Int.J.Curr.Microbiol.App.Sci (2025) 14(08): 233-242

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Volume 14 Number 8 (2025)
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2025.1408.022

System Analysis of Organic Production Principles in Sustainable Agriculture

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Keywords

Organic product, organic agriculture, organic production, biohumus, zoohumus, *Anethum graveolens* L.

Article Info

Received: 20 June 2025
Accepted: 30 July 2025
Available Online: 10 August 2025

A B S T R A C T

This article presents scientifically grounded proposals for addressing existing challenges in the production of organic products and organic farming, both in the countries of the global community and in the Republic of Uzbekistan. The latest analytical data on the global market for organic dill (*Anethum graveolens* L.) and its growth dynamics are provided. In addition, the article highlights current problems in the process of cultivating organic dill and offers analytical insights into their systematic solutions. Based on the principles of obtaining organic products, the scientific foundations of cultivating dill with very low nitrate content are analyzed as an example to examine existing challenges and their solutions. Through a systematic analysis of state reforms and scientific research carried out in different countries and in Uzbekistan within the framework of "Organic products" and "Organic farming" principles, the authors conclude that the government should assume the role of the main reformer in widely introducing organic product and organic farming principles among the population and producers, as well as implement systemic reforms to support the economic subsidization of producers.

Introduction

Organic farming, or the cultivation of agricultural products under the label of organic products, has also brought about considerable challenges even among the world's leading producers. In particular, practical attempts to reduce production costs by increasing output volumes have had a strongly negative effect on the sale of organic products, since consumer demand for organic goods varies widely from country to country. Discussion. Current problems in organic farming in Uzbekistan and their explanation (Abdalhi, *et al.*, 2016). The Government of Uzbekistan, fully recognizing the scale of global environmental issues, is placing high priority on developing the agricultural sector without causing harm to natural resources (Sharma, et al., 2018). Consequently, the development of organic farming and the promotion of environmentally clean and sustainable production systems represent crucial factors in enhancing the competitiveness of local products and boosting export potential (Yusupov, 2021). At the global level, the task of collecting, analyzing, and monitoring data on organic agriculture is carried out by the major international scientific research institute known as FiBL and IFOAM (Research Institute of Organic Agriculture – FiBL and IFOAM – Organics International) (Rajiv, 2010).

According to statistical data from FiBL and IFOAM, in 2020 the total retail sales of organic products increased by €14 billion, reaching €120 billion. In 2021, the demand for organic products also showed a sharp increase compared to 2020 (Table 1).

Furthermore, the volume of land areas worldwide dedicated to organic farming grew by 1.6%, amounting to 75 million hectares (Helga, 2022). In 2020, more than 74.9 million hectares of land were used for organic agriculture and land under conversion was also recorded (Dimov, *et al*., 2020; Helga, 2022).

The largest areas of organic farmland are recorded in the Oceania region, accounting for 35.9 million hectares, which represents nearly half of the world's organic agricultural land (Helga, 2022). In Europe, organic farmland covers 17.1 million hectares (23%), followed by Latin America with 9.9 million hectares (13.3%), Asia with 6.1 million hectares (8.2%), North America with 3.7 million hectares (5.0%), and Africa with 2.1 million hectares (2.8%) (Helga, 2022).

In 2020, global organic farmland increased by 3.0 million hectares (4.1%), with the highest growth recorded in Chile—650% or 0.135 million hectares, mainly due to the expansion of organic pasture areas-and in Papua New Guinea, where organic farmland increased by 322%, exceeding 72,000 hectares (Helga, 2022).

According to Table 2, among CIS countries, Uzbekistan has allocated the least land to organic agriculture. Meanwhile, India is emerging as one of the world's leading countries in the production of organic agricultural products.

Veeresh emphasized that organic farming should be considered as one of the alternative methods to traditional agriculture in order to maintain production without causing serious harm to the environment and ecology (Veeresh, 1999).

However, he also noted that organic farming is perceived differently across countries. In developed nations, its primary focus is on preventing chemical pollution, whereas in India it is mainly regarded as a method to improve low soil fertility. In this context, even the soil's ability to absorb fertilizers is understood as being closely linked to its organic composition (Veeresh, 1999).

It is well known that vegetable cultivation in greenhouses differs significantly depending on the type and variety of vegetables, their growth and development phases, as well as the applied agrotechnological methods. However, in the context of cultivating vegetables under the principles of organic agriculture or organic products, several challenges remain.

These challenges cannot be resolved simultaneously or placed within a clearly defined developmental system, which negatively affects the global scale of organic production. In Uzbekistan, similar problems exist as in the rest of the world, although certain aspects differ due to the country's specific economic capacities.

We find it appropriate to explain these problems in the following order:

First, there is a very high demand for agricultural products, which creates the necessity of producing large volumes of products within a short period of time.

Second, the volume of production of biological fertilizers used in organic farming is insufficient, and yields of crops grown organically are still relatively lower compared to those produced with traditional mineral fertilizers.

Third, during organic production, fertilization is carried out in response to the soil's demand for organo-mineral inputs. While mineral fertilizers may be replaced by biological ones, in practice, farmers are often compelled to use strong chemical agents in fields or greenhouses against various diseases, pests, and weeds. This necessity is explained by the relatively slow effect of biological fertilizers and biocontrol agents.

Fourth, despite the active global efforts to expand the practical application of organic farming principles, the cost of organic products remains high. Given the population's economic capabilities, these products are still too expensive for daily consumption.

Fifth, production, storage, and marketing of organic products face excessively strict requirements. For example, the ban on using genetically modified varieties in organic farming poses a challenge, since varieties selected through conventional breeding methods still demonstrate much lower productivity and weaker resistance to abiotic and biotic stresses compared to genetically modified ones.

Sixth, when addressing these problems, each country approaches them based on its economic and social capacities. As a result, significant disparities emerge between developed countries with strong agricultural production, developing nations, and those with limited resources (Nodira K. Ruzmetova, *et al*., 2024). For economically constrained states, this creates barriers to exporting organic products at competitive prices under international requirements, as they are unable to fully comply with the standards set by agriculturally advanced nations. This hinders the broad realization of organic products.

Seventh, in the countries of the former Soviet Union—particularly Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan—the widespread use of chemical pesticides in the past century, combined with soil degradation, increased salinity of soil and water, the expansion of desertification zones, and the unequal distribution of transboundary water resources, has significantly limited the potential to fully implement organic farming practices and principles of organic production.

Eighth, alongside the traditional methods of cultivating organic products (large open fields, large- or small-scale closed greenhouse systems, and nurseries), the lack of knowledge and skills among the population in applying non-traditional methods to meet their own demand for certain organic products should be considered a serious challenge. For example, in multi-story apartment buildings or in areas with small courtyards where farming opportunities are limited, the practice of balcony greenhouses could meet daily needs through simple organic methods. It is therefore necessary to promote such practices more widely and to ensure that they receive due attention at the government level.

Ninth, in open fields, seasonal yields typically amount to 10–20 kg per square meter. However, in closed greenhouse systems with reliable and continuous heating, yields can reach 30–35 kg over an extended period. Despite this advantage, interruptions in the supply of heating energy—caused by problems with the government's provision of electricity, gas, coal, or other fuels—have a strong negative impact on greenhouse operations.

The uninterrupted supply of fuel and lubricants for agricultural production should therefore be guaranteed by the government. In practice, seedlings or harvests cultivated in greenhouses over several months have sometimes perished within a few hours or days. For instance, in Uzbekistan, the anomalous cold weather of 2022 caused significant losses of greenhouse tomatoes and cucumbers. Wider adoption of solar panels, biogas plants, and wind generators for lighting and heating in greenhouses would not only help meet heating needs but also serve as a key factor in reducing the production costs of organic products.

Tenth, it would be advisable to focus on establishing large-scale greenhouses specialized in organic production—supported by government or international donor organizations—in locations close to areas with uninterrupted heating and electricity supply. For example, large industrial enterprises producing hot water, electricity, or gas, as well as plants generating substantial amounts of steam or gas (such as fertilizer, coal, or metal factories), could host adjacent greenhouse facilities. This would allow efficient use of industrial heat sources, positively contributing to the effectiveness of organic product production.

Eleventh, ensuring continuous subsidies for enterprises engaged in organic production and creating a mechanism by which the government compensates losses caused by natural disasters under abnormal climatic conditions play an important role in the stable development of organic agriculture.

For example, in vegetable production using non-traditional methods compared to conventional methods, yields decline by about 10–12%. In general, a yield reduction of up to 20% compared to expected harvests is considered normal in organic farming (Li, 2017b). Such decreases are commonly observed in organic vegetable production: cabbage yields decline by 10–24%, radish by 6–7% (Chen, 2019), and in some cases, the reduction reaches 25–37% in carrots and cabbages (Li, 2017a).

Very large yield losses of 65–90% have been recorded for potatoes, onions, peas, carrots, and cabbages (Ni, 2019; Panwar, 2011). For this reason, until organic greenhouse farms-established under organic farming principles—achieve stable economic indicators and align with market demands, it is a vital strategic task for governments to support them through subsidies and tax incentives. Additionally, government procurement of harvested products and the guarantee of their realization remain among the most important factors in fostering organic agriculture.

Organic Product Cultivation: Using dill as an examplehe

In the global fruit and vegetable sector, including greenhouse cultivation of vegetables and greens (spices and medicinal plants), particular attention is paid to the use of biofertilizers in seedling preparation for organic farming. This involves establishing norms for their use, applying appropriate agrotechnological methods, and implementing continuous monitoring systems to control the safety indicators of applied biofertilizers.

In the case of dill, the global production volume is not assessed in terms of its yield as a spice. For this reason, sufficient statistical data are not found in the periodic reports of global scientific and trade centers. Thus, dill production volumes are usually estimated based on its seed and seed oil production. For example, in the global market, the gross production volume of dill seed in 2021 accounted for 1.7%, valued at USD 675.2 billion, in 2022 at USD 974.09 billion, in 2023 at USD 1.83 trillion, and in 2024 exceeding USD 1.897 trillion (Dill Seed Oil Market, 2025). According to Global Market Insights, the global retail value of dill seed is expected to increase by 3.7% by 2032, reaching USD 2.52 trillion (Global Market Insights, 2024).

The world's leading dill seed producers are India, Germany, the Netherlands, Poland, the United Kingdom, and the USA. The largest dill seed oil companies include Arganisme, Lalla Izza, OLVEA, Nadifi Argan, BioAdorates, Oriental Group, Vima Souss, Madanargan, Malak Bio, Zineglob, and Sidi Yassine (Global Market Insights, 2024). While the global market for dill seed and oil production shows stable growth, the consumption of dill as fresh greens also represents one of the most important sectors. In recent years, dill has been increasingly consumed as a dietary herb, playing a critical role in strengthening immunity and preventing immune-related diseases. Therefore, there is a growing need to develop sustainable agro-technologies and biotechnologies for dill cultivation.

Dill production, like other agricultural crops, depends on several interrelated factors and faces multiple challenges

First, most of the problems in dill cultivation are linked to global climate change—rising temperatures, water scarcity, soil erosion, and declining soil humus content.

Second, there is rapidly growing consumer demand for dill. Traditionally, it has been cultivated mainly with chemical mineral fertilizers, which often leads to excess mineral salt content.

This conflicts with organic farming principles and reduces the acceptability of dill as a fresh green product. In addition, the widespread adoption of hydroponic systems for dill cultivation in recent years does not align with organic production principles and fails to meet consumer expectations.

Third, compared to other spice crops, dill is highly susceptible to weeds, insect pests, and diseases, while also having a stronger tendency to accumulate heavy metals. This makes dill cultivation riskier than that of other spice plants.

Fourth, as consumers become more familiar with the principles of organic production, they are increasingly growing dill at home in small containers with organic fertilizers. This trend is significantly influencing the overall market volume of dill sold as a green vegetable.

Fifth, dill, like other spices and medicinal herbs consumed as fresh greens, faces serious storage challenges, particularly due to its very short shelf life. The high costs of cold storage and ice for transportation directly raise the final retail price of fresh dill.

Addressing these challenges, particularly through the development and wide application of agrotechnologies for organic dill cultivation, will provide consumers with affordable, environmentally clean spices and medicinal plants.

One of the most crucial aspects of dill production is the correct selection of fertilizer types and their application norms. All types of fertilizers - whether chemical or biological—have unique advantages and disadvantages both in terms of providing essential nutrients for plants and in ensuring environmental protection and the use of ecologically clean products (Chen, 2006). In recent years, there has been extensive use of microbiological fertilizers based on microorganisms that convert soil nutrients into easily accessible forms, thereby stimulating root system development and seed germination.

Alongside this, traditionally widespread biological fertilizers (such as vermicompost, manure, compost, liquid compost, and biogas slurry) are being evaluated and tested as effective substitutes (Nejatzadeh-Barandozi *et al.,* 2014).

Biological fertilizers are considered cleaner and more effective compared to chemical fertilizers (Nejatzadeh-Barandozi, 2014; Elsen, 2000). Nevertheless, from an ecological and environmental perspective, the widespread application of biological fertilizers also has certain limitations.

First, livestock manure and its decomposed forms, while rich in humus, also contain a variety of weed and wild plant seeds as well as pathogenic microorganisms, posing significant risks to ecology and environmental protection. In particular, imported composted manure and manure-based products (various biofertilizers) may contain weed seeds, phytopathogenic microorganisms, and their spores, which can spread widely across agricultural lands.

For instance, highly dangerous pathogenic microbes and their spores, such as *Listeria monocytogenes*, *Staphylococcus aureus* (Johannessen *et al.,* 2002), *Enterococcus faecium*, *E.faecalis*, *L.monocytogenes* (Johnston *et al.,* 2006), *Salmonella enterica* (Branquinho Bordini *et al.,* 2007), *Escherichia coli* O157:H7 (Beretti and Stuart, 2008), and *E.coli* O104:H4 (Mellmann *et al.,* 2011), have been found in such biofertilizers, indicating a serious risk (Vassileva *et al.,* 2022).

In Germany, for example, the seeds of the medicinal plant *Trigonella foenum-graecum* grown using cattle manure were found to contain the highly dangerous E.*coli* (STEC) O104:H4 toxin. As a result, 53 people died and more than 800 required hospitalization, with similar cases reported in four other European countries (European Food Safety Authority, 2011).

Second, biofertilizers such as vermicompost and biogumus—produced with the help of different species of earthworms and containing high levels of organic matter and humus—are of great importance in agriculture (Qiamudin Abad, 2024).

However, these biofertilizers also may not completely neutralize weed seeds, phytonematodes, phytopathogenic microflora, and their spores (including Salmonella spp., *Escherichia coli*, Yersinia enterocolitica, Shigella, and Clostridium perfringens), which means they cannot be considered entirely environmentally safe products (Atanda *et al.,* 2018).

Third, fertilizers derived from sludge residues of wastewater treatment facilities are also widely used as biofertilizers for agricultural crops. While these are rich in easily absorbable nutrients and organic matter, their safety depends greatly on strict adherence to technological processes during production.

For example, the extensive use of chlorine and its derivatives in wastewater treatment may affect the chemical stability of these fertilizers. Additionally, the vegetative cells and spores of pathogenic and highly pathogenic microorganisms may not be fully destroyed during treatment, raising environmental safety concerns that require deeper investigation (Panikkar *et al.,* 2003).

Fourth, in recent years, microbial fertilizers have played an increasingly important role in maintaining ecological sustainability. Microbial fertilizers are vital in transforming poorly accessible nutrients into readily available forms in soil. Their production is relatively inexpensive compared to other fertilizers, easy to apply, and environmentally cleaner.

Although the ecological purity of these biofertilizers remains debatable, their broad application is significant because they reduce reliance on chemical and mineral fertilizers (Sifolo *et al.,* 2018). For this reason, their use continues to expand globally.

At the same time, large-scale research is being conducted worldwide to identify more effective alternatives to livestock manure, composted manure, and vermicompost as biofertilizers, and to implement such solutions in practice.

In Uzbekistan, particularly since independence, systematic measures have been undertaken to stabilize the ecological situation and accelerate the process of biologization in agricultural production. Specifically, the adoption of the Law “On Organic Products” introduced fundamental requirements for organic product production into practice (Law of the Republic of Uzbekistan, 2022).

Table.1 Key Indicators of Organic Agriculture and Leading Countries (FiBL Survey, 2022)

Indicator	Global Figures	Leading Countries
Countries with organic activities	2020: 190 countries	–
Land area suitable for organic agriculture	2020: 74.9 million ha (1999: 11 million ha)	Australia (35.7 million ha) Argentina (4.5 million ha) Uruguay (2.7 million ha)
Share of total farmland allocated to organic agriculture	2020: 1.6% growth	Liechtenstein (41.6%) Austria (26.5%) Estonia (22.4%)
Growth of organic farmland (2019–2020)	Increase of 3.0 million ha; +4.1%	Argentina – 781,000 ha (+21%) Uruguay – 589,000 ha (+28%) India – 359,000 ha (+16%)
Wild collection and other non-agricultural areas	2020: 28.5 million ha (1999: 4.1 million ha)	Finland – 5.5 million ha Namibia – 2.6 million ha Zambia – 2.5 million ha
Producers	2020: 3.4 million producers (1999: 200,000 producers)	India – 1,599,010 Ethiopia – 219,566 Tanzania – 148,607
Organic product sales	2020: €120.6 billion (2000: €15.1 billion)	USA – €49.5 billion Germany – €15.0 billion France – €12.7 billion

Source: United Nations Statistics Division – M49 Standard

Table.2 Land Areas Allocated for Organic Agriculture (including land under conversion) Worldwide (FiBL Survey, 2022)

S.№	Country	Area, hectares	№	Country	Area, hectares
1	Australia	5,687,799	10	Germany	1,702,240
2	Argentina	4,453,639	11	Russia	615,188
3	Uruguay	2,742,368	12	Ukraine	462,225
4	India	2,657,889	13	Kazakhstan	114,886
5	France	2,548,677	14	Azerbaijan	38,080
6	Spain	2,437,891	15	Kyrgyzstan	30,259
7	China	2,435,000	16	Tajikistan	11,818
8	USA	2,326,551	17	Belarus	6,838
9	Italy	2,095,380	18	Uzbekistan	3,781

Note: In total, 168 countries are included in this global ranking. From this list, the author has selected the countries with the largest areas of organic farmland, along with CIS countries (FiBL Survey, 2022)

This has further highlighted the necessity of expanding the use of biofertilizers in organic agricultural production. In addition, Uzbekistan's Development Strategy of New Uzbekistan (Decree of the President of the Republic of Uzbekistan, 2022) and the Presidential Decree of February 28, 2023, "On the State Program for the Implementation of the Development Strategy of New Uzbekistan for 2022–2026 in the Year of Attention to People and Quality Education" (PF-27), emphasize the need to implement innovative solutions for "producing export-oriented products, developing fruit and vegetable farming, increasing the area of intensive orchards by 1.5 times, expanding greenhouse facilities by 1.2 times, and improving and preserving soil fertility" (Decree of the President of the Republic of Uzbekistan, 2023).

In fulfilling these tasks, conducting research in Uzbekistan under greenhouse conditions on monitoring the agrochemical properties of soils and ensuring the effective use of biofertilizers for producing environmentally clean products within the principles of organic agriculture holds significant importance. According to the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 729 of November 18, 2020, *"*On the approval of certain regulatory legal documents on the safety of organic products and raw materials, as well as organic-mineral fertilizers*"*, the Annex "Regulation on the procedure for forming and maintaining the register of producers of organic products and raw materials" was adopted (Cabinet of Ministers of the Republic of Uzbekistan, 2020).

In this document, biogumus is defined as follows: biogumus (vermicompost) is an organic fertilizer obtained through the processing of organic waste by earthworms, consisting of high molecular organic compounds formed in the process of their life activities (processing the manure of cattle, pigs, and other animals). Fermented waste such as rabbit and poultry manure, forage, tree leaves, as well as residues from food industry and household waste are excluded from this category. In Uzbekistan, organic production is still largely based only on biogumus obtained through earthworm processing, in accordance with this resolution. At the international level, numerous scientific studies have been carried out by organizations, local and foreign scholars, aimed at organizing production processes, monitoring agrochemical, ecological, and biological aspects, setting clear standards for produced goods, certification, and coordinating systems for organic agriculture.

However, in Uzbekistan, no comprehensive scientific studies have yet been conducted on producing organic products in greenhouses, monitoring mineral substances and heavy metal content in soils, or assessing the concentration of chemical elements in the final products. Our systematic observations in line with the principles of "organic product" and "organic farming" show that the most promising greenhouse crops in Uzbekistan are cucumbers, tomatoes, sweet peppers, and chili peppers.

To date, only one production cluster has attempted to implement organic cotton cultivation in open fields (Namangan region, Pop district). Yet, due to the numerous issues outlined earlier, there has been little progress in producing organic cotton, organic tomatoes, organic cucumbers, or organic peppers.

In addition, not only in Uzbekistan but across Central Asia, during the spring season, people widely consume naturally growing greens from mountain and foothill areas, such as *Rumex* (dock), *Spinacia* (spinach), *Capsella Bursa-Pastoris Medic* (shepherd's purse), *Mentha asiatica* (Asian mint), and *Origanum titthanthum* (mountain basil). Over the past twenty years, the mass greenhouse cultivation of these greens has expanded significantly, with production also supplied to neighboring countries. These crops are commonly cultivated in greenhouses using mineral fertilizers as part of widespread agrotechnological practices. However, one of the most critical problems arising from greenhouse cultivation of these greens with mineral fertilizers is their high accumulation of nitrate salts. Therefore, promoting the greenhouse cultivation of these nutritious and medicinal greens under the principles of organic agriculture and organic products would serve as an important factor in enhancing the country's export potential.

The large-scale use of chemical fertilizers and pesticides in global agricultural production has caused significant environmental degradation and posed serious ecological problems related to human health. The broad application of biofertilizers in agricultural processes is therefore of great importance, as it not only enables the production of environmentally friendly products but also plays a crucial role in controlling the transfer of heavy metals from soils into final products. The quality indicators of crops produced through conventional farming methods - particularly their chemical composition, the retention of chemical residues within food products, and the accumulation of excessively applied mineral fertilizers- have increasingly negative effects on human health. These consequences have, in recent years, become one of the main drivers behind the rapid global development of organic agriculture.

Therefore, in addition to traditional biofertilizers such as vermicompost (biogumus), the use of non-traditional fertilizers like zoohumus is considered appropriate in organic-based production. Furthermore, the application of microbiological biopreparations is of critical importance in the sustainable agricultural context for advancing the cultivation of organic products. Based on a systematic analysis of state reforms and scientific research carried out in both the international community and Uzbekistan under the principles of "organic products" and "organic agriculture," the following conclusion can be drawn: in order to ensure the widespread adoption of organic agriculture and organic product principles among the population and producers, the government must assume the role of the primary reformer. At the same time, it is necessary to implement systemic reforms that support producers economically through a robust subsidy mechanism.

Author Contributions

N. A. Khujamshukurov: Investigation, formal analysis, writing—original draft. M. Z. Abdutolibov: Validation, methodology, writing—reviewing. K. S. Maksumkhodjaeva:—Formal analysis, writing—review and editing. D. Kh. Kuchkarova: Investigation, writing—reviewing. Alvina Farooqui: Resources, investigation writing—reviewing. Tripath Gyanendra: Validation, formal analysis, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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How to cite this article:

Nortoji A.Khujamshukurov, Mukhriddin Z. Abutolibov, Kamola S. Maksumkhodjaeva , Dilafruz Kh.Kuchkarova, Alvina Farooqui, and Tripath Gyanendra. 2025. System Analysis of Organic Production Principles in Sustainable Agriculture. *Int.J.Curr.Microbiol.App.Sci.* 14(08): 233-242. **doi:** https://doi.org/10.20546/ijcmas.2025.1408.022