REVIEW ARTICLE

SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua

Scientific Horizons, 25(6), 129-137

UDC 631.82

DOI: 10.48077/scihor.25(6).2022.129-137

Smart Fertilizers as a Solution for the Biodiversity and Food Security During the War in Ukraine

Ermir Shahini[1*], Eugen Skuraj[2], Fatbardh Sallaku[2], Shpend Shahini[2]

[1]Aleksandër Moisiu University of Durrës
2001, 14 Currila Str., Durres, Albania

[2]Agricultural University of Tirana
1025, Paisi Vodica Str., Tirana, Albania

Article's History:
Received: 14.07.2022
Revised: 15.08.2022
Accepted: 14.09.2022

Suggested Citation:
Shahini, E., Skuraj, E., Sallaku, F., & Shahini, Sh. (2022). Smart fertilizers as a solution for the biodiversity and food security during the war in Ukraine. *Scientific Horizons*, 25(6), 129-137.

Abstract. The ongoing war between Russia and Ukraine has resulted in widespread damages and loss of lives in highly populated cities, advanced to rural settings as well as sparked massive displacement amongst the population. The two nations are the key exporters of agronomic goods, and they play a huge role in supplying international markets with food products and fertilizers and the ongoing war has led to shortage of supply of these products. The purpose of this study is to present the current aspects related to the use of smart fertilizers as an opportunity to ensure food security and biodiversity. To fulfil this purpose, scientific publications were analysed, and the following groups of methods were employed: dialectical method of scientific cognition, general scientific and special methods. To summarise the scientific and methodological nature, an abstract-logical method of approach to examining the possibilities of using smart fertilizers in agriculture and drawing conclusions was used. Furthermore, the method of logical observation and analysis was used, and based on input data and correlations, conclusions were made that correspond to the object of the study. The generalization method was used to summarise the results of the study. As a result of the study, it was found that the use of smart fertilizers leads to less absorption of resources by agricultural crops, lesser losses in the form of leaching, run-off and denitrification, and a favourable impact on the surrounding natural environment. Moreover, their use is a necessary approach to increase the production of foods, which is necessary to make provision for the population and support economic development. The findings of the current study show that smart fertilizers can serve as a solution for the biodiversity and food security during the Russian invasion in Ukraine

Keywords: russian invasion, innovation, sustainable agriculture, nanotechnology, international markets

**Corresponding author*

INTRODUCTION

The Russian invasion in Ukraine has subjected the international markets to more vulnerabilities due to shocks and be more volatile. On average, both nations account for 19%, 14%, and 4% respectively, of worldwide production of wheat, barley, and maize for 2016-2020. In terms of oilseed production, their output globally was significant for sunflower oil, in which half of the global production originated from two nations (Astrov, 2022; Blinnikov, 2021). In 2021, both Russia and Ukraine were among the world's top three producers of corn, wheat, sunflower oil, seeds, and rapeseed, while Russia ranked the world's top three for nitrogen fertilizer supplier, potassium fertilizer export, and phosphorus fertilizer supplier, respectively (Boincean & Dent, 2019; Mbah & Wasum, 2022). The ongoing invasion in Ukraine has therefore subjected global markets to shock since food markets are striving because of increasing prices and other constraints faced globally due to the COVID-19 pandemic. Several nations that highly depend on Russia and Ukraine for importation of food products and fertilizers including less developed countries are currently facing serious deficits since they had the challenges of soaring prices globally of foodstuffs and fertilizers as well as dealing with the COVID-19 pandemic (Butzen, 2013; Calabi-Floody *et al.*, 2012).

Further, the invasion in Ukraine has led to persistence in insecurity and eventually the disruption of local and state supply chain which has resulted to individuals falling into more hunger and increased cases of malnutrition (Nagarjuna, 2022; Nevzorova, 2020). Particularly, the war has disrupted winter harvest and spring planting and has also led to agricultural labour accessibility due to massive displacement that has taken place. This invasion has also led to limited access to agricultural inputs including fuel, seedlings, fertilizers as well as insecticides and eventually disrupted logistics and every aspect of food supply chain. The military activities in Ukraine have also damaged food crops and destructed agri-food systems and infrastructure (Calabi-Floody *et al.*, 2018; Dobermann *et al.*, 2020).

According to M. Ranjith and S. Surapaneni (2021), world population growth will increase, as will the pressure on global food systems and agriculture. Therefore, it will be extremely necessary to use modern technologies in agroecosystems to ensure adequate nutrition and minimise the adverse environmental impact caused by chemical fertilizers and inadequate processing of agricultural waste. A. Dobermann *et al.* (2020) noted that the next 10-20 years will be crucial for the transition to a global food system wherein mineral nutrients in agriculture must be used in a more holistic way, and achieving this requires highly efficient use of all available organic and inorganic nutrient sources substances adapted to the specific features of food systems and agroecosystems in different regions of the world.

Continuous application of fertilizers is essential to support and increase food production. However, there are problems associated with the use of mineral fertilizers due to the low uptake of nutrients by crops in productive systems (Hunt *et al.*, 2021). To provide solutions for current and future issues in agriculture and the possibilities of solving them, the optimal combination of biotechnologies and nanotechnologies has great potential. According to foreign studies by M.Y. Naz and S.A. Sulaimann (2016) – the development and use of intelligent fertilizers with controlled release of nutrients together with biopreparations based on bacteria or enzymes is essential for the revolution in agricultural systems.

M. Calabi-Floody *et al.* (2018) conducted research to provide a critical understanding of current food security challenges and the role of smart fertilizer development in future food production. The authors also focused on advances in the development of biofertilizers and the use of crop residues as coating and carrier materials. Furthermore, R.K. Sastry *et al.* (2021) have argued in their paper "Smart Fertilizers as a Strategy for Sustainable Agriculture" that new types of smart fertilizers with controlled nutrient release are needed to improve nutrient use efficiency. The development of such fertilizers can be based on the use of microorganisms (biofertilizers) and/or nanomaterials (nanofertilizers). In this context, nanotechnology is a promising and rapidly developing field of interdisciplinary research that can revolutionise food systems. Nanotechnology involves the development, synthesis, and use of materials at the nanoscale level from 1 to 100 nm. In this aspect, the properties of materials are fundamentally different from the properties of individual atoms, molecules, or mass of matter (Mammadov, 2022). The ability to manipulate matter at the nanoscale can lead to a better understanding of biological, physical, and chemical processes and to the creation of improved materials, structures, devices, and systems that can be used in agroecosystems (Jeločnik *et al.*, 2020; Qian & Hinestroza, 2004).

The purpose of this study is to present the modern aspects related to the use of smart fertilizers as an opportunity to ensure food security. Since there is a great interest in the development of new innovative fertilizers to increase the efficiency of growing agricultural crops, this is of particular relevance to the research.

MATERIALS AND METHODS

The current study used a systematic review method to analyse existing literature on the topic under study. The theoretical framework of this study included the main provisions and results of the studies carried out by many researchers, which relate to the use of smart fertilizers in the technologies of growing agricultural crops to overcome the issue of ensuring food security.

Scientific literature was analysed through a series of searches refined by journal type, year of publication, subject area, and specific keywords. The procedure that was followed involves first identifying the articles, then

screening them and including only those publications that are relevant to the current topic under study. Information gathered was analysed by use of the Farm Economics and Solvency Projector model while assuming that the fertilizers utilised in farming were procured in 2022.

Since the purpose of this study was to identify modern aspects of the use of smart fertilizers as an opportunity to ensure food security and biodiversity, it was important to analyse the world practices of using smart fertilizers and their impact on the environment. Furthermore, an essential aspect was also to find the future perspective of the use of smart fertilizers and the possibility of their introduction in Ukraine, especially against the background of the risk of military aggression and the growing food crisis.

In the article, the following methods were used: dialectical method of scientific cognition, general scientific and special methods. To summarise the scientific and methodological nature, an abstract-logical method of approach to studying the possibilities of using smart fertilizers in agriculture and drawing conclusions was used. In addition, the method of logical observation and analysis was used in the study, based on input data and correlations, conclusions were made that correspond to the object under study. To conclude the results of the study, the generalisation method was used.

The presented study was carried out in three main stages.

1. Theoretical analysis was used to identify the available methodological approaches dedicated to the issue of ensuring food security, especially as a result of military aggression; the problem, purpose, and methods of study were identified, and a plan of scientific research was drawn up.

2. An analysis of the results of the use of smart fertilizers was carried out; scientific research, analysis, and formation of the results obtained during the study.

3. Based on the obtained results, the final conclusions of this study were formulated; the main aspects of the possibilities of using smart fertilizers to ensure food security and biodiversity were analysed; the obtained results were summarised and systematised.

The provisions and proposals formulated and substantiated in this paper constitute a strong basis for solving the research-to-practice foundations concerning the organisational and economic justification of developing opportunities for solving the global food crisis through the rational use of smart fertilizers.

RESULTS

The Russian invasion of Ukraine will affect the global food security and biodiversity because the world community is so interconnected that a crisis at any point is felt everywhere. The war in Ukraine has an impact on losses that lead to critical disruptions in the supply chain, food production, access to fertilizers, energy carriers, which were already barely organised due to the global pandemic. Furthermore, the cost of food products and basic niche agricultural products is rising rapidly. As a result, more people are at risk of becoming vulnerable to famine. The very issue of preventing a food crisis has become serious, especially against the background of Russia's war against Ukraine.

The significant role played by Russia and Ukraine in the agricultural arena globally is clear as seen in the global trade viewpoint. The two nations are the biggest suppliers of agricultural goods globally. For instance, Russia is the net exporter of wheat globally since in 2021, it shipped 32.9 million tonnes of wheat which translates to 18% of worldwide shipment. In addition, Ukraine ranked sixth amongst the top wheat exporters in 2021, supplying 20 million tonnes of wheat which stands for 10% worldwide market share (Jorquera *et al.*, 2021). Russia and Ukraine are also both prominent in the international trade arena since they are the largest exporters of maize, barley, and rapeseed as well as sunflower oil in which they hold a market share of approximately 80% from the year 2018 to 2021 (Kirilenko & Dronin, 2022). Apart from exporting food products, these two countries also important in the export of fertilizers with Russia being the lead exporter of fertilizer. In 2021, the Russia was ranked as the leading supplier of nitrogen (N) fertilizers, came in second position of supplying potassium (K) fertilizers and in third position in exporting phosphorous (P) fertilizers (Korovkin & Makarin, 2021). Both Russia and Ukraine are the biggest exporters to several nations that entirely depend imported agricultural products and fertilizers. Many of these nations fall under the group of the less-developed nations while others are characterised by low-income economies. For instance, a country like Eritrea entirely sourced its wheat products in 2021 from Russia 53% and Ukraine 47%. Additionally, several nations located in North, West, and Central Africa entirely depend on supplies from Russia and Ukraine (Kumar *et al.*, 2007; Lang & McKee, 2022).

The actual level of application of smart fertilizers in different countries of the world is quite high. First of all, the highest indicator is observed in the Netherlands, where on average 258 kg of fertilizers are used for agricultural production per 1 ha of available land, in Great Britain – 247 kg, Israel – 240 kg, Germany – 202 kg, Poland – 176 kg, France – 169 kg, the Czech Republic – 153 kg, the USA – 137 kg, Italy – 129 kg, Hungary – 118 kg, Turkey – 107 kg (Gutiérrez-Moya *et al.*, 2021). During 2021-2022, the total amount of smart fertilizers applied in agricultural enterprises of Ukraine with a land use area of more than 1 ha increased from 98 kg to 123 kg (Hosseini, 2022). However, the current level of use of smart fertilizers in Ukrainian agriculture, despite the positive trends of recent years, is still quite low.

According to preliminary data, the average yield of wheat in the territories controlled by Ukraine in 2022 is 4.14 t/ha (Lang & McKee, 2022). Odesa region becomes the main "wheat region of Ukraine" in the wartime agricultural season. Here, in the part controlled by Ukraine, 18.1 million tons of wheat grain were collected. The application of smart fertilizers positively affected the growth and development of wheat and at the same time increased the yield in the final result (Fig. 1).

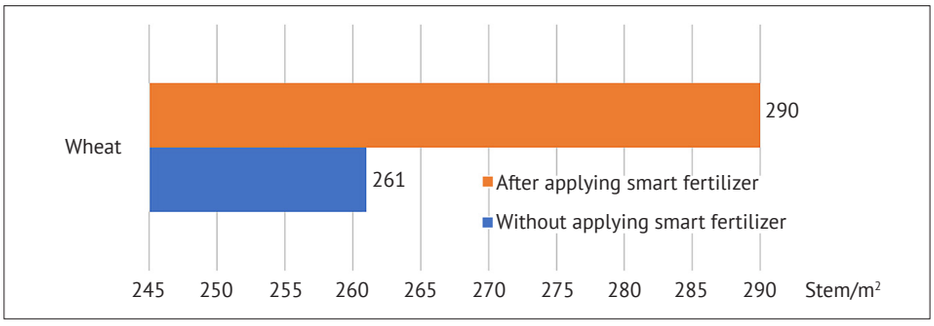

***Figure 1**. The number of productive stalks of wheat, depending on the application of reasonable fertilizers*
***Source:** compiled by the author*

Canada is Ukraine's closest competitor on the world wheat market (Fig. 2). Analysts of Agriculture and Agri-Food Canada (2022) in the May report increased the forecast of wheat production in Canada in 2022-2023 by 0.4 million tons to the previous indicator (31.6 million tons). It will also significantly exceed the grain harvest collected in the previous season (21.7 million tons). In turn, USDA experts left unchanged the wheat production forecast for Ukraine for 2022-2023, which amounted to 19.5 million tons (World Agricultural Supply..., 2022).

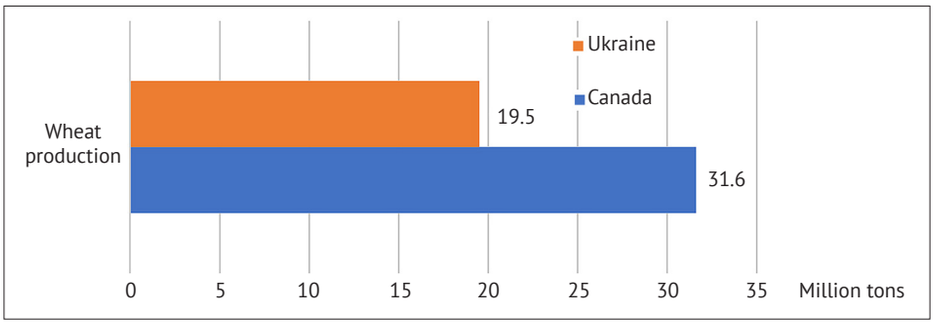

***Figure 2**. Wheat production forecast for Ukraine and Canada for 2022-2023*
***Source:** compiled by the author*

Experts (Astrov *et al.*, 2022) warn that Russia's military actions on the territory of Ukraine will negatively affect the functioning of food systems and even lead to serious threats to global food security. Considering the exceedingly difficult conditions in which Ukrainian farmers have to work, it is necessary to take a very rational approach to all production processes, as well as to the selection of fertilizers. Mineral fertilizers help farmers get high yields and feed the population, however, they still harm nature. In turn, smart fertilizers are in special "capsules", they enter the soil more slowly, which allows plants to absorb them more than once. The capsules can be set to release doses of fertilizer at specific intervals, depending on the nuances of the soil, temperature, acidity, and humidity. This allows saving on costs and improve the condition of local ecosystems. When using smart, high-quality fertilizers, farmers can reduce the rate of sowing, shorten the time of sowing, and reduce the use of added nutrition.

The outcome of the invasion in Ukraine implies that nations that entirely depend on Russia and Ukraine for essential foodstuffs and fertilizers ought to produce other approaches including the use of smart fertilizers as a solution for the biodiversity and food security during this war period in Ukraine. The invasion has resulted in limited supply of food products and fertilizers to the international food system resulting to food insecurity. As a result of the looming food shortage across the globe, it is imperative that nations that initially depended on Russia and Ukraine for foodstuffs and fertilizers adopt innovative technology with the aim of producing enough food and agricultural inputs to curb food insecurity. This can be achieved through combining biotechnology and nanotechnology to transform the agricultural system and offer a solution to the present and imminent challenges associated with food insecurity. Innovative technology that can be adopted include the adoption of smart fertilizers while controlling nutrients released as well as the use of

bioformulations composed of bacteria and enzymes. Fertilizers can only be classified as smart if, on application to the soil surface, it can allow control over the amount, time, and period of nutrient release. Therefore, smart fertilizers can be defined as a single or composition of (sub) nanomaterials, multi-components as well as bioformulations which contain various nutrients that can physically, chemically or biologically adapt the timing of releasing nutrients to the plants as per their demand and enhance the agricultural output as well as be able to reduce the environmental effect at sustainable expenses in comparison to traditional fertilizers (Gutiérrez-Moya *et al.*, 2021; Hartmann *et al.*, 2010).

To ensure global food security, sustainable methods of agriculture are needed, which today faces several urgent and complex challenges that require innovative solutions. The three most significant are population growth, escalating consumer demand, and the introduction of innovative technology. Farming systems in the world involve the intensive use of substantial amounts of fertilizers and plant protection products to achieve higher productivity per unit of arable land to support and increase food production. However, there are problems associated with the use of mineral fertilizers, such as soil, water, air pollution, low efficiency of their use, development of resistance to diseases, pests and weeds, soil degradation, etc., which leads to increased doses of fertilizers. Unfortunately, more fertilizers do not guarantee increased crop yields, and nutrient utilisation efficiency is still extremely low due to many loss pathways, such as leaching, denitrification, microbial immobilisation, fixation.

Scientists have proposed several strategies to increase the efficiency of fertilizer use, such as precision fertilizer application, split or localised application, fertigation, and the use of nanofertilizers. Nanofertilizers are nanoparticle-based fertilizers where nutrients are provided to maximise plant growth, have higher utilisation efficiency by recycling plant-unavailable nutrients in the rhizosphere, and can be delivered to the rhizosphere in real-time or through foliar spray (Hosseini, 2022). The small size, high surface area and reactivity of nanofertilizers increase the solubility, diffusion, and availabilityof plant nutrients and increase the productivity of crops. Biopreparations are microbial preparations containing specific beneficial microorganisms that can fix, solubilise, or mobilise plant nutrients to promote plant growth and yield. Smart fertilizers are a better choice for farmers to increase crop yields with low inputs in an environmentally friendly way without degrading the natural environment.

The review of existing literature showed that nano fertilizer which is a form of smart fertilizers has the capability of increasing the use of nutrients in an efficient manner and subsequently minimise negative environmental impact as opposed to the use of traditional fertilizers (Manjunatha *et al.*, 2016; Ramona *et al.*, 2020). A study by L. Mastronardi *et al.* (2015) showed three different forms of nano fertilizers: nanoscale fertilizers, nanoscale additives and nanoscale coated fertilizers (Table 1). Nano fertilizers and nano composites that are slowly released are proper substitutes to solvent fertilizers. The release of nutrients takes place slowly when crops are growing which reduces losses. To ensure that nutrients are released slowly to the environ, there is need to use zeolites or natural clay, which plays the role of reserving nutrients (Shahini *et al.*, 2022). That nutrients which the plants for growth can be compressed in the nano materials including nano tubes as well as nano porous constituents, covered with a slight shielding polymer coat or nano scale elements (Lun *et al.*, 2021).

***Table 1**. Changes in price of organic fertilizers*

Price of organic fertilizers	Year 2020	Year 2021	Year 2022
Nitrogen Fertilizer	-3.22	7.29	9.94
Potassium Fertilizer	-0.79	5.87	13.61
Phosphate Fertilizer	-6.05	4.78	7.67

***Source:** compiled by the author*

According to the application method, it is likely to utilise artificial as well as natural nano particles acquired through different means such as plants, soil surface as well as microbes. Nano clays, which by nature are found on the soil surface are incredibly significant in today's agricultural activities since they hold physicochemical properties elements. Nano clays play a key role in terms of stabilising enzymes and in that way enhance their catalytic action for various biotechnology related functions (Hosseini, 2022). According to the works of some scientists (Jorquera *et al.*, 2011), the impact of synthetic allophane which is composed of artificial iron-covered allophanes as well as naturally occurring solid montmorillonite functions as support of phytases. This study further showed that immobilisation pattern within diverse pH values highly depend on enzymes and support features. Additionally, montmorillonite is seen as suitable immobility support for Escherichia coli phytase, while it inhibits Aspergillus Niger phytase action. M. Calabi-Floody *et al.* (2012) did another study aimed at evaluating and implementing the utilisation of natural clay and nano clay acquired from montmorillonite as well as allophonic clay as supporting elements for Acid Phosphatase in nano clay-cow manure-AP components.

The study established the existence of an obvious stabilisation of Acid Phosphate by the components through the process of encapsulation. It was further established an upsurge of both precise action at 48% and Vmax at 38% of the enzymes. Acid Phosphate was also found to immobilise on allophonic nano clay which enhances the process of releasing inorganic P from cow manure in comparison with free Acid Phosphate (Kirilenko and Dronin, 2022).

Advances in the application of biotechnology and nanotechnology have the potential to improve the management and efficiency of nutrient use in agroecosystems, including in Ukraine. Slow/controlled release smart fertilizers increase crop yields, improve soil productivity, and provide less nutrient loss compared to conventional fertilizers. Thus, as a result of this study, it was established that the use of smart fertilizers optimises the absorption and use of resources by agricultural crops, ensures lower losses in the form of leaching, run-off, denitrification, and a favourable impact on the natural environment. Furthermore, the use of smart fertilizers is a necessary approach to increase food production, which is incumbent to support the world's population in overcoming the food crisis and supporting economic development.

DISCUSSION

The modern agricultural system faces several challenges, the most important of which is the ability to supply food for a growing world population and mitigate climate change. To ensure food security for a growing world population, sustainable agricultural practices are required. The production of foods is usually associated with a high supply of nutrients in the form of mineral fertilizers, which are not always fully used by the plant itself. Since the beginning of agriculture, this practice has led to soil degradation and the release of environmental pollutants. In this context, increasing the effectiveness of fertilizers while reducing their cost and impact on the environment is one of the most critical tasks. Scientists and researchers have made many efforts to develop innovative fertilizers, defined as "smart fertilizers".

In the coming decades, pressure on global food systems will increase, and agriculture will face the challenge of ensuring food security for a growing world population without affecting environmental security. It will be necessary to use modern technologies in agroecosystems to ensure sufficient food and reduce the adverse environmental impact caused by chemical fertilizers and inadequate disposal or reuse of agricultural waste.

As for today, the issue of the ability of current crop improvement methods to ensure food security in the future still is uncertain. The demand for agricultural products will be further impacted by such factors as the reduction of the workforce in rural areas, climate change, moisture deficit, etc., which can have a massive impact on the quantity and quality of food products (FAO…, 2020). New types of smart fertilizers with controlled nutrient release are required to improve nutrient use efficiency. The development of modern fertilizers can be based on the use of microorganisms (biofertilizers) and/or nanomaterials (nanofertilizers).

In this context, nanotechnology constitutes a promising and rapidly developing area, as nanotechnology has many potential benefits, ranging from improving the quality and safety of food products to reducing the costs of agricultural production (Veronica *et al.*, 2015).

The combination of biotechnology and nanotechnology has the potential to revolutionise agricultural systems and provide solutions to current and future challenges. These include the development and use of smart fertilizers with a controlled release of nutrients together with biologics based on bacteria or enzymes. Smart fertilizers can also be a solution to increase food production and environmental quality.

Polymers are also smart fertilizer formulations that can serve as a solution for biodiversity and food security. Polymers are to a considerable extent utilised in agriculture particularly for the development of fertilizers. Smart polymeric components are applicable to smart delivery mechanisms of various agrochemicals (Puoci *et al.*, 2008; Jeločnik *et al.*, 2020). Different type of artificial components including polymers based on petroleum are useful in the encapsulation of solvent fertilizers. The key components that are presently utilised in coating include Polysulfide, polyacrylonitrile, polyvinyl chloride, polyurethane, as well as polystyrene (Sindhwani *et al.*, 2022). A study was carried out by A. Jarosiewicz and M. Tomaszewska (2003) with the aim of comparing the usage of the artificial polymers; polysulfide and polyacrylonitrile together with the recyclable cellulose acetate to develop a fertilizer that can be gradually released. The study established that physical features of the coating are capable of influencing the macronutrients including N, P, and K are released which are mainly found in the centre of the fertilizers with a coating. In addition, artificial nondegradable components have a gradual releasing rate as opposed materials with cellulose acetate. Another study by Y. Tao *et al.* (2011) was done to determine the utility of triple polymer fertilizers in encapsulating and enhancing the functional features of urea. The data obtained showed that the use of polyethylene, acrylic acrylamide, and butyl methacrylate as the third layers improved the controlled production of urea. Additionally, incorporating triple polymer fertilizers into the soil surface improves its ability to hold water which enhances the intake of nutrients and crop produce. However, replacing sulphur with dicyclopentadiene to enhance coating features, humidity as well as abrasion resistance and mechanical ability enhances the gradual release of fertilizers. The mechanical ability of the covering is associated with the dicyclopentadiene component, which is released efficiently by ameliorated nutrients (Blinnikov, 2021; Boincean and Dent, 2019).

Biodegradable polymers have also been widely utilised as alternatives of other polymers in farming. It was found that biodegradable polymers can be utilised for the gradual release of N and K fertilizer. A study by J. Zhang *et al.* (2016) showed polymer-covered N fertilizer can be developed by use of biobased polyurethane acquired through liquifying grasshopper sawdust as coating element. This study proved that the fertilizer showed high efficiency in releasing N to maize plants as opposed to traditional form of urea. Biodegradable polymers can therefore be utilised in bioformulations where they act as bacterial carriers. The carriers safeguard bacterial inoculants from distinct types of stress and extend their survival (Hartmann *et al.*, 2010; Kumar *et al.*, 2007). For instance, calcium alginate gel can protect bacterial cells as well contribute to increased duration of survival. In addition, Sodium alginates are to a great extent utilised for bioformulations, particularly microbial fertilizers together with insecticides. Despite being highly affordable and environmentally friendly, it is significant to blend biodegradable polymers with artificial materials to enhance their performance (Shahini *et al.*, 2022; Richardson *et al.*, 2016).

The research of M. Mora *et al.* (2021) serves as a confirmation of the results of this study, according to which, since the beginning of the development of agriculture, the practice of mindless application of fertilizers has led to soil degradation and the release of environmental pollutants, and therefore it is essential to focus on innovations in the production of organic and inorganic fertilizers and the development of smart fertilizers, including biological preparations with mineral particles, nanomaterials, and microorganisms that promote plant growth.

Furthermore, this study correlates with scientific claims (Veronica *et al.*, 2015; Butzen, 2013) that nanobiotechnologies can improve the understanding of the nature and genetics of various agricultural crops and thus potentially increase the yield or quality of products. As nutrient leaching causes environmental and water pollution, and excess nutrients promote the wide spread of pests and weeds, the rationalisation and optimisation of resources is a pressing issue and increasing the efficiency of plant nutrition without compromising productivity and economic sustainability will be imperative. Moreover, there is an opportunity to develop and improve systems to monitor environmental conditions and improve the ability of plants to absorb nutrients or respond to pesticides. Advances in the application of biotechnology and nanotechnology have the potential to improve nutrient management and utilisation and overall efficiency in agroecosystems.

The results of this study especially demonstrate the conclusions of many researchers, who claim that smart fertilizers due to their availability of nutrients are considered a new and effective way to achieve sustainable existence, the main thing is to develop the correct concept of using smart fertilizers.

Although knowledge of the balance between benefits and potential risk is in the initial stages of development, nanotechnology has the potential to improve agricultural productivity and contribute to food security. And among the latest lines of technological innovation, nanotechnology occupies a prominent place in the transformation of agriculture and food production. The development of nanodevices and nanomaterials can open new areas of application in plant biotechnology and agriculture. Therefore, smart fertilizers due to the availability of nutrients are considered a new and effective way to achieve sustainable management in agriculture.

CONCLUSIONS

The Russian invasion on Ukraine has led to various negative impacts on food security in the domestic and international arena. In the domestic setting, the invasion has constrained the nation's agricultural production which in turn will lead to food shortage in the whole country. In the global arena, the invasion has resulted to limited supply of food products as well as fertilizers to other countries which entirely depend on Russia and Ukraine for agricultural inputs and food stuffs.

Global challenges are changing rapidly, and with a growing population, limited resources and climate change, the complex challenge of providing the world with food is emerging. Increasing global food production sustainably can only be achieved thanks to balanced and rational use of fertilizers and organic agriculture because global food security is clearly impossible without fertilizers. The scientific research performed was undertaken to provide a critical review of information related to current food security issues and the role of smart fertilizer development in future food production.

Smart fertilizers such as slow and controlled release fertilizers, nanofertilizers, and biofertilizers are emerging technologies to improve nutrient use efficiency by increasing crop yields sustainably. The use of slow and controlled release fertilizers increases the efficiency of nutrient use and minimises the risks of water and environmental pollution.

Thanks to nanotechnology, many unresolved issues in the field of agriculture can be solved. The authors of this study expect that more focused research on energy, environment, crop improvement, disease control, and resource efficiency is needed to increase productivity and profit without harming the natural ecosystem. Future research should continue to evaluate the composition, production, agronomic, and environmental performance of different smart fertilizers.

It is recommended that the trade in food stuffs and fertilizer products is kept open through prevention of the invasion from having an impact on production and trade to make it possible to supply these products locally and internationally. It is also recommended that nations relying on Russia and Ukraine for food stuffs and fertilizers produce modern and diverse sources for these products.

REFERENCES

[[1] Agriculture and Agri-Food Canada. (2022). Retrieved from https://agriculture.canada.ca/en.
[2] Astrov, V., Grieveson, R., Kochnev, A., Landesmann, M., & Pindyuk, O. (2022). Possible Russian invasion of Ukraine, scenarios for sanctions, and likely economic impact on Russia, Ukraine and the EU. *Policy Notes and Reports*, 55, 1-28.
[3] Blinnikov, M.S. (2021). *A geography of Russia and its Neighbors*. New York: The Guilford Press.
[4] Boincean, B.P., & Dent, D.L. (2019). *Farming the black earth: Sustainable and climate-smart management of chernozem soil.* Cham: Springer Nature Switherland AG.
[5] Butzen, S. (2013). *Common nitrogen fertilizers and stabilizers for corn production*. Retrieved from https://www.pioneer.com/us/agronomy/common_n_fertilizers_stabilizers.html.
[6] Calabi-Floody, M., Rumpel, C., Medina, J., & Condron, L. (2018). Smart fertilizers as a strategy for sustainable agriculture. *Advances in Agronomy*, 147, 119-157.
[7] Calabi-Floody, M., Velásquez, G., Gianfreda, L., Saggar, S., Bolan, N., Rumpel, C., & Mora, M.L. (2012). Improving bioavailability of phosphorous from cattle dung by using phosphatase immobilized on natural clay and nanoclay. *Chemosphere*, 89(6), 648-655.
[8] Dobermann, A., Bruulsemab, T., Cakmakc, I., Gerardd, B., Majumdare, K., McLaughlinf, M., Reidsmag, P., Lini, V., Fusuo, W., & Xin, Z. (2020). Responsible plant nutrition: A new paradigm to support food system transformation. *Global Food Security*, 33, article number 100636.
[9] FAO Yearbook. (2022). Retrieved from https://www.fao.org/3/cb9236en/cb9236en.pdf.
[10] Gutiérrez-Moya, E., Adenso-Díaz, B., & Lozano, S. (2021). Analysis and vulnerability of the international wheat trade network. *Food Security*, 13(1), 113-128.
[11] Hartmann, M., Berditsch, M., Hawecker, J., Ardakani, M.F., Gerthsen, D., & Ulrich, A.S. (2010). Damage of the bacterial cell envelope by antimicrobial peptides gramicidin S and PGLa as revealed by transmission and scanning electron microscopy. *Antimicrobial Agents and Chemotherapy*, 54(8), 3132-3142.
[12] Hosseini, S.E. (2022). Transition away from fossil fuels toward renewables: Lessons from Russia-Ukraine crisis. *Future Energy*, 1(1), 2-5.
[13] Hunt, E., Femia, F., Werrell, C., Christian, J. I., Otkin, J. A., Basara, J., & McGaughey, K. (2021). Agricultural and food security impacts from the 2010 Russia flash drought. *Weather and Climate Extremes*, 34, articke number 100383.
[14] Jarosiewicz, A., & Tomaszewska, M. (2003). Controlled-release NPK fertilizer encapsulated by polymeric membranes. *Journal of Agricultural and Food Chemistry*, 51(2), 413-417.
[15] Jeločnik, M., Subić, J., & Kovačević, V. (2020). Agriculture practice as support for agro-tourism development at the family farms. In *Innovative aspects of the development service and tourism* (pp. 49-59). Stavropol: Stavropol State Agrarian University.
[16] Jorquera, M.A., Crowley, D.E., Marschner, P., Greiner, R., Fernández, M.T., Romero, D., & De La Luz Mora, M. (2011). Identification of β-propeller phytase-encoding genes in culturable Paenibacillus and Bacillus spp. from the rhizosphere of pasture plants on volcanic soils. *FEMS Microbiology Ecology*, 75(1), 163-172.
[17] Kirilenko, A., & Dronin, N. (2022). Recent grain production boom in Russia in historical context. *Climatic Change*, 171(3), 1-19.
[18] Korovkin, V., & Makarin, A. (2021). *Conflict and inter-group trade: Evidence from the 2014 Russia-Ukraine crisis*. Retrieved from https://d101vc9winf8ln.cloudfront.net/documents/38681/original/KorovkinMakarin_ConflictTrade_GMU2021.pdf?1614349763.
[19] Kumar, R., Mishra, A.K., Dubey, N.K., & Tripathi, Y.B. (2007). Evaluation of Chenopodium ambrosioides oil as a potential source of antifungal, antiaflatoxigenic and antioxidant activity. *International Journal of Food Microbiology*, 115(2), 159-164.
[20] Lang, T., & McKee, M. (2022). The reinvasion of Ukraine threatens global food supplies. *The BMJ*, article number 376. doi: 10.1136/bmj.o676.
[21] Lun, F., Sardans, J., Sun, D., Xiao, X., Liu, M., Li, Z., & Penuelas, J. (2021). Influences of international agricultural trade on the global phosphorus cycle and its associated issues. *Global Environmental Change*, 69, article number 102282.
[22] Mammadov, E. (2022). *The economic consequences of Russia-Ukraine war for Azerbaijan*. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4058963.
[23] Manjunatha, S.B., Biradar, D.P., & Aladakatti, Y.R. (2016). Nanotechnology and its applications in agriculture: A review. *Journal of Farm Sciences,* 29(1), 1-13.
[24] Mastronardi, L., Giaccio, V., Giannelli, A., & Scardera, A. (2015). Is agritourism eco-friendly? A comparison between agritourisms and other farms in Italy using farm accountancy data network dataset. *SpringerPlus*, 4(1), 1-12.
[25] Mbah, R.E., & Wasum, D.F. (2022). Russian-Ukraine 2022 War: A review of the economic impact of Russian-Ukraine crisis on the USA, UK, Canada, and Europe. *Advances in Social Sciences Research Journal*, 9(3), 144-153.
[26] Mora, M., Rumpel, C., & Calabi-Floody, M. (2021). *Smart fertilizers and innovative organic amendments for sustainable agricultural systems*. Basel: Agronomy.
[27] Nagarjuna, B. (2022). Russia's invasion of Ukraine: impact on Indian economy-strategies to mitigate and sustain. *EPRA International Journal of Multidisciplinary Research*, 8(3), 204-209.

[28] Naz, M.Y., & Sulaiman, S.A. (2016). Slow-release coating remedy for nitrogen loss from con-venational urea: A review. *Journal of Controlled Release*, 225(10), 109-120.
[29] Nevzorova, T. (2020). Biogas production in the Russian federation: Current status, potential, and barriers. *Energies*, 13(14), article number 3620.
[30] Puoci, F., Iemma, F., Spizzirri, U.G., Cirillo, G., Curcio, M., & Picci, N. (2008). Polymer in agriculture: A review. *American Journal of Agricultural and Biological Sciences*, 3(1), 299-314.
[31] Qian, L., & Hinestroza, J.P. (2004). Application of nanotechnology for high performance tex-tiles. *Journal of Textile and Apparel, Technology and Management*, 4, 1-7.
[32] Ramona, C., Nicoleta, M.S., Tabita, A., & Diana, M. (2020). Agritourism-organisation between tradition and modernity. *Lucrari Stiintifice Seria I*, 22(3), 1-8.
[33] Ranjith, M., & Surapaneni, S. (2021). Smart fertilizers as the best option for ecofriendly agriculture. *Yigyan Varta*, 2, 51-55.
[34] Richardson, J.W., Outlaw, J.L., Knapek, G.M., Raulston, J.M., Herbst, B.K., Anderson, D.P., & Klose, S.L. (2016). *Representative farms economic outlook for the January 2016 FAPRI/AFPC baseline*. Retrieved from https://www.econstor.eu/bitstream/10419/201765/1/1016354711.pdf.
[35] Sastry, R.K., Rashmi, H.B., & Rao, N.H. (2011). Nanotechnology for enhancing food security in India. *Food Policy*, 36, 391-400.
[36] Shahini, E., Skuraj, E., Sallaku, F., & Shahini, S. (2022). The supply shock in organic fertilizers for agriculture caused by the effect of Russia-Ukraine war. *Scientific Horizons*, 25(2), 97-103.
[37] Sindhwani, R., Chakraborty, S., Behl, A., & Pereira, V. (2022). Building resilience to handle disruptions in critical environmental and energy sectors: Implications for cleaner production in the oil and gas industry. *Journal of Cleaner Production*, article number 132692.
[38] Tao, Y., Yang, C., & Qin, J. (2011). Organic host materials for phosphorescent organic light-emitting diodes. *Chemical Society Reviews*, 40(5), 2943-2970.
[39] Veronica, N., Guru, T., Thatikunta, R., & Reddy, N.S. (2015). Role of Nano fertilizers in agricultural farming. *International Journal of Environmental Science and Technology*, 1(1), 1-3.
[40] World Agricultural Supply and Demand Estimates. (2022). Retrieved from https://www.usda.gov/oce/commodity/wasde/wasde0822.pdf.
[41] Zhang, J., Terrones, M., Park, C.R., Mukherjee, R., Monthioux, M., Koratkar, N., & Bianco, A. (2016). Carbon science in 2016: Status, challenges and perspectives. *Carbon*, 98(70), 708-732.

Розумні добрива як рішення для біорізноманіття та продовольчої безпеки під час війни в Україні

Ермір Шахіні[1], Євген Скурай[2], Фатбард Саллаку[2], Шпенд Шахіні[2]

[1]Дуррський університет імені Олександра Мойсіу
2001, вул. Currila, 14, м. Дуррес, Албанія

[2]Аграрний університет Тирани
1025, вул. Paisi Vodica, м. Тирана, Албанія

Анотація. Триваюча війна між Росією та Україною призвела до широкомасштабних руйнувань та загибелі людей у густонаселених містах, у сільській місцевості, а також до величезного переміщення населення. Ці дві країни є ключовими експортерами сільськогосподарської продукції і відіграють величезну роль у постачанні міжнародних ринків продуктами харчування та добривами, а війна, що триває, призвела до дефіциту поставок цих товарів. Мета цього дослідження – представити сучасні аспекти, пов'язані з використанням розумних добрив як можливості забезпечення продовольчої безпеки та біорізноманіття. Для досягнення цієї мети було проаналізовано наукові публікації, а також використано такі групи методів: діалектичний метод наукового пізнання, загальнонаукові та спеціальні методи. Для узагальнення науково-методичного характеру було використано абстрактно-логічний метод підходи до вивчення можливостей використання розумних добрив у сільському господарстві та формулювання висновків. Крім того, використовувався метод логічного спостереження та аналізу, на основі вихідних даних та кореляцій були зроблені висновки, що відповідають об'єкту дослідження. Для узагальнення результатів дослідження використали метод узагальнення. В результаті дослідження було встановлено, що використання інтелектуальних добрив призводить до меншого поглинання ресурсів сільськогосподарськими культурами, менших втрат у вигляді вилуговування, стоку та денітрифікації, а також сприятливого впливу на навколишнє природне середовище. Крім того, їх використання є необхідним підходом до збільшення виробництва продуктів харчування, що необхідно для забезпечення населення та підтримки економічного розвитку. Результати цього дослідження показують, що розумні добрива можуть бути вирішенням проблеми біорізноманіття та продовольчої безпеки під час російського вторгнення в Україну

Ключові слова: російське вторгнення, інновації, стійке сільське господарство, нанотехнології, міжнародні ринки