 10-point scale (Table 3), with the average of 5.55 out of 10-point scale (Table 3). It is significant that more than half of the respondent farmers have a willingness to use biofertilizers in the future. Likewise, all 21 respondent farmers from the 4 different oblasts of Ukraine shared their willingness to try a new/innovative product on 10-point scale (Table 4). Their average score on this scale was 7.3 (Table 4). This score is higher than the respondent farmers using only chemical fertilizers, which may be because the users of biofertilizers have already adopted new products and innovations and thus are more willing to try another set of innovations.

As certification and standards are key to the acceptance and preference of biofertilizers, respondent farmers using chemical fertilizers were surveyed, but they did not provide responses (Table 3). The same was true of respondent farmers using biofertilizers (Table 4). Together, they have equal trust in both kinds of certifications and standards. They noted the names of the two trusted certifications – ECO Control (Ukrainian) and EU Organic Bio (international) (Table 4). Respondent Ukrainian users of biofertilizers informed that they exclusively use soil amendment products such as Humate, Biocomplex BTU, Agritema products, Bayer products, K, Na, and Enzim (Table 4). The respondent farmers using biofertilizers shared their experiences concerning problems they are facing with impoverished soil (Table 4). Some respondent farmers answered negatively, while others stated that soil in Ukraine is losing fertility very fast and they are constantly facing difficulties (Table 4).

DISCUSSION

1. Soil performance under chemical fertilizers

Chemical fertilizers affect soil, plants, ecosystems and human health. When using chemical fertilizers, the soil becomes drought-prone, water-deficit, hard, compact, water-scarce, infertile, polluted and less productive. After the introduction of mineral fertilizers, the intensity of the natural conversion of atmospheric nitrogen to the compounds that can be assimilated by plants is reduced. The mineral salt solutions are harmful to soil microorganisms that form a layer on the fertile soil, and hence the formation of humus slows down. Chemical fertilizers can increase the radioactive lead (^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb), which causes accumulation of heavy metals in soil and plant bodies. A few respondent Ukrainian farmers stated that the impact of chemical fertilizers on soil depends on the quantum of chemicals being used and that only excess of mineral fertilizers cause harmful effects on soil.

2. Health and ecological risks from chemical fertilizers

The common diseases that can be attributed to usage of chemical fertilizers are: skin diseases, kidney problems, respiratory diseases, indigestion, memory loss, lung ailments, mental and physical weakness, menstrual disorders, loss of immunity, loss of work efficiency, eyesight weakness, gastrointestinal problems, poisoning, vomiting, cancer (if residues persist), phlegm of the upper respiratory tract, rhinitis, laryngitis, bronchitis, pneumoconiosis, hepatitis, chronic intoxication of the body, asthma, weakened immune system, miscarriages of pregnant women, and mutagenic and embryotoxic effects. Mineral fertilizers accelerate leaching of calcium, magnesium, zinc, copper, and manganese from the soil. Leaching affects the processes of photosynthesis and reduces the resistance of plants to diseases. Mineral fertilizers lead to reducing soil porosity and granular aggregates, and finally leads to acidification of the soil. Nitrogenous fertilizers pose the greatest danger to humans and agroecosystems. Nitrates are especially dangerous for infants, because their enzyme base is imperfect, and recovery of methemoglobin into hemoglobin is slow. Biofertilizers, on the other hand, are safer compared to chemical fertilizers. Biofertilizers do not pollute water and air and keep the environment clean as they trigger oxidation of soil. Biofertilizers remove ions of heavy metals from soil and clean the contaminated soil.

3. Soil performance under biofertilizers

Biofertilizers are confirmed to improve the soil texture and profile, while enhancing soil fertility. Another significant advantage of using biofertilizers is that they are toxin-free, non-poisonous, harmless to soil, environment friendly, and disease resistant. Biofertilizers are also claimed to support plants and human health, reducing carbon footprints, while helping plants grow better and more safely. The microbes of biofertilizers solubilize nutrients (micronutrients too) of the soil and make them available to plant roots. Another aspect of microbes acting in the soil is their ability to enhance soil's water retention capacity, enabling the soil to retain moisture in which nutrients dissolve and become available to plants. Biofertilizers increase soil temperature by 2-5^{o}C which enhances root formation and germination of seeds. Fruiting, blooming, germination, and root formation are supported by the bacteria that feed on root secretions and release growth metabolites.

The bacteria feed on secretions of root system in rhizosphere. Some biofertilizers have additional strength to defy enemy insects and pests, thereby reducing the use of plant protection chemicals. Biofertilizers are also reported as increasing plant and soil immunity while improving quality of produce. Biofertilizers work on a synergistic basis or on antagonism principles and, as a result, fermentation process makes leaves and fruits of plants inedible to the pathogenic microbes. Finally, plants becomes more resistant to pathogens, drought and frost. As a result, soil becomes resistant to fungal diseases, drought and other pathogens since biofertilizers reduce negative impacts of chemicals on soil fertility and reduce the residues by 60%. The respondent farmers also indicated that biofertilizers solve salinity problems in the soil.

4. Soil-water regime under biofertilizers

Biofertilizers reduce irrigation needs by 2 times at least for a crop (e.g. wheat) grown with biofertilizer(s) usage. The moisture is built up in soil when biofertilizers are applied, as the biofertilizers provide natural water permeability of the fertile layer of soil. Moisture remains for longer in the soil and 40-70% of water is kept in rhizosphere once biofertilizers are applied. Biofertilizers synthesize biologically active substances by dissolving, for example, silicate and other substances including nitrogen, potassium and phosphorus. They humidify soil layers and maintain air and water permeability of soil layer (at least 60 cm deep). Biofertilizers transform microelements to become easily digestible by plants and also contribute to the aeration of the soil, water retention, filtration ability, rate of cation exchange in the soil. Moreover, humus that causes plant growth is formed, aiding in resistance to drought and water holding capacity of the soil. Consequently, moisture solubilizes nutrients and enhances uptake by plant roots and hence nutrients intake is facilitated by moisture. Therefore, the effect of dry spell is minimized. Some farmers stated that the bacteria dissolve phosphorus in soil and increase salt index level that regulates pH of the soil. This all supports plant growth. The bacteria recycle and dissolve intractable phosphorus in soil and make it accessible to the plants. Certain bacteria strain dissolve ammonia, amino-silicate and release potassium and hard nitrogen. As a result, quality and size of grain (I & II grades) and straw improve.

5. Comparative yield & characteristics of produce

There is a reported 10-15% increase in yield and production after using biofertilizers. For example, the use of *Bacillus amyloliquefaciens* increases yield by 10%. The tubers, grains and fruits have better taste, size, quality, production, shelf-life, and color after biofertilizers are used. Noticeably, the size of the harvest depends on the density of productive stalk and mass of grain from one ear, and biofertilizers boost all these entities. Likewise, *Actinomycetes* inhibit the growth of pathogens and stubble. In fact, bacteria help the plants produce higher growth by mobilizing the vitamins, carotenes, proteins and increasing qualitative indicators of plants. The respondent farmers also confirmed that plant products get saturated color and better quality once biofertilizers are applied.

6. Comparative investment and economic risks

Expenditures per unit area of land on buying chemical pesticides/fertilizers and biofertilizers/biopesticides were compared. Ukrainian farmers stated that it costs more than 2-3 times the price of chemical fertilizers/pesticides when compared to biofertilizers or organic fertilizers and biopesticides. In Ukraine, the average spending on biologicals was UAH 3000 per annum versus average spending of UAH 7504 on chemical fertilizers and pesticides. An investment or economic risk if the crops grown by using biologicals exists. When the risk of the losses was quite high (60-70%) with the chemically grown crops, the risk of losses reduces to average 33% if crops grown by using biologicals. Therefore, risks reduce considerably if biologicals are used.

7. Farmers' preferences for fertilizers and biofertilizers

Nitrogen, phosphorus and potash are the main nutrients used in crops. Micronutrients and calcium or magnesium attained least priority. Common fertilizers include NPK (nitrogen, phosphorus, potassium), calcium nitrate, DAP (diammonium phosphate), MoP (molybdenum phosphate), ammonium nitrate, unical and complex fertilizer. Among the micronutrients, only the molybdenum was found being used by some farmers. How are biofertilizers applied? The respondent farmers confirmed that they use chemical fertilizers and biofertilizer(s) simultaneously. What drives respondent user farmers to purchase biofertilizers? Some advantages of using biofertilizers were stated to be production sustainability, input cost reduction, cheaper prices, ecologically safe, organic status, health and safety.

The respondent farmers' average willingness to adopt biofertilizers was measured. The respondent Ukrainian non-user of biofertilizers showed an average willingness of 5.55 out of 10-point scale (nearly 55%). On the other hand, the average willingness score of users of biofertilizers is 7.3 (i.e. 73%). This reflects that users of biofertilizers express greater willingness to adopt biofertilizers, yet the willingness of non-users of biofertilizers is not less. These respondent farmers showed preferences for using both local and foreign made biofertilizers. Moreover, they also trust both local and international organic certification.

CONCLUSION

A biofertilizer contains living microorganisms that are applied to seed, plant surfaces, or soil, and that colonize the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Some common agents in biofertilizers include *Rhizobium*, *Azotobacter*, *Azospirillum*, phosphorus solubilizing bacteria (PSB) and *Mycorrhizae*. The agronomic advantage of biofertilizers compared to conventional chemical fertilizers is well proved biologically and in economic terms. The biofertilizers are safer ecologically and in context of public health. The biofertilizer is broad spectrum efficient inoculum tested to boost production, soil biology and agroecosystem sustainability. In the study, two important economic angles are highlighted by the respondents: 1) reduced risks of crop failure if using the biofertilizers; and 2) comparatively lesser inputs and investment are needed to grow crops if biofertilizers are added. Such economic and scientific advantages of using biofertilizers ultimately mobilize the respondent farmers preferring biofertilizers over the chemical fertilizers.

A problem lies with the production and supply of biofertilizers in Ukraine. Both the production and distribution are inadequate compared to the demand for microbial biofertilizers. However, a dozen companies are operational in Ukraine trading and supplying biofertilizers and other soil nutrients. The farmers using biofertilizers prefer using the microbial products, with certain reservations about quality of products, effectiveness and shelf life of microorganisms. The findings of this study revealed the scientific and practical advantages of using biofertilizers, however, studies need to be pursued to understand reasons of such trade gaps and slow growth of biofertilizers in agriculture sector of Ukraine.

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Appendix 1. Questions for Scientists/Academics

- *Scientific features of biologicals being manufactured*
  - Composition or ingredients of biologicals
  - Physico-chemical properties or characteristics of biologicals
  - Fertility or Epidemiological functions
  - Efficacy or efficiency of biologicals
  - Toxicological information
  - Shelf-life of the biological product
- *Characteristics of biologicals*
  - How can biofertilizer be distinguished from chemical fertilizer?
  - What are the general characteristics of biofertilizers?
  - How do biofertilizers function when they are applied onto soil or plants?
  - What are ecological functions of biofertilizers?
- *Comparative advantage of using biologicals*
  - Are biofertilizers economic compared to chemical fertilizers?
  - Can you give any calculation of the costs of both?
  - How are biofertilizers advantageous to chemical fertilizers?
  - What are ecological advantaged of biofertilizers?
  - Biosafety and hazardousness related issues: which is better?
  - What area advantages related to soil biology?
  - How will the use of biofertilizers solve environmental problems?

Appendix 2. Manufacturers, suppliers, importers and traders of microbial biofertilizers

Questions	*Responses – Ukraine*
What kinds of biologicals in what quantities with what effectiveness are being used by farmers?	
Categories of biofertilizers manufactured or supplied/traded	• Microbes-based
Any efficacy or efficiency tests/data of such biofertilizers?	• Field trials result 42% increase of the yield of wheat. • For all products stated tests were conducted. 10-30% increase in efficiency.

Appendix 3. Questions for Government Officers

Status of Existing Microbial Biotechnologies and Natural Compound Technologies of Biofertilizers & Biopesticides

- What kinds of biologicals in what quantities with what effectiveness are being used by farmers?
  - Categories of existing biofertilizers
  - What's basis of this classification/categorization?
  - Any list of category-wise (registered) biofertilizers?
  - What recommended quantities of these different biofertilizers are applied for which crops?
  - Any efficacy or efficiency data of such biofertilizers?