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CIRCULAR ECONOMY FOR GLOBAL WATER SECURITY

The effect of organic farming on water reusability, sustainable ecosystem, and food toxicity

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Abstract
Water is a fundamental necessity for people's well-being and the ecosystem's sustainability; however, its toxicity due to agrochemicals usage for food production leads to the deterioration of water quality. The poor water quality diminishes its reusability, thus limiting efficient water usage. Organic farming is one of the best ways that does not only reduce the deterioration of water quality but also decrease food toxicity. In organic farming, the crop is grown with no/less chemical usage. Besides, organic farming maintains biodiversity and reduces the anthropogenic footprint on soil, air, water, wildlife, and especially on the farming communities. Fields that are organically managed continuously for years have fewer pest populations and were attributed to increased biodiversity and abundance of multi-trophic interactions as well as to changes in plant metabolites. Fewer insect pests (pathogen vectors), in turn, would result in fewer crop diseases and increase crop production. This review highlights that organic farming may play a critical role in the reduction of pests and pathogens, which eventually would reduce the need for chemical reagents to protect crops, improving yield quality and water reusability.

Keywords *Bacillus thuringiensis*, · Ecology, · Natural conservation, · Pest management, · Runoff, · Sustainability, · Virus

Introduction

Water is a remarkable natural resource being vital for the sustenance of any ecosystem that makes it a prerequisite to be used with utmost care. The food and agriculture organization of the United Nations (FAO) had reported that, among different anthropogenic activities, agriculture takes one of the most significant shares in water usage (Frenken and Kiersch 2011). Depending upon countries, at least 70 to 90% of water is consumed in agriculture-related activities. Due to the advent of green revolution technologies in the last decade, tremendous growth and improvement in global food security had occurred (Evenson and Gollin 2003; Qaim 2017). However, FAO reported that approximately 800 million people are still undernourished, mainly from developing countries (FAO 2017). By 2050, the human population is projected to increase by 50%, which will further cause a burden on natural resources, critically on clean water and agriculture. According to studies, to keep up with the burgeoning human population, global agricultural productivity has to increase by 100% until 2050 (Godfray et al. 2010; Hertel 2015). Due to the further eagerness to use renewable energy sources for a healthier environment, farming has become much more intensified than ever before as the demand for biofuel is also increasing along with other plant-derived products. On the negative side, agriculture has been associated in many ways to diminish the water quality that includes but is not limited to nutrient and pesticides leaching and runoff, eutrophication, pathogen accumulation in water bodies, etc. (Sivaranjani and Rakshit 2019). Thus, the onus lies on agriculture to use water efficiently to have sustainable growth and increase productivity.

To ensure stable future development, it is critical to safeguard the surface and groundwater resources that are limited for consumption. In spite of limited availability, water has been reported to be often polluted with agrochemicals intensively applied in agriculture, e.g., pesticides, insecticides, herbicides, weedicides, fungicides that are detrimental to human

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health and the environment (Xiaofei et al. 2008; Fernandez-Gomez et al. 2012; Rezaei et al. 2019). Indeed, a recent study reported worldwide use of pesticides over four million tons per year (Weber 2018). In a river basin, surrounded by a wide range of anthropogenic activities, it is found to have pollutants ranging from pesticides to personal care products (Fernandez-Gomez et al. 2012). Diazinon, a potent organophosphorus insecticide, WHO classified as chemicals with moderate hazard Class II was found to be stable in both water and soil and can exist in the environment for several months (Wang and Shih 2016). Moreover, some agrochemicals contain persistent organic pollutants (POPs) that are not susceptible to degradation and can be found even for years (Chandra et al. 2015). Thus, the stable agrochemicals accumulate and bio-magnifies, leading to bioconcentration of several tens of thousands-fold relative to initial concentration (Hernández et al. 2013). Apart from being a threat to humans, these chemicals have the potential to affect some other beneficial organisms and destabilize the ecosystem pertaining to its high stability in water (Simeonov et al. 2013). It is sufficed to say modern agriculture needs good water management for increasing the sustainability of food security.

Indeed, water treatment techniques are available, although it is challenging to prevent the contamination of water from agricultural sources as the economic conditions of small farmers from developing countries impedes a successful implementation of water management techniques. Developing countries cannot afford expensive water treatment techniques, leading to poor water quality (Sivaranjani and Rakshit 2019). Moreover, the use of agrochemicals seems to increase the crop yield manifold; however, in long-term usage, it had been found to decrease the soil quality and the water holding capacity. Eventually, the land becomes infertile, causing a decrease in crop production (Fox et al. 2007). This suggests that the use of chemicals is not only detrimental for humans and the environment but also ultimately bad for sustained food production.

Unless water management techniques get affordable, alternate strategies that are environmentally friendly and use water efficiently for agriculture needs to be exploited more. The current report suggests that worldwide there is a trend of a significant increase in organic farming and is largely seen as a substitute to agrochemical-free farming that, in turn, will enhance the water reusability from agricultural sources (Tal 2018). Organic farming had been first introduced in the early 1900s and is defined in many ways (Adamchak 2021). Simply put, it can be said, harnessing the natural resources for the improvement and sustainable food production. Here, we synthesized the literature to show how organic farming has multifunctional effects with respect to the sustainable ecosystem, food toxicity, and water reusability. We also highlight the molecular mechanism of organic farming benefitting the ecosystem, which may be useful for the agricultural industry to apply in organic fields. Understanding the underlying mechanism of organic farming will not only increase its' efficiency but will also increase the agricultural water reusability along with significantly reducing the food toxicity. The current challenges faced in organic farming have also been addressed here that would lead to future research directions.

Organic farming effects on ecosystem

Pests and pathogens

Pests and pathogens of crops are one of the major challenges that limit the increase in production. Controlling the pest population in fields is necessary as it destroys crops with its foraging activity and pests like phloem-feeding insects remove nutrients from phloem sap that is detrimental to plant productivity (Carena and Glogoza 2004). Moreover, insects have the potential for acting as vectors for many pathogens, e.g., fungi, phytoplasmas, bacteria, viruses, which further hampers food production (Perilla-henao and Casteel 2016; Eigenbrode et al. 2018; Bera et al. 2020). Worldwide, it has been estimated that pests, pathogens, and weeds, altogether cause around 40% loss in major crops (Oerke 2006). In conventional farming, through the use of chemicals (insecticides, weedicides, fungicides, etc.) and disease-resistant cultivars (monocropping) assisted in increasing crop production. However, at the same time, it has also facilitated the increase in chemicals-resistant insects or weeds and resistant-breaking pathogens. Along with this, the use of chemicals had a significant negative impact on the environment and decreased the quality of water. Thus, organic farming is considered a great alternative that is more environmentally friendly, durable, and can be exploited to decrease pests and pathogens in crops.

Among all the pathogens transmitted by insects, viruses are of special importance as it had been estimated that viruses constitute approximately 50% of all the epidemic outbreaks in the field (Anderson et al. 2004; Parizad et al. 2012b; Nateqi et al. 2014, 2015; Movi et al. 2021). One of the main reasons that explain frequent viral epidemic outbreaks is the fast-evolving capacity of viruses that breaks the resistance bred into the cultivars (Berzal-Herranz et al. 1995; de la Cruz et al. 1997; Gilardi et al. 2004; Jones 2009; López-Córcoles et al. 2011; Moury and Verdin 2012; Elena et al. 2014; Bera et al. 2017, 2018; Dennehy 2017). Thus, farmers rely more on pesticides and insecticides to remove insects from fields and prevent viral epidemics. However, as the virus evolves to break the host resistance or expand its host range, viruses might get less virulent in other susceptible hosts indicating the fitness costs associated with resistance breaking mutant strains (Moreno-Pérez et al. 2016; Bera et al. 2016, 2017, Bera, 2018). The fitness costs might occur as mutations can disrupt the multi-functionality of a viral protein and the functional elements in viral RNA that are necessary for virulent infection (May et al. 2020; Ilyas et al. 2021; Liu et al. 2021). A recent review by Roossinck and García-Arenal 2015, suggested that large-scale mono-cropping and the loss of species richness in fields are the major contributing factors that lead to the rapid virus evolution and emergence of virus epidemics (Roossinck and García-Arenal 2015). Therefore, it is sufficed to say that the use of organic farming that promotes natural practices to keep the pest population low along with enriching the species diversity in the field will impede the rapid virus evolution and prevent viral epidemics. Indeed, studies have shown that an increase in biodiversity leads to a decrease in viral infection risk (Pagán et al. 2012; Rodelo-Urrego et al. 2013).

Currently, in organic farming, strategies are implemented to reduce the risk of viral disease outbreaks. For example, use of disease-free seeds or propagating materials, spatial isolation and removal of specific weeds known for attracting pests or reservoir of pathogens (van Bruggen et al. 2016). Growing susceptible crops is encouraged at certain times of the year that is known to have a low risk from pathogens and pests (van Bruggen et al. 2016). The practice of using disease-free propagating material is a prerequisite to reduce the risk of spreading pathogens; as a case in point, it had been reported that saffron plants that are propagated by their corms might had been infected with a novel virus called Saffron latent virus (SaLV) and got distributed to all saffron fields of Iran (Sabze et al. 2012; Parizad et al. 2016, 2017a, 2017b, 2018). Subsequent studies from the same research group showed that the virus might have negatively impacted saffron's secondary metabolites that are of high economic importance (Parizad et al. 2012a, 2018, 2019; Movi et al. 2018; Moratalla-López et al. 2021). Thus, improving the certified and virus-free propagation organs is crucial, which is currently done for potatoes, strawberries, and flower bulbs (Daugaard 1999). Moreover, a current study did a comparison between conventional and organic farming and reported that viral infection risk was indeed lower in organic farms in two non-consecutive years (Lázaro et al. 2019).

As the use of chemicals is strictly prohibited in organic farming, farmers are encouraged to follow practices that negatively affect pests or promote natural enemies of pests in the field that includes enriching the species diversity. In a broad sense, species diversity is defined as the number of different species present in a particular area. A way to prevent insect vectors from probing plants is the use of straw or plastic mulches or oils that repel aphids (Stapleton and Summers 2002; Schuster et al. 2009). Straw mulch was indeed reported to be effective in decreasing viral infections (Saucke and Doring 2004). Another study showed farmers from Africa produced maize without using any pesticides (Eisenstein 2020). A push-pull cropping strategy was implemented; grasses were planted near the maize plots that "pull" a common pest, the maize stalk borer (Busseola fusca), away from crops, and simultaneously the maize plants attracted parasitic wasps that prey on the stalk borer. Moreover, legumes were grown with the maize to increase the nitrogen content of the soil and produce compounds that 'push' away pests and kill off a genus of invasive weed (Eisenstein 2020). Thus in line with the above study, several studies also suggested that species richness is vital for keeping pests and diseases in check (Pagán et al. 2012; Rodelo-Urrego et al. 2013; Muneret et al. 2019). However, a study by Crowder et al. 2010 suggested that more than richness, evenness of species was critical to keep pests densities low that means to have negative impact on pests population it is vital to consider an equal number of different species more than the species diversity in a community (Crowder et al. 2010).

Molecular mechanism mediating the effect of organic farming

Though in the past few years, numerous studies got published highlighting the benefits of organic farming; however, the underlying molecular mechanism that keeps the pest infestation and disease risk low in the organically managed field is still in the nascent stage. One of the reasons that can be attributed to low infestation is the absence of any fertilizer usage in organic farming. Plants tend to have lower nitrogen content that, in turn, make them less attractive to pests, which might explain the lower risk of pest infestation in an organic system (Mattson 1980; Drinkwater et al. 1995; Garratt et al. 2011; Megali et al. 2014). Studies on plants and mycorrhizal fungi association reported induction of plant systemic resistance that might be responsible for decreasing susceptibility to pests and pathogens (Fritz et al. 2006; Pozo and Azcón-Aguilar 2007; Kempel et al. 2010; Vannette and Hunter 2010).

Moreover, there is a rising trend of soil microbes' usage in organic farms that makes the plant more resilient to pests; studies have demonstrated that it is often mediated by modulation of plant signalling and defence responses (Gilbert and Johnson 2015; Bastías et al. 2018; Zhu et al. 2018; Howard et al. 2020). The study of Blundell et al. 2020 is of particular relevance here, demonstrating leafhopper pests prefer tomato plants that are conventionally managed over the organically managed system (Blundell et al. 2020). Due to the presence of soil microbes in the organically managed system, the modulation of a phytohormone, salicylic acid (SA), was speculated to be mediating the behavioural changes in pests. This finding is in line with other studies that also reported behavioural changes in pests were often mediated through modulation in phytohormones pathway, specifically, Jasmonic and salicylic acid (Kessler et al. 2004; Morkunas and Van 2011; Abe et al. 2012; Bera et al. 2019, 2020).

Apart from phytohormones, there are studies indicating the critical role of plant volatiles, amino-acid content, and secondary metabolites in plant defence response against pests and pathogens (Zaynab et al. 2018; Lee et al. 2021a). A precursor of JA, 12-oxo-phytodienoic Acid, was shown to enhance callose deposition in JA deficient plants and increased resistance against aphids (Varsani et al. 2019). Some of the major plant secondary metabolites, e.g., phenolics and terpenes, had been documented acting as a defence response against insects, viruses, fungi, and bacteria (Walling 2000; An et al. 2001; Ito et al. 2007; Nuessly et al. 2007; Wang et al. 2007; Keeling 2008; Velasco et al. 2013; Shen et al. 2015). However, the role of secondary metabolites in organic farming to manage pests and pathogens remains to be investigated. Nevertheless, it had been shown that plants grown in an organic system tend to have higher phenolic content (Barański et al. 2014; Veberic 2016). Thus, it would be tempting to speculate that secondary metabolites in organic farming might be playing a vital role in keeping pests and disease risks low.

Organic farming effect on food toxicity

Due to the growing public consciousness on a clean environment related to the use of agrochemicals and the concerns about their health and food toxicity, it has been reported that approximately 97% of the people are worried about chemical residues in the environment, especially in food (Pimentel and Greiner 1997; Bansal 2017). Indeed around 35% of foods in the US contain measurable pesticide residues, and 1–3% of these foods have levels above the approved tolerance level (National Research Council 1993). Among all, fruits and vegetables have higher pollutants since a tremendous amount of chemicals are used for them, and this toxicity can remain even after washing and peeling them (Wiles and Campbell 1994).

Based on the functional, biological, nutritional, sensual, ethical, and "authentic" factors, food safety can be evaluated in the following way: food output with rich in quality and adequate quantity, growing them within the natural cycles and using local sources, preservation and subsequent improvement of the fertility of the soil, safe environment, tastes better, animal welfare, and minimal processing (Bansal 2017). Based on the criteria mentioned above, organic crops have a high standard in food safety. Moreover, organic crops are generally characterized by a higher amount of dry matter, some minerals (Fe, Mg), and antioxidant micronutrients (phenols, resveratrol). With respect to the food toxicity, organic products, apart from their high nutritional value and minimum artificial chemical residues, are also enriched in affirmative aspects, such as in antioxidant phytomicronutrients content, and have less nitrate accumulation and toxic phytochemical residue levels (Lairon 2010; Bansal 2017).

Prohibiting the use of toxic chemicals, including pesticides, fungicides, and herbicides, in organic agriculture is a really valuable effort, conserving farmers' health and environmental biodiversity and well-being (Lairon 2010). Accordingly, food is healthier in organic than in conventional farming since it is based on the precautionary approaches in which organic regulations and food safety evaluation are considered (Hansen et al. 2002). The high standards of chemical-free organic foods are undoubtedly achievable by the less usage of nitrogen (decreasing the nitrate concentrations) and limiting the human-made chemicals and other environmentally toxic compounds (leading to nearly no pesticide residues); thus, bringing about the least venture of food toxicity (chemicals contamination) (Hansen et al. 2002). In a broad range of organic products (94–100%), no pesticide remnants had been detected. Also, organic vegetables had considerably fewer amount of nitrates. In fact, using composts in organic agriculture instead of chemical fertilizers gives rise to lower nitrate contents in some crops (Lairon et al. 1984a, b). Nitrogen-rich organic fertilizers will produce less nitrate, although, in some desirable conditions, they can contribute to high nitrate accumulations (Lairon et al. 1985; Termine et al. 1987). Regarding the level of food contamination as per environmental pollution, there are a lot of studies showing no or fewer (all being below the threshold) chemical remnants in organic samples compared to conventional products (Poulsen and Andersen 2003; Tasiopoulou et al. 2007). These residues in conventional products can be toxic due to their detrimental effect as mutagens and carcinogens. Hence by assessment of the toxicity, the risky chemicals should be eliminated (Lairon 2010).

However, despite the strict limitation of pesticide usage, a number of certain chemicals can be applied in organic farming. For instance, some nonsynthetic pesticide products, considering their origin, environmental influence, and the possible remaining as residues, have been allowed to use. These compounds are copper sulfate, copper ammonium carbonate, pyrethrum, sulfur, copper oxychloride, soft soap, and derris (rotenone). In addition, some plant oils, such as neem, and microbial agents, such as *Bacillus thuringiensis* (Bt), can be used. Due to their simple structure than conventional farming materials, these compounds have a faster rate of breaking down (Chaudhari et al. 2021); thus, makes them appealing to be used in organic farming.

Regarding the comparison of nutritional properties of food in organic and conventional farming, two categories are considered. First primary essential nutrients (e.g., water, proteins, fiber, carbohydrates, vitamins, fats, dry matter, and minerals) and second, secondary metabolites (e.g., terpenes, phytonutrients phenolic, alkaloids, and sulfur-containing compounds). Through diverse researches, it has been revealed that there are a remarkably higher amount of these nutrients in organic crops than non-organic ones (Brandt and Mølgaard 2001). However, this is hard to confirm this conclusion as some studies have repudiated these results (Bansal 2017). Nevertheless, to summarize all the data, organic products do reduce food toxicity and may contain more nutrients in comparison to traditional products.

Organic farming effect on water reusability

Today, it is inevitably essential to protect the limited surface and groundwater water bodies since the annual usage of pesticides has been estimated more than four million tons, which is harmful to human health and environmental resources (Weber 2018). Not only are most of these compounds highly stable and resistant in the environment, but also they can biomagnify in organisms living in the water (Rezaei et al. 2019). As a case in point, diazinon (Organophosphorus) persists in water and soil even for several months (Cruz et al. 2017). Moreover, in recent decades, a substantial amount of this insecticide has been detected in different water and soil parts (Perry 2008; Esfandian et al. 2016). Accordingly, in organic agriculture, due to the significantly reduced usage of chemicals applied than conventional farming systems, especially nitrogen and phosphorous ones, the water contamination is less, increasing the water reusability (Trewavas 2004).

Moreover, organic farming depends on improving soil structure by using compost as an alternative to inorganic fertilizers and animal manure to provide the plant's nitrogen source. It has been indicated that compost application decreases nitrogen and phosphorus runoff and their concentration in wastes, increasing water reusability (Benitez et al. 2003; Wolkowski 2003; Evanylo et al. 2008). Besides, nitrate contamination in groundwater can be inhibited by assessing the nitrogen mineralization rate and using a nitrogen-scavenging cover crop. In compost-rectified soils, the possible venture of exceeding the concentration of nitrogen and phosphorus in runoff water can be balanced by enhancing infiltration, porosity, and water-holding capacity; thus, diminishing the runoff bulk (Evanylo et al. 2008).

In organic farming, the practices by which the conservation and recycling of nutrients in the farming system are implemented will guarantee and prevent water contamination. In field management, if the nutrient balances keep along with holding water inside the fields, diminishing and preventing water flows onto/into the fields and vice versa, the nutrients will get conserved within the field besides preserving the environment. In addition, planting cover crops and rotation crops can protect the soil, increase water infiltration, and decrease nutrient runoff and erosion (Tully and McAskill 2020). Also, these crops positively affect the soil quality, nutrient capturing, as well as aid in recycling nutrients instead of leaching through the soil (Sivaranjani and Rakshit 2019). Trap crops that are also used for integrated pest management in organic farming can help in increasing the water-retaining capacity, decreasing water consumption in agriculture (Hassanali et al. 2008).

Various soil organisms and active organic matter can increase nutrients storing capacity in the soil and reduce possible transportation of these nutrients to ground or surface waters. Eventually, the functions through which nutrients conserve inside the crop fields will protect the environmental quality of adjacent streams, lakes, and rivers (Sivaranjani and Rakshit 2019).

Challenges in organic farming

Although organic farming is considered environmentally friendly, however, there are limitations associated with it. As a last resort to manage pest infestations in organic fields, some organic pesticides are allowed to be used, namely, rotenone, pyrethrum; both are plant extracts that are largely used in organic fields (Isman 2006; Sivaranjani and Rakshit 2019). Similar to synthetic pesticides, not only are they potent against pests, but also were found to be toxic to fish, humans, and animals. Thus, the over-application of organic pesticides might lead to runoffs from the field and contaminate nearby water bodies, which is well documented for synthetic pesticides.

Rotenone's mode of action is to inhibit the electron transport chain and prevent energy production, so it is also known as mitochondrial poison (Hollingworth et al. 1994). It is found to be potent against insects upon being ingested. Similar to synthetic insecticides, such as DDT, pure rotenone is also found to be acutely toxic to mammals; however, it is much less toxic present in formulated products (Isman 2006). With respect to humans, rotenone was recognized to be neurotoxic and had also been linked to Parkinson's disease (Sherer et al. 2003; Tanner et al. 2011). A study concerning on stability of rotenone in a field application showed it to have a half-life of four days, and, during the time of harvesting, rotenone residues were detected above the tolerance level (Cabras et al. 2002). Moreover, the study also highlighted the increase in residues concentration in the oil derived from the crop. Similar to rotenone, pyrethrum is also found to be neurotoxic, and it inhibits the voltage-gated sodium channels in nerve axons (Meurer-Grimes 1996). When pure pyrethrum is used, it is classified as moderately toxic to mammals, and thus, this needs to be used with caution.

A systemic study by Bahlai et al. 2010, indicated that organic pesticides not necessarily was better than synthetic ones. As organic pesticides were not as efficient as synthetic ones, a large amount had to be applied in fields that affected all the insects in the fields irrespective of whether the insect is a pest or a predatory insect. The predatory insects are beneficial and protect the crops from pests by feeding on them, so the lack of specificity in organic pesticides caused more harm to the environment (Bahlai et al. 2010).

As organic farming productivity is low, a bigger area needs to be irrigated to get the same amount of production as in traditional farming (Mcgee 2015). The study of Tuomisto et al. 2012, estimated that organic farming would take up about 84% more land on average in relative to conventional farming (Tuomisto et al. 2012). Thus, the cultivation of larger areas would cause more deforestation and will have a detrimental effect on the environment. Moreover, to cover the area in organic farming, more heavy agro-machinery will be used that might lead to an increase in greenhouse gas emissions (Mcgee 2015).

The use of manure in organic farming, instead of synthetic fertilizers, is a very common practice that might be of concern to human health. These manures are often found to contain microbial pathogens such as *E. coli*, *Salmonella*, and can contaminate fresh fruits and vegetables (Buchanan and Doyle 1997). Root crops and leafy vegetables are prone to be the carrier of these pathogens that can cause gastrointestinal problems in humans, especially in children (Beuchat and Ryu 1997). Moreover, due to the proximity of fields near water bodies, there is a high chance of frequently contaminating the water, decreasing the reusability of water (Sivaranjani and Rakshit 2019). Furthermore, a recent study analyzed the post-harvested shelf-life of organically grown fruit, apple, and reported that they tend to have less shelf-life upon storage (Wassermann et al. 2019). The main reason for getting spoiled fast can be the heavy usage of manures that is rich in microorganisms along with no usage of chemical preservatives in organic farming.

Management of organic farming also faces challenges related to molecular ecological interactions. The use of aluminum-based yellow mulches in Israel was highly detrimental for whiteflies that attracted whiteflies onto the hot film, but the same system was not effective in Florida that might be due to change in behaviour of aphids resulting from climatic differences (Frank and Liburd 2005; Lapidot et al. 2014). Similar studies on the use of biocontrol agents were reported to be ineffective in some conditions (Van Diepeningen et al. 2005; van Bruggen et al. 2016). This may have occurred due to the large microbial diversity of organically managed soil that can dilute the effectiveness of biocontrol agents (Hiddink et al. 2005).

Moreover, a recent study has reported that the induction of the phytohormones pathway, mediating the defence response against pests and pathogens, is highly complex that gets modulated by non-vector insects and also by order of their interactions with the plants (Basu et al. 2021). Furthermore, the same research group also showed that the biocontrol agents, predators, contributed to controlling the insect population; however, the rapid movement of insects in the presence of predators may lead to either an increase or decrease in pathogen transmission in plants depending upon the kind of predation risk (Lee et al. 2021a, b). Thus, studies should be implemented before releasing predators in a field as it may not always cause a decrease in pathogen transmission. Therefore, it should be noted that the kind of organic management implemented in one place may not be effective in other places and may vary according to abiotic and biotic conditions.

Future perspectives

For human health, it is of utmost importance to have easy access to clean and good quality water. However, due to the rapid increase in population, the availability of clean water has become an issue. Surprisingly, a recent report of UN, 2019, highlighted that by the end of this century, 2100, the rise in population would mostly occur in developing countries, e.g., India, China, Nigeria, Pakistan, D R Congo (United Nations 2019). In other words, this increase in population will happen mostly in countries where the natural resources are already limited and severely challenged by water shortages and poor quality of water. In addition, the economy of developing countries is heavily dependent on agriculture that uses about 70% of the world's accessible freshwater, and to keep up with the population growth while mitigating the hunger issue, it is expected to increase crop production by 100%. Furthermore, suggesting a critical role of agriculture in using the water efficiently to have sustainable growth where enough crop and clean water is accessible for humans.

Here we did a comprehensive review of literature focusing on organic farming, which in general is considered to be environmentally friendlier than conventional farming. While synthesizing the literature on organic farming's effect on food toxicity, water reusability, and the underlying molecular mechanism that highlights the low risks of pests and diseases in organic crops, we identified some knowledge gaps that would direct future research directions.

To have sustainable development, it is a prerequisite to follow practices that are not detrimental to the environment, but at the same time, allows an increase in crop production. Data indicate that, in the presence of agrochemicals rich in nitrogen and phosphorus, more vegetative growth can be detected in plants. Consequently, there will be more productivity per unit area that is often limited in organic farming, and it is only implemented on an industrial scale which covers more land. Due to the use of the large area to grow organic crops, it is estimated that organic crops require more water to have similar productivity as in conventional farming, which would cause more shortage of clean water for human consumption. Therefore, the focus should be given to increase the productivity in organic farming per unit area and not only on integrated pest management that would be valuable to farmers, especially from developing countries that own small lands.

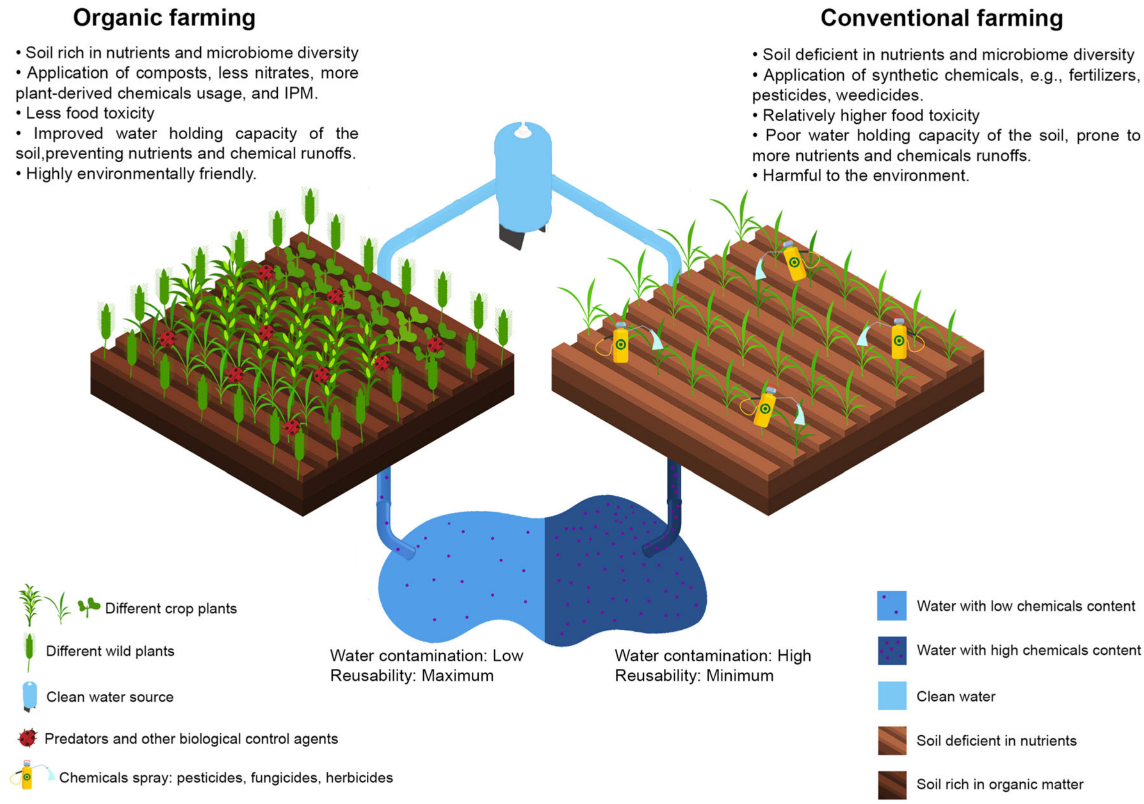

Fig. 1 An illustration highlighting the critical role of organic farming in sustainable development over conventional farming. Organic farming exploits natural resources instead of synthetic chemicals to manage pests and pathogens in fields subsequently, decreasing food toxicity and water contamination

Although practices are encouraged to keep the risk of pests and diseases low in organic fields, due to some unavoidable circumstances, organic pesticides had to be used to save the crops and prevent losses to farmers. Notwithstanding, plant-derived products are currently used in organic pesticides, e.g., rotenone, pyrethrum; their lack of specificity and being potent against unintended insects make them toxic for the environment. The use of Bt toxin can be one such alternative that is specific to certain pests but is not much implemented in organic farming. Considerable interests have been directed towards microbial control of pests, particularly by means of Bt, as the most successful entomopathogenic bacterium. Due to the high and specific insecticidal activity of Bt toxins, several studies have been focused on the isolation and characterization of Bt strains (Khorramnejad et al. 2018b). Identification of novel insecticidal proteins (Khorramnejad et al. 2020b) with higher insecticidal activity (Khoramnezhad et al. 2016), a different mode of action (Khorramnejad et al. 2020a), new specificities, and a broader range of toxicity (Khorramnejad et al. 2018a) are of crucial importance for the efficient management of insect pests. Also, more considerations have to be given to bio-insecticides utilization as a part of integrated pest management strategies and organic farming to diminish the application of chemical insecticides. Currently, a relevant state of the art applied research is going on in Iran, where different strains of Bt-based bio-pesticides are being developed and registered by the Nature Biotechnology Company (Biorun) (Khorramnejad et al. 2021).

Another critical gap that was noticeable was the lack of integration of molecular knowledge into organic farming that would not only make organic farming more efficient but can also be exploited to estimate the success of integrated pest management in different environments. A recent novel study by Machado et al. 2021 showed the role of primary and secondary metabolites as chemical cues that assists in pests foraging by helping them to locate hosts (plants) in a short distance (Machado et al. 2021). There are similar other studies that had identified chemical cues that can be used as the "push-pull strategy" under the integrated pest management program in organic farming. Moreover, a spin-off of this information can also be used that is using the molecular cues as markers; quantification of these markers can tell us at the early stages of implementation if the pest management program is working in different field conditions or not. The recent study of Arce et al. 2021 is of importance here which showed corn rootworm exploits carbon dioxide (CO_2) gradient to locate distant host plants; thus, the quantification of CO_2 in the soil can be a candidate marker to manage corn rootworms in fields (Arce et al. 2021). In the future, it would be interesting to see how much molecular knowledge is exploited for the benefit of organic farming.

In the coming years, it is expected that the production of organic food would increase. Thus, adequate attention should be given to increase the shelf-life of food upon storage. Lack of use of synthetic chemicals on organic goods makes them susceptible to faster spoiling. Preservatives that are derived from plants, rich in anti-microbial and antioxidant activity, should help in extending the storage time of food so that consumers can get a good quality of food (Ng et al. 2019). A recent study by Ng et al. 2019 suggested the use of flavonoids as natural food preservatives and reported that the application of flavonoids increases the storage life by two days. Moreover, as there is no information on toxicity associated with flavonoids make them a good alternative as food preservatives (Ng et al. 2019). Subsequently, this kind of related research should be encouraged that demonstrates the use of natural preservatives while not diminishing the quality of water, keeps the food toxicity at a low level, and mitigate the impending hunger problem.

Conclusion

In the current era of global warming, agriculture has a sheer responsibility to use water in a highly efficient manner that does not diminish the quality of water. Here, while highlighting the benefits of organic farming over conventional farming in terms of decreasing food toxicity, increasing water reusability, and keeping pests and pathogens' risk low, we also stressed over the current challenges that need to be overcome to have sustainable development. The transition from conventional farming to organic farming would take time which is a prerequisite to enrich the soil microbiota and maintain adequate chemicals level to sustain organic crops with fewer pathogens pressure. This transition period may prolong for about 5 years, during which there will be no crop production (van Bruggen et al. 2016). However, to sum up all the pros and cons in terms of environmental friendliness, organic farming still outcompetes conventional farming in the long term (Fig. 1). Though the studies show organic farming requires more water per productivity, due to less chemical usage (almost negligible), the water would be contamination-free and highly reusable (Fig. 1). Moreover, organic farming also increases the water holding capacity of the soil that would decrease the runoffs and leaching of soil nutrients and keep water bodies clean (Fig. 1). Nevertheless, more focus needs to be given to research that increases productivity, enriches food with more beneficial nutrients, and keeps the price of food minimal that is affordable to everyone.

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