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Chemical Farming *vs.* Organic Farming : A Comparative Assessment

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Abstract

Chemical farming is being practiced in 98.5% of its total land of the world while the global area of organic farming (certified) is only 1.5%. In India, about 2 million hectares (Mha) land is organic against net sown area of 142 Mha and the present status of organic area in the world is 71.5 Mha. During last 70 years (1950-2020) in India, the chemical farming helped in enhancement of food grain initially, but later its excessive and imbalanced use seriously degraded the environmental quality. Because of chemical farming, there has been a shrinkage in biodiversity including crops/crop species, wild life disturbance, decline in soil fertility, deterioration in food quality, adverse effect on human as well as animal health. Organic farming is a movement launched to combat the negative effects of chemical farming. It has been projected to be an environmentally and ecologically sustainable production system. At present, the global market for organic food is 100 billion US$. Value of Indian organic products export is Rs. 5,151 crore (757 million US$). Organic farming is catching up fast with farmers across the world, but there are limitations also. Data related to organic farming in comparison to chemical farming in the country is still inadequate. This paper attempts to compare the chemical and organic farming with focus on soil health, pest control, crop yield, food quality, ecology, economy and overall sustainability.

Key words: Chemical farming, organic farming, fertilizers, pesticides, pollution, bio-organic inputs, soil health, crop protection, organic food, market, sustainability

Introduction

Total land area is 13.2 billion hectares (Bha) globally, out of which 12% (1.6 Bha) is used for cultivation of agricultural crops. About 98.5% of the agricultural land is engaged for conventional farming and rest 1.5% is only under organic farming (FiBL & IFOAM, 2019). Although the comparative platform is not substantially strong for small size of organic area, numerous studies have reported on the comparative performance of these two farming practices during last 35-40 years (Carbonaro et al. 2002; Chassy et al,. 2006; Sharma et al., 2008; de Ponti et al., 2012; Schrama et al. 2018).

Conventional farming as practiced is a typical chemical farming as it mainly depends on the use of agrochemicals like chemical fertilizers, pesticides, herbicides etc. with an aim to enhance more food production with efficient farming practices. It is also known as industrial farming or factory farming in India as factory firms have commanded the farmer's farms for more than six decades (since 1960s).

A. Chemical Farming

Synthetic fertilizers and pesticides constitute the core of chemical farming.

I. Fertilizer Growth

a) History and Concept

The history of fertilizer in the world is 180 years old. German Chemist Justus von Liebig (1803-1873) was the first to advocate in 1840 that a cropped soil is restored to fertility by adding to it all minerals and nitrogen (N) removed by the plants. Development of phosphatic fertilizer (SSP) by British Scientist John Bennet Lawes in 1842, and synthesis of ammonia by German Scientists Fritz Haber and Carl Bosch in 1910 paved the way for foundation of fertilizer industry in Germany, United Kingdom (UK) and United States of America (Tandon, 2009).

Mineral fertilizers contain nutrients required for growth and development of plants which uptakes nitrogen as NH_4^+ and NO_3^-, phosphorus as $H_2PO_4^-$ and HPO_4^{2-}, potassium as K^+ etc. Seventeen nutrients have been identified as essential for plant growth. Out of these 17, four [Carbon (C), oxygen (O), nitrogen (N) and hydrogen (H)] form bulk (92-98%) of the dry matter of the plant and a plant can potentially derive these from environment. Remaining 13 can be either taken up by the plants or supplanted through other external sources. Nutrient uptake by plants in ionic form helped by direct fertilizer application, provides strength to chemical farming concept over organic farming as fertilizer takes a central role in chemical farming.

b) Global Status

In the last 7 decades, fertilizers have been a subject of prime concern among the researchers, companies

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and policy makers like. World fertilizer consumption in 1950-51, measured in terms of three major nutrients – N, P_2O_5 and K_2O, was 14.85 million tonnes (Mt) which increased to 186.67 Mt (12.5 times more) against the total supply of 245.76 Mt (FAO, 2017a). This consumption figure is expected to cross 200 Mt shortly. Top fertilizer producers in the world include China (36.95 Mt), India (13.79 Mt) and USA (11.32 Mt).

c) India's Status

Contribution of agriculture to India's gross domestic product (GDP) is 14%. Fertilizer industry in India made a beginning with establishment of first single superphosphate (SSP) plant by Eid Perry in 1906 in Ranipet, Tamil Nadu. It was followed by first setting up of ammonium sulphate plant in 1933 at Jamshedpur, urea in 1959 at Sindri, and DAP at Vadodara in 1967. These developments gave huge momentum to production and consumption of fertilizers in India. Currently, Indian farmers are using about 110 products of fertilizers. These include straight N, P, K and S fertilizers; NP/ NPK complex fertilizers; micronutrient fertilizers; fortified fertilizers; 100% water soluble complex fertilizers and the list is increasing with every passing year.

Nutrient-wise consumption (Mt) of N, P_2O_5 and K_2O during 2019-20 was 18.86, 7.46 and 2.64 respectively, totalling 28.96 Mt. During 1950-51, the fertilizer (NPK) consumption was 0.07 Mt (FAI, 2020). Interestingly, the food grain produced in India during 1950-51 was 50.8 Mt which is now predicted to be around 306 Mt in 2020-21. Six times more food grain production obtained with use of nearly 400 times more fertilizer nutrients during last 70 years creates doubts on the sustainability of chemical farming.

II. Pesticide Growth

a) History and Concept

Establishment of the insecticidal property of DDT by Swiss Chemist Paul Hermann Muller during Second World War heralded the use of pesticides in agriculture. Crop losses due to pests, diseases and weeds have been estimated at 10-30% of the total produce. Crops grown in the field are damaged by over 10000 species of insects, accounting for estimated annual losses of 13.6% globally, and 23.3% in India (Dhaliwal, 2004).

b) Global Status

Enormous data exist on use of pesticides in India and abroad (Pimentel et al. 2005; Sharma et al. 2010; FAO, 2017; Subash et al. 2017). Data on the global production status of pesticides during 1950-51 is not available as the supply situation for all pesticides was very tight at that time. But there was a demand for DDT and BHC, albeit the potential capacity was not fully utilised. Currently, the global consumption of pesticides is more than 2 Mt which is estimated to increase up to 3.5 Mt (Personal communication with O.P. Sharma, 2020). Per hectare pesticide consumption in China, USA, Argentina and Brazil has been reported to be 13.1, 2.5 kg, 4.9 kg, and 6.0 kg, respectively.

The insecticides market was estimated in 2017 to be US$ 14.5 billion (www.marketstandmarket.com,2017) and it is projected to grow at a compound annual growth rate (CAGR) of 5.8% to reach US$ 19.3 billion by 2022. The global fungicide market was estimated at US$ 18.7 billion in 2019.

c) India Status

In 1952, India introduced pesticide use with the production of benzene hexachloride (BHC) followed by DDT. Initially (during 1958), 5000 t of synthetic pesticides were produced in India. But in the aftermath of Green Revolution, the production reached gradually to 102,204 t in 1998 (Aktar et al., 2009). Currently, the pesticide consumption is estimated in the range of 55,000-60,000 t yr^{-1} (Indira Devi et al., 2017). Consumption of pesticides follows the sequence: insecticides (53%) > herbicides (23%) > fungicides (19%); rest constitute only 4% of the total. The average per hectare consumption of pesticides in India varies between 550 - 600 g. Indian pesticide industry was worth 4.25 billion US$ in 2014 with 12.13% growth and was expected to reach 7.5 billion US$ in 2019. India is 4^{th} largest global producer of pesticides after USA, Japan, and China.

Adverse Impacts of Chemical farming

I. Fertilizer use

a) Soil health deterioration: In popular perception, the long-term use of mineral fertilizers is implicated with the deterioration of soil health. Of course, there are very few reports vouching for this thinking. Soil fertility has been closely linked with soil organic matter (Goswami and Rattan, 2004; Dwivedi and Dwivedi, 2007; Katyal and Rattan, 2007; Sharma, 2008; Sharma et al. 2017; Rao et al., 2019) and its decline is a matter of serious concern. Manna et al. (2019) reported that the chemical fertilizer application has negative effect on SOC storage in the soil; Wang et al. (2015), however, reported to the

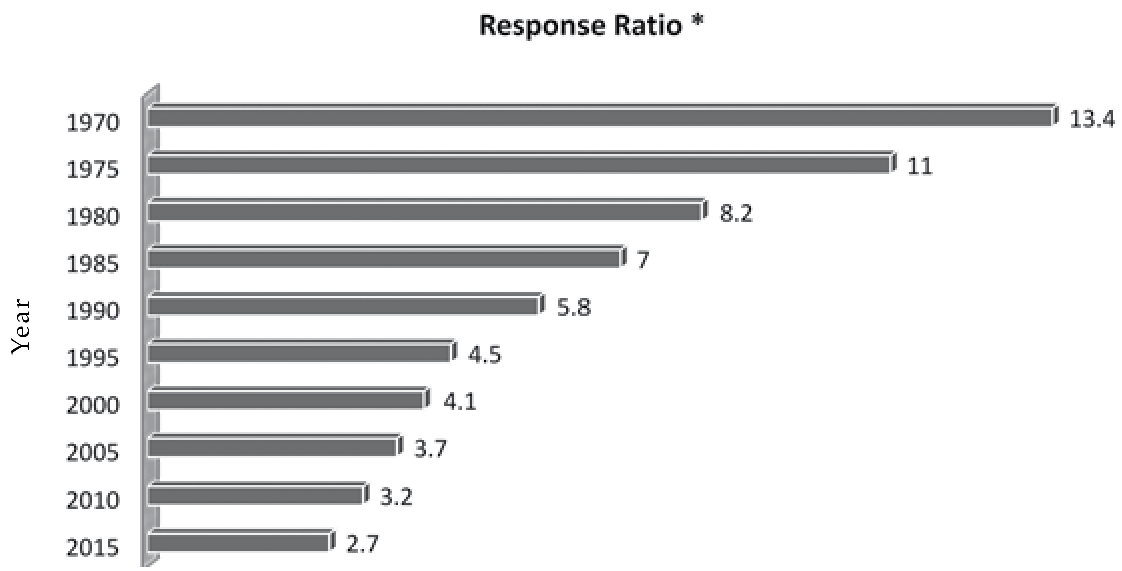

Figure 1. Fertilizer response ratio in kg grain kg^{-1} nutrient use from 1970 to 2015 (Source: Chaudhari et al., 2015)

contrary. Imbalanced use of mineral fertilizers has resulted in emergence of deficiencies of secondary and micronutrients. For example , 25.8%, 33.7%, 31.3%, 22.6%, 12.5% and 4.8% samples were deficient in sulphur (S), zinc (Zn), iron (Fe), boron (B), manganese (Mn) and copper (Cu) respectively. (https://soilhealth.dac.gov.in/NewHomePage/StateWiseNPKChart as assessed on February, 2021).

b) Declining fertilizer response and yield stagnation: The fertilizer response ratio [kg grain/ kg of nutrient used] declined four times, from 13.4 in 1970 to 2.7 in 2015 (**Figure 1**). Chaudhari and Biswas (2020) reported that at present, application of 280 kg nutrient ha^{-1} is required to produce 2 t additional grains against 54 kg nutrient needed in 1970 to produce the same quantity. Because of low fertilizer use efficiency (30-50% for N, 10-20 % for P, 60-80% for K, 2-5% Zn, 1-2% Fe, Mn, Cu) food grain productivity growth rate (% per year) has almost stagnated after 1981-90 (Yogendra-Kumar, 2018).

c) Pollution by fertilizers: Excessive N applications are implicated with environmental pollution via ammonia volatilization, nitrate leaching to ground water, and emissions of nitrous oxide (N_2O), a greenhouse gas responsible for global warming, into the air. Emissions of NH_3 (10.1-22.8 kg ha^{-1}) and N_2O (0.16-0.93 kg ha^{-1}) from the rice soil is a matter of concern (Pathak, 2016). There are reports of nitrate (NO_3) contamination of ground water (beyond the acceptable level, 45 mg NO_3^- L^{-1}) for Haryana (Kakar 1981; Mittal et al. 2009). In Punjab, 41% of the farmers apply fertilizer more than 260 kg ha^{-1}. Besides, fertilizer contains trace quantities of metals like As, Cd, Cr, Pb etc. (Pathak et al., 2019). Phosphatic fertilizers are implicated with cadmium (Cd) contamination of agricultural soils, as phosphate rocks, raw material for the phosphatic fertilizers, contain appreciable amounts of Cd. In Europe, average Cd content in mineral fertilizer is reported to vary from 68 mg kg^{-1} P to 83 mg kg^{-1} P. Excessive use of N-fertilizer causes acidification, eutrophication in water bodies leading to diseases like methemoglobinemia, and cancer in humans. Seneviratne (2009) reported the collapse of beneficial microbes in soils which had continuously received fertilizers and pesticides; there occurred the deterioration of soil health.

d) Fossil exploitation: Production of N fertilizer is energy-dependent. Naphtha, a natural gas acts as feedstock for N-fertilizer production. The current consumption of naphtha in fertilizer industry is 350,000 t with average price of naphtha being Rs. 40,000 t^{-1} (FAI, 2020). On the other hand, fertilizer plants used a total of 46 million standard cubic meters per day (MMSCMD) of natural gas out of which at least 50% had to be imported. The cost of production of urea is high due to use of imported gas and liquid fuels (Chander and Nand, 2013).

Financial burden: The major problem in conventional farming associated with chemical fertilizers is subsidy burden. Over the years there has been phenomenal increase in fertilizer subsidy which has gone up from a moderate Rs. 375 crores in 1981-82 to whopping Rs. 1,00,000 crores in 2012-13. Currently the subsidy amount is around Rs. 80,000 crores. Apart from the subsidy, there is also a huge financial load on foreign exchange needed for importing fertilizers or its raw materials.

II. Pesticide Use

a) Toxic substances: There are several reports (Aktar et al. 2009; Pimentel et al. 2005; Sharma et al. 2010;

Zhang et al. 2011; Tuomisto et al., 2012; Subash et al. 2017) on impact of pesticide use on human health. Pesticides contain toxic substances and these are present in water, air and soils in large quantities. Insecticides (pyrethroids, organophosphorus, carbamate, organochlorine, manganese compounds), fungicides (thiocarbamates, dithiocarbamates, cupric salts, tiabendazoles, triazoles, dicarboximides, dinitrophenols), herbicides (bipyridins, chlorophenox, glyphosates, triazine etc.) cause damage to both human health and environment. Persistent organic pollutants like aldrin, dieldrin, DDT, heptachlor etc. are critical; being less degradable, these persist for a long time, are lypolytic in nature and accumulate in food chain. Many food products have detectable levels of pesticides. Routine sprays (more than the actual requirement) on fruits and vegetables are a matter of serious concern. More than 70% of fruits and vegetables contain high level of pesticide residues, although they might look fresh in the market.

b) Adverse impact on health: According to United Nations, an average of about 2,00,000 people die every year due to pesticide poisoning (https://www.aljazeera.com/news/2017). Many countries have banned or restricted the use of pesticides like BHC, DDT, aldrin, parathion etc. (Bhattacharyya, 2004; Bhattacharyya and Purohit, 2008). Nicolopoulou-Stamity et al. (2016) reported that the pesticides may be metabolized, excreted, stored, or bioaccumulated in body fat of human or animals and cause many negative health effects like dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive and endocrine effects etc. Organochlorine pesticides are associated with endocrine diseases and hepatic alterations, and are even carcinogenic. Organophosphorus pesticides like glyphosate, malathion etc. are known for their endocrine disrupting potential (Mader et al., 2002). The presence of pesticide residues (more than maximum residue limits – MRL) in foods, beverages, fruits, juices, teas, coffee etc. pose huge threat to human health. Because of toxic pesticide use, environment is also damaged seriously as reflected in the bird poisoning, bee poisoning, damages to eco–friendly insects, and aquatic life.

c) Genetically modified crops: In the field of agriculture, genetically modified (GM) crops like corn, potatoes tomatoes, rice, soybeans, flax, cotton, sugar beets, canola etc. have already come into existence. Conventional farming has been promoting the cultivation of GM crops across the world (de Vendômois et al., 2010). Currently four countries account for 99% of the total global area under GM crops (USA 37.5 Mha, Argentina 11.8 Mha, Canada 3.2 Mha, and China 1.5 Mha). One of the major health concerns with GM food for human is the potential to increase allergies and anaphylaxis (hypersensitivity to foreign proteins).

ORGANIC FARMING

Organic Farming: History, Concept and Progress

a) History and Concept

As per definition of Lampkin (1990), the term ORGANIC refers not to the type of inputs used, but to the concept of the farm as an organism, in which all the components – the soil minerals, organic matter, microorganisms, insects, plants, animals and humans – interact to create a coherent, self-regulatory and stable system where reliance on external inputs, whether chemical or organic, is reduced as far as possible. The four principles of organic agriculture as advocated by International Federation of Organic Agricultural Movement (IFOAM) include: principles of health, ecology, fairness and care.

Various studies have highlighted the role and status of organic farming in India and abroad (Lampkin, 1990; Bhattacharyya 2004; Sharma and Singh 2004; Alvares, 2014; Ramesh 2014; Yadav, 2014; Aulakh and Ravisankar, 2015; Barabanova et al., 2015; Niggli et al., 2017; Rahmann et al. 2017**).** Organic farming or natural farming finds its origin to 10,000 years back when ancient farmers started cultivation with the use of natural sources only (Bhattacharyya and Chakraborty, 2005). In fact, organic agriculture has its roots in traditional agricultural practices that were evolved in countless villages and farming communities over the millennium.

The first scientific studies on organic agricultural practices were discovery of biological nitrogen fixation by Hellriegel and Wilfarth (German Scientists) in 1888 and isolation of nitrogen fixing bacteria like *Rhizobium*, *Azotobacter* by Martinus Beijerinck, a renowned Dutch Microbiologist during 1888-1905. It led to enrichment of knowledge about biological aspects of soil fertility and importance of soil fauna and soil organic matter (Rahmann et al., 2017). During the same period, Rudolf Steiner (1861-1925) gave the idea of biodynamic farming which focused on farm as an organism and linked the same to holistic and spiritual thinking. The concept of organic biological system was developed at Switzerland under the guidance of Hans (1891-1988) and Maria (1894- 1969). Other pioneer stakeholders were Lady Eve Balfour (1898-1990), Sir Albert Howard (1873- 1947) in the UK and Jerome Rodale (1898-1971) in the USA.

Ancient Indian literature like "Vrikshayurveda", Krishi Parashar (400 BC) and the contribution of scholars like Kautilya and Surapala suggested on the use of organic inputs from natural resources in improving crop production. When Sir Albert Howard, a British botanist, worked in India during 1905 to 1924 as an Agricultural Advisor, he initiated scientific production of compost (Indore Method), and later in 1942 he wrote a book entitled "An Agricultural Testament" where he emphasised on need of organic farming. Sir Howard is called the Father of Organic Farming in India. During last 30 years or so, some great philosophers-cum-agriculturists like Bhaskar Save, Subhash Sharma, Shripad Dhabolkar, influenced by the activities of Masanobu Fukuaka, a renowned scientist of Japan and author of "One Straw Revolution (1978)" dedicated their life for promotion of eco-friendly natural farming to combat the ill-effects of chemical farming. Although, Subhash Palekar does not support the organic farming, but following the principle of safe agriculture he is promoting the zero budget natural farming (ZBNF) in spite of its limitations.

Global Status

Globally, 1.5% of the farm land is organic. In 2004, the total acreage under organic farming was around 24.0 Mha spread across around 100 countries. It increased to 71.5 Mha by the end of 2018 (about 3 times more than 2004). Australia has the largest area under organic agriculture (35.7 Mha), followed by Argentina (3.6 Mha), and China (3.1 Mha) (FiBL-IFOAM Survey, 2018). Currently, 186 countries are promoting organic agriculture (https://www.foam-bio/global-organic-area-continue grow-2020).

As per the study conducted by a market research company by the name Ecovia Intelligence, the global market for organic food surpassed 100 billion US$ (almost 97 billion euros) in 2018. The United States was the market leader with 40.6 billion euros, followed by Germany (10.9 billion euros), and France (9.1 billion euros). Denmark had the highest organic market share with 11.5% of its total food market. Besides International Society of Organic Agricultural Research (ISOFAR) (www.isofar.org), Organic Farming Research Foundation (OFRF), Louis Bolk Institute, Driebergen, Netherlands (1976); Elm Farm Research Centre, UK (1982) etc. are engaged in organic agriculture research activities.

India's Status

Organic farming is rapidly gaining momentum in India. There are both opportunities as well as challenges in organic agriculture (Sharma and Singh, 2004; Bhattacharyya and Chakraborty, 2005; Pandey and Singh, 2012; Ramesh et al., 2010; Ramesh, 2014; FAO, 2017). During 2003-04, the certified organic area in India was 42,000 ha which grew almost 35-fold, touching a figure of 1.45 Mha during 2016-17. Almost all types of agricultural, horticultural and non-food crops are being grown under organic certification (APEDA, 2017). The total certified organic area in 2017-18 was 3.56 Mha which included 1.78 Mha cultivable area and 1.78 Mha for wild harvest collection. It is estimated that the organic area of India will touch 2.0 Mha by 2020-21.

As per the data of FiBL-IFOAM Survey (2018), India ranks 9th in terms of the world's organic agricultural land. The total number of organic producers across the world is 2.8 million. India has a distinction of inhabiting highest number of organic producers (11,49,000) followed by Uganda (2,10,000), and Ethiopia (2,04,000). Madhya Pradesh has the largest organic-certified area (4,64,859 ha) in the country, followed by Maharashtra (2,24,007 ha) and Rajasthan (1,51,609.9 ha) (APEDA, 2017). During 2016, Sikkim achieved a remarkable distinction of covering its entire land (more than 75,000 ha) under organic certification.

Issues Related to Organic Farming

i) Crop Yields/Farm Productivity

During last 20 years, many research reports on the status of crop yield under organic farming have been published (de Ponti et al, 2012; Seufert et al., 2012; Chandran–Wadia, 2014; Ravisankar et al., 2018; Schrama et al., 2018). Most of these findings indicate that there is a possibility of the increasing the yield of few crops and attaining stability of food production in the future under organic farming. There has been a concern that worldwide the average gap between organic and conventional agriculture ranges between 20% and 30% with high standard variations (±21%) (Seufert et al., 2012; Niggli et al., 2017; Rahmann et al., 2017; Reganold and Wachter, 2016 ; Schrama et al., 2018). Initially, yields in the organic farming system are low, but approach those of conventional systems after 10-30 years, requiring lower N-inputs in the former (Schrama et al., 2018). But the yield gap is marked in those areas where intensive conventional agricultural systems are high-yielding ones. In fact, there will be a drop in production after the start of conversion, especially in those situations where the previous system has depended heavily on the excessive use of agrochemicals.

An overview by Ramesh (2014) on how a conversion to organic agriculture affects the yields indicated that there is a yield reduction in organic agriculture practiced on the conversion of the intensive farm systems; the range of yield reduction depends on the intensity of external inputs use before conversion. Further, conversion of organic agriculture in Green Revolution areas (irrigated lands) may lead to the equalization of crop yields. Huang et al. (1993) reported that organic farming has a potential to increase the crop yields in traditional rainfed agriculture areas where low external inputs are used.

Some Scientists (For example, Borlaug and Dowswell, 1994; Tiwari et al. 2005) are of the opinion that farming without use of fertilizers will prove disastrous for food security and nutritional security. This may be an oversimplification because of the paucity of sufficient data to support or reject the possibility that organic systems can produce yields comparable to the conventional systems (de Ponti et al., 2012; Rahmann et al., 2017; Seufert et al., 2012). Based on the assessment of 40 studies, Reganold and Wachter (2016) concluded that practicing organic farming can solve food problems particularly in low input-low output systems by out-performing the local conventional systems. In this context, it may be mentioned that 60% of the 142 Mha cultivated area in India is rainfed where the vast majority of farmers in remote areas still practice low external input or no external input agriculture.

As per the study undertaken by ICAR-NPOF, 18 crops responded positively to yield on a par or higher under organic systems after the conversion period of 2-3 years. Organic management of basmati rice, rice, maize, green gram, chickpea, soybean, cotton, garlic, cauliflower and tomato gave a yield advantage of 4% to 14% over inorganic management. Yield reduction (after eighth cycle across the locations) of 5-8% was observed in wheat, radish and potato (www.vikalpsangam.org/article/theroad tosustainability). Based on the six-year long-term study conducted at the ICAR Institute of Farming Systems Research (IIFSR), Modipuram on evaluation of organic and inorganic production systems, Ravisankar et al. (2018) reported that the crops such as basmati rice, rice, soybean, cotton, sunflower, lentil, groundnut, and French bean recorded higher sustainable yield index (SYI) under organic nutrient management practices, with SYI ranging from 0.61 to 0.75 (**Table 1**). Wheat (0.58) and mustard (0.34) recorded higher SYI under inorganic production system.

Table 1. Sustainable yield index (SYI) of various crops under organic and inorganic farming (Ravisankar et al., 2018)

S. No.	Crops	Organic	Inorganic
1.	Basmati rice	0.75 ± 0.04	0.68 ± 0.04
2.	Rice	0.54 ± 0.04	0.51 ± 0.05
3.	Cotton	0.71 ± 0.17	0.55 ± 0.16
4.	Soybean	0.56 ± 0.06	0.56 ± 0.07
5.	Sunflower	0.61 ± 0.08	0.43 ± 0.08
6.	Wheat	0.52 ± 0.07	0.58 ± 0.07
7.	Maize	0.18 ± 0.05	0.23 ± 0.07
8.	Mustard	0.17 ± 0.12	0.34 ± 0.15
9.	Groundnut	0.62 ± 0.04	0.52 ± 0.11
10.	Lentil	0.71 ± 0.16	0.68 ± 0.12
11.	Potato	0.53 ± 0.12	0.59 ± 0.08
12	French bean	0.61 ± 0.13	0.44 ± 0.11

ii) Organic Management of Soil Health

Soil health has been defined by Sharma et al. (2017) as "the capacity of a soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality and promote plant and animal health". The health of soil depends mainly on physical, chemical and biological properties of soil. A healthy soil is 'biologically active' containing a wide diversity of microorganisms (Rao et al., 2019). There is a sufficient improvement/ build up in the SOC content under organic farming (Sharma and Singh, 2004).

Issues of soil health under organic management have been discussed by many scientists (Mader et al. 2002; Rupela, 2008; Ikemura and Shukla, 2009; Biswas et al., 2014; ; Reeve et al. 2016; Debjani et al., 2017). Organic farming centres on the concept of '*Feed the soil to feed the plant*' (Bhattacharyya and Chakraborty, 2005; Goswami and Rattan, 2004). It advocates the returning of sufficient quantities of biodegradable material of microbial, plant or animal origin to the soil to increase or at least maintain its fertility and biological activity.

Availability of Organic Nutrient Resources

India is endowed with vast resources of organic inputs. Tandon (1997) computed the country's tappable nutrients at 5.05-7.75 Mt (Tandon, 1997). while Bhattacharyya (2007) estimated the total available quantities of nutrient from organic resources (including biofertilizers) at 8.95 Mt. Potential availability of crop residues, farmyard manure, rural compost, urban compost, and vermicompost is estimated at 603.46 Mt, 223.4 Mt, 184.30 Mt, 11.1 Mt, and 11.4 Mt, respectively, while bio-fertilizer production is around 1.6 lakh t. As per the FCO specifications, composition for city

Table 2. Nutrient potential of green manure crops (Source: ICAR- CISH Lucknow, 2005; IFOAM Manual, 2002)

S. No.	Common names	Botanical name	Biomass (t ha^{-1})	Nitrogen incorporation (kg ha^{-1})
1.	*Dhaincha*	*Sesbania aculeata*	22.50	125.0
2.	*Dhaincha*	*Sesbania rostrata*	20.06	146.0
3.	Sunhemp	*Crotalaria juncea*	18.40	113.0
4.	Wild indigo	*Tephrosia purpurea*	6.80	6.00
5.	Green gram	*Vigna radiata*	6.50	60.20
6.	Black gram	*Vigna mungo*	5.12	51.00
7.	Cowpea	*Vigna unguiculata*	7.17	63.30

compost (Org. C 12% , 1.2% N, P_2O_5, K_2O each, C:N ratio <20:1), vermicompost (Org. C 18%, total N 1%, total P_2O_5 and K_2O 0.8% each), PROM (phosphate rich organic manure) (Org. C 7.9%, total N 0.4%, total P_2O_5 10.4% , C : N ratio <20:1) , organic manure (Org. C 14%, total N, total P_2O_5, total K_2O 0.5% each), castor de-oiled cake (Org. C 25% , total N 4.5%, total P_2O_5 and total K_2O 1.0% each, C:N ratio <10:1) etc. The success of organic manure efficiency depends on its C:N ratio. The lower the C:N ratio, faster is the mineralisation (Bhattacharyya and Chakraborty, 2005).

a) Bio-fertilizers

Bio-fertilizers are products (carrier or liquid based) containing living or dormant micro-organisms like bacteria, fungi, actinomycetes, algae alone or in combination which on application help in fixing atmospheric nitrogen or solubilise / mobilise soil nutrients in addition to secretion of growth promoting substances for enhancing crop growth and soil fertility (Venkateswarlu, 2008; Bhattacharyya and Tandon, 2012; Yadav, 2014; Yadav et al., 2016). These are considered as cheap and eco-friendly sources of nutrients. Microbes play important role in making soil living (Saxena et al., 2017; Shailaja et al., 2014). *Rhizobium, Azotobacter, Azospirillum, Gluconoacetobacter*, and blue green algae (BGA) play role as nitrogen bio-fertilizers. On the other hand, phosphate solubilising bio-fertilizers (PSB) and vesicular arbuscular mycorrhizae (VAM or AM) help in providing P to the growing crops. Besides, potash solubilising (KBF) and zinc solubilising (ZSB) bio-fertilizers have been approved for inclusion in FCO, in addition to the consortium bio-fertilizers.

The specifications of different bio-fertilizers (*Rhizobium, Azotobacter, Azospirillum*, PSB, KSB, ZSB ensure minimum viable count (cfu) of 5 x 10^7cells g^{-1} of carrier material or 1 x 10^8 cell mL^{-1} of liquid (FCO, 2019). Bhattacharyya and Tandon (2012) and Bhattacharyya (2014) have discussed the impact of bio-fertilizer use in organic farming and reported that bio-fertilizers application may result in an average increase of 11.4% in crop yield. Bio-fertilizer production in the country was around 1,60,000 t during 2017-18 (FAI, 2019).

b) Role of Legumes

Legumes play a significant role in maintaining soil health. Mostly, the fast-growing leguminous plants (*Dhaincha*, sunhemp, cowpea etc.) are grown and buried in the soil before planting a main crop (such as rice, sugarcane, others) (Venkateswarlu, 2008). Upon incorporation in soil, these add N to the soil (**Table 2**). Subhash Palekar in his concept on zero budget natural farming (ZBNF) has given considerable importance to the use of leguminous plants for maintaining soil health. Biologically fixed N can supplement 25-60% of N requirement of different crops grown under diverse environments. Intercropping with leguminous plants or crop rotation is a prerequisite for organic farming.

c) Cover Crop/Green Leaf Manure

Green leaf manure can be obtained from several trees like glyricidia (*Saranga* or *Giripushpa*) and tephrosia (*Jangli neel* or *Sharpunkha*). Plant biomass seems to be the engine of crop productivity in organic farming. At ICRISAT, the use of *Glyricidia sepium* grown on the boundary gave good biomass and added to the nitrogen fertility of soil (Tandon, 2009). Glyricidia leaves contain 2.4% N, 0.1% P and 1.8% K besides all the secondary and micronutrients. Glyricidia plants grown on 700 m long bunds can provide about 30 kg N ha^{-1} yr^{-1}. One tonne of glyricidia leaves provide 24 kg N, 1 kg P, 18 kg K, 85 g Zn 165 g Mn, 365 g Cu, and 72 g Fe.

Indigenous (ITK-based) bio-organic products: The concept of indigenous knowledge is the traditional wisdom used for conservation of resources involving subsistence agriculture. Organic farmers use

Table 3. Physical, chemical and microbiological status of few indigenous preparations used in organic farming

S.No.	Parameter	*Panchgavya*	*Amrit pani*	*Beejamrut*	*Sanjibani*	*Jeevamruth*
*I. **Physical/Chemical parameters***						
1	Nitrogen (%)	0.007, (1.4[++])	0.008 [+]	40 ppm [+++]	1.03 [++]	1.96?
2	Phosphorus (%)	0.01[+], (0.08[++])	0.016[+]	155 ppm [+++]	0.04 [++]	0.173?
3	Potash (%)	0.06 [+], (0.5[++])	0.06[+]	252 ppm [+++]	0.5 [++]	0.28?
4	pH	5.6 [++]	-	8.2 [+++]	7.8 [++]	4.92?
5	EC(dS m^{-1})	4.6[++]	-	5.5 [+++]	3.5 [++]	-
6.	Organic carbon (%)	14[++]	-	-	10.3 [++]	-
7	Zinc (ppm)	2.9[+]	7.9[+]	2.96[+++]	-	-
8	Copper (ppm)	2.4[+]	4.0[+]	0.52[+++]	-	51?
9	Manganese (ppm)	1.7[+]	18.8[+]	3.52[+++]	-	46?
10.	Iron (ppm)	25.8[+]	213.2[+]	15.35[+++]	-	-
II. Microbial parameters						
11	Bacteria (cfu mL^{-1})	$34x10^6$[@]	6.96[**]	15.4×10^5[+++]	$137x10^6$[++]	$692x10^5$?
12	Fungi (cfu mL^{-1})	$22x10^6$[@]	4.00 **	$1.5x10^3$[+++]	-	$7x10^4$?
13	Actinomycetes (cfu mL^{-1})	$3x10^2$[@]	4.00**	$6.8x10^3$[+++]	-	$1x10^3$?
14	N-Fixer (cfu mL^{-1})	2×10^2[@]	5.0 **	3.1×10^3[+++]	-	20×10^4?
15	P- Solubiliser (cfu mL^{-1})	-	5.85**	2.7×10^2[+++]	-	61×10^4?

Source: [+]Pathak et al. (2010); **Rupela et al. (2006) [Microbial population {Log_{10} cfu g^{-1}}]; [+++] Sreenivasa et al. (2009); ?Devakumar et al. (2014); [++] Ali et al. (2011); @ Somasundaram (2005)

Panchgavya, Amrit Pani, *Beejamruth*, *Jeevamruth,* and *Sanjibani* as farm-made organic inputs which consist of five products from cow *e.g.*, dung, urine, milk, curd and ghee in different proportions or with some value addition. *Kunapajala* - a liquid ferment from animal wastes containing animal flesh, dung, urine, bones, marrow, and skin, application improves significantly the crop growth (Nene, 2012). For a long time, there has been a demand for scientific validation of ITK–based indigenous bio-organic inputs. Data on physical, chemical and biological properties of these inputs have been generated (**Table 3**). All of these inputs have been found to produce different growth promoting substances like IAA, GA etc. and because of these ingredients, organic farmers prefer them for field application. Rupela et al. (2006) found very high microbial population in these indigenous products. Organic farming always faces a criticism that sufficiently large quantities of organic manures (including FYM) needed for replacing NPK quantities are simply not available. But instead of using large quantities of cow dung, organic farmers prefer use of these indigenous products which make the soil living *i.e.*, active and ensure the availability of nutrients. The research findings from ICRISAT indicate that the organic plots had 17-27% more soil respiration, 28-29% more microbial biomass carbon, 23-28% more microbial biomass nitrogen (MBN), and 5-13% higher acid and alkaline phosphatase activity than the conventionally fertilized plots (Rupela et al., 2006).

Under the ICAR's Network Project on Organic Farming, Gill and Prasad (2009) reported some of a) non-edible oilcake (NEOC) + cow dung manure (CDM) + enriched compost (EC) at Raipur; b) farmyard manure (FYM) + NEOC at Ranchi; c) CDM-CDM + poultry manure (PM); and d) EC+ VC + green leaf manure (GLM) + neem cake (NC) at Dharwad etc. as the best performing treatments.

Impact on Soil Health

Pathak et al (2010) observed significant improvement in physical, chemical and biological

Table 4. Effect of biodynamic/organic farming practices on soil properties over 5 years period (Source: Pathak et al., 2010)

S. No.	Constituents	Improvement after organic cultivation			
		Initial	II year	III year	IV year
1.	Organic carbon (%)	0.53	0.80	1.00	1.16
2.	Phosphorus (ppm)	8.63	8.66	22.66	56.27
3.	Potassium (ppm)	140.00	142.50	202.50	1062.25
4.	Yeast and mould (cfu g^{-1})	1.3×10^4	5.8×10^4	8.5×10^4	8.5×10^4
5.	Bacteria (cfu g^{-1})	3.7×10^6	4.8×10^6	8.0×10^6	3.1×10^8

properties of the soil under biodynamic practices followed for a period of 4 years. In their study, soil organic carbon (SOC) content increased from initial 0.53% to 1.16% in the 4th year (**Table 4**). There was also a considerable improvement in the count of bacterial population, available P, and available K. Gill and Prasad (2009) also reported improvement in soil health under organic and integrated nutrient management systems (INM). The organic carbon was 0.37% under chemical system against 0.54% under organic management and 0.50% under INM systems. There was also a higher build-up of available P and K in the organic and INM systems as compared to the chemical system. Based on their study, Gill and Prasad (2009) reported that "the continuous practice of raising the crops organically has good potential to sequester the carbon (up to 63% higher carbon stock in 10 years), higher soil organic carbon (22% increase in six years), reduction in energy requirement (by almost 10-15 %), and increase in water holding capacity (by 15-20%).

Bhattacharyya et al. (1984, 1986) reported positive effect of organic manures on total nitrogen, nitrogen fixing power, mineralisation, and phosphate solubilising power of rice and succeeding wheat rhizosphere soils. The efficiency of N-fixing power and P-solubilising power was highly influenced by value addition with the organic manures.

Organic farming following the natural cycle maintains soil fertility and increases the SOC content. Biswas et al. (2014) reported that organic farming had a positive effect on soil physical properties namely, soil structure, water holding capacity, soil aeration etc. Papadopoulos et al. (2014) also recorded improvement in soil structure, organic matter content and soil porosity; introduction of crop rotation with leguminous plants under organic farming had synergistic influence on physical properties of the soil. Biswas et al. (2014) opined that the organically managed soil holds more available N than the soil receiving only inorganic fertilizers, mainly due to relatively slower and constant mineralisation rates in the former. They reported 20-30% and 30-100% increase in microbial biomass and microbial activity, respectively.

Organic Management of Plant Protection

First public awareness in relation to toxicity and non-target effects of pesticides came into light with the publication of Rachel Karson's "Silent Spring" in 1962 that led to the ban of DDT. To overcome the health hazards associated with pesticides, importance has been given on biological pest management practiced either through biological, cultural or organically accepted chemical alternatives as prescribed by organic standard (Bhattacharyya, 2004). This is a part of knowledge-intensive farmer-based management approach termed as integrated pest management (IPM), which encourages the natural control of pest population by anticipating pest problems and preventing pests reaching the economically-damaging levels.

Bio-pesticides, Bio-control agents, Microbial and Botanical pesticides

Bio-pesticides or biological pesticides are certain type of pesticides that are derived from natural materials like plants (botanical origin), bacteria, fungi and virus (microbial origin) and certain minerals (**Table 5**). During the last 30-40 years, several researchers have undertaken studies on the use of bio-pesticides, bio-control agents, microbial and botanical pesticides (Manjunath, 1997; Rodgers, 1993; Sharma et al., 2008; Vimala Devi, 2008).

Use of bio-control agents like parasitoids (*e.g.*, *Trichogramma* spp., *Telenomus remus*), predators (*e.g.*, Chrysopids and Coccinellids etc.), microbial pesticides like bacterial pesticides [*e.g.*, *Bacillus thuringiensis* (BT), *Pseudomonas fluorescence* etc . as bacterial pathogens], fungal pesticides like *Beauveria bassiana*, *Verticillium lecanii*, *Metarhizium amisopliae* (bio-insecticides), *Paecilomyces lilacinus* (bionematicides), *Trichoderma viride*, *Trichoderma harzianum* (bio-fungicides), *Phytophthora palmivora* (bio-weedicides) and viral pesticides (nuclear polyhydrosis virus – NPV) are common (Bhattacharyya, 2004; Bhattacharyya and Purohit, 2008; Sharma et al., 2008; Chaudhari and Biswas, 2020). Among botanical pesticides, *Azadirachta indica* and *Pongamia glabra* etc. are being used by organic farmers to control pests (Bhattacharyya, 2004).

ITK-based Indigenous Products

Use of indigenous technical knowledge (ITK) is considered as eco-friendly and economical tool for pest management (Radhakrishnan, 2005). Cow urine is a natural animal by- product for insect pest suppression (Huber et al., 2011). Based on ITK, organic farmers use several products like *panchgavya, amritpani, sanjibanee, jeebamruth, beejamruth* (cow products-based). *Neemastra*, *brahmastro* (neem-based), *dashparni* extract (mixture of leaf extracts of neem, *karanj*, castor, green chilli, garlic etc,), *agneyastra* (Ipomea-based) which are quite popular in organic plant protection system and these are made at the farm and are also cost-effective.

Presence of Bioactive Compounds

Botanical or microbiological pesticides contain

Table 5. Presence of toxins in pesticides

Parameters and name	Toxin	Chemical formula	Chemical type or nature	Mode of action
Botanical pesticides				
i) Neem (leaf, seed, kernel) (*Azadirachta indica*)	Azadirachtin, Selanin, Nimbin	$C_{35}H_{44}O_{16}$ $C_{34}H_{44}O_9$ $C_{30}H_{36}O_9$	Limonoid or triterpenoid organo-compound	GR, PC, R
ii) Garlic (Rhizome) (*Allium sativum*)	Allicin	$C_6H_{10}OS_2$	Organo Sulphur Compound	B, BC, FC
iii) Hingot (Seed, root) *Balanites roxburghii*)	Diosgenin	$C_{27}H_{42}O_3$	Phyto steroid sapogenin	AF, FC
iv) Panlata or Kalilata (root) (*Derris elliptica*)	Rotenone	$C_{23}H_{22}O_6$	Isoflavone	PC
v) Karanj (seed) (*Pongamia pinnata*)	Karanjin	$C_{18}H_{12}O_4$	Furrano flavonoid	PC
vi) Marigold (root) (*Targetes* spp.)	Terthienyl	$C_{12}H_8S_3$	Oligomer sulphur compound	PC
Microbial pesticides				
a. Bacterial insecticides/ fungicides				
i) *Bacillus thuringiensis*	Crystal (Cry) and Cytolectic (Cyt) protein		Endotoxin	BA, GC, IC
ii) *Pseudomonas fluoroscens.*	Phenazine	$(C_6H_4)_2N_2$	Nitrogen containing heterocyclic compound	IC
b) Fungal insecticides / nematicides				
i) *Beauveria bassiana*	Bassianolide	$C_{45}H_{57}N_3O_9$	Cyclodepsi peptide	GC, IC
ii) *Verticillium Iecanii*	Bassianolide Dipicolinic acid	$C_{45}H_{57}N_3O_9C_7H_5NO_4$	Cyclodepsi peptide	GC, IC
iii) *Metarhizium anisopliae*	Destruxin	$C_{29}H_{47}N_5O_8$	Cyclodepsi Peplide	GC, IC
iv) *Paecilomyces lilacinus*	Leucinostatin	$C_{61}H_{109}N_{11}o_3$	A peptide antibiotic	NC, FC
v) *Trichoderma viride*	Trichodermin	$C_{17}H_{24}O_4$	Sesquinterpenes mycotoxin	FC

BC = Bactericidal; FC: Fungicidal , FC = Insecticides; GC: Growth Control; NC = Nematicidal; PC= Pesticidal; GR = Repellent.
Abbreviations used. BC = Bactericidal; FC: Fungicidal; FC = Insecticides; GC: Growth Control
NC = Nematicidal; PC= Pesticidal; GR = Repellent.

some toxins or bioactive chemicals which help to control pests and pathogens (Gohukar, 2010). Some of these bioactive compounds are *Azadirachtin, Allicin, Rotenone, Karanjin, Phenazine, Bassianolide, Trichodermin* etc. **(Table 5)**

Other Measures

Apart from this, some IPM-based applications like use of pheromone traps, cultural control (tillage, removal of weeds etc.), disease resistant varieties are common practices done by the organic farmers.

Impacts and Status

Many review reports indicate the success of bio-pesticides against target insects or specific diseases (Prasad, 2008; Sharma et al., 2008; Pathak et al., 2010). A dose of 30 to 60 g azadirachtin ha^{-1} is sufficient to combat and repel the key pests of various crops**.** Application of formulation of fungal bio-agent *Trichoderma* (2×10^7cfu g^{-1}), bacterial bio-agent *Pseudomonas fluorescens* (1×10^9 cfu g^{-1}) or yeast bio-agent *Sporidiobolus pararoseus* (1×10^9 cfu mL^{-1}) is successful in controlling the diseases like dry root rot of chickpea and cotton, stem rot of mustard, fruit dropping in kinnow etc.

Based on the Network Project on Organic Farming study, Gill and Prasad (2009) reported a significant reduction in incidence of stem borer and green leaf hopper in the rice-chickpea system with combined soil application of mahua cake (100 kg ha^{-1}) + neem cake (100 kg ha^{-1}) + *Trichogramma japonicum* at tillering initiation + neem spray (0.5%) + use of bird pirches in rice. At Dharwad, a schedule of seedling dip with cow urine + dung slurry, botanical spray at 30 days after transplanting (DAT), cow urine + 5 % NSKE spray at 45 DAT, *panchgavya* @ 3% + botanical spray at 60 DAT, butter milk (20%) + *panchgavya* (3%) spray at 75 DAT, botanicals + butter milk (20%) spray at 90 DAT in chillies was found to be effective against fruit borer and leaf curl index in chillies.

In India, the consumption and production of bio-pesticides was 219 t in 1996-97 (Bhattacharyya, 2004). India's chemical pesticide consumption in 1997-98 was 102,204 t. But in 2017, because of farmers' awareness and with policy support from the Government, the consumption or production of chemical pesticide was in the range of 55,000 – 65,000 t (Indira Devi et al., 2017). The current consumption of bio-pesticides in India is estimated at 7203 t (Sharma, 2020; personal communication). During last 10 years, the consumption of bio-pesticides increased by 23%, while that of chemical pesticides grew only by 2%. As per Sharma's communication, the annual growth rate of bio-pesticide production is estimated to be 2.5%. There are 970 bio-pesticide companies registered with India's Central Insecticide Board and Registration Committee (CIBRC). In 2016, the bio-pesticide consumption was recorded as 15% of the total pesticide consumption. The world market for microbial pesticides is in excess of US$ 125 million per annum which is still less than 1% of the total global market for agrochemical crop production of US$ 20-25 billion. The market is dominated by *Bacillus thuringiensis* (80%), with the rest accounting for only 20%. During last decade the Govt. of India has spent nearly Rs 14,926 million for bio-control programme in different crops.

Impact on Ecology, Diversity and Climate Change

Vandana Shiva (1992), an environmental activist, viewed chemical farming as the one having adverse impact on our environment including landscape, relief, soil, water, air, fauna, flora etc. (cited by Pimentel et al., 2005). Environmental issues related relevant to organic and conventional agriculture have been reviewed in depth discussed by several scientists (Gomiero et al., 2008; Tuomisto et al., 2012). On the other hand, genetic diversity across many species has declined globally, especially many domestic species. We have lost precious breeds, seeds, and species. Many traditional rice varieties face extinction from West Bengal (Deb, 2000).

Emission of greenhouse gases (GHGs) has been responsible for the climate change. During last 130 years (1882-2012), the world temperature at the land and the ocean's surface has exhibited an average increase of 0.85 ºC (Rahmann et al., 2017). These researchers (Rahmann et al., 2017) reported that the organic farming helps in conservation of biodiversity by resorting to the reduced/nil use of fewer pesticides and inorganic fertilizers. Absence of agrochemicals use reduces the risk of ground water pollution and improves the ecosystem by providing a suitable habitat for wild life. Following the crop rotation practice reduces the loss of agricultural biodiversity and with encouragement of the growth of soil fauna and flora improves the formation and structure of soil. Since organic farmers prefer to use traditional varieties, it helps in conserving the seeds of local varieties.

Organic agriculture contributes to mitigate the greenhouse effect and reduce the global warming through its ability to sequester more carbon in the soil. Thus, carbon sequestration through organic farming is a win-win situation as it ensures: a) reduction of CO_2 concentration in the atmosphere, b) higher organic matter levels in soil, and c) better crop yields through improvement in soil health.

Organic Food Quality

There are many reports on food quality under organic farming (Woese et al., 1997; Worthington, 2001; Carbonaro, et al. 2002; Rembialkowska 2007; Stracke et al. 2011; Debjani et al., 2017). Woese et al. (1997) reported that organically produced foods have lower level of pesticides. There is a public perception that excessive use of agrochemicals has led to the contamination of food and it has created high demand for organic foods, which according to them are free of contaminants or poisons. It is known that pesticide residues usually found in higher contents in conventionally produced plant products exert genotoxic, carcinogenic, neuro-destructive, and endocrine allergenic effects.

Huber et al. (2011) did not find any significant difference in the contents of vitamin C and phenolic compounds between organic plant products and those grown on conventional agriculture; lower nitrate contents and less pesticide residues were obtained in the organic foods. Baranski et al. (2014) and Lairon (2010) recorded significantly lower pesticide residues in the organic crops. A higher carotenoid content was found in the organically-grown sweet peppers, yellow plums, tomatoes, and carrots (Chassy et al., 2006; Lombardi-Boccia, et al., 2004; Perez-Lopez et al., 2007; Stracke et al., 2011). The contents of phenolic compounds might have a chemo-preventive role in humans by modulating the cancer cell cycle , inhibiting proliferation and inducing apoptosis (Huber et al., 2011).

Meta analyses of organically produced meat and dairy products showed that organic milk and meat contain significantly more beneficial omega – 3 fatty

Table 6. Quality parameters of guava and aonla under the influence of organic / biodynamic farming (Source: Pathak et al., 2010)

S. No.	Quality parameters	Guava variety: Allahabad Safeda		Aonla variety: NA-7	
		Conventional (Control)	Organic	Conventional (Control)	Organic
1.	TSS (°B)	12.06	12.66	8.80	9.20
2.	Acidity (%)	0.13	0.12	2.26	1.79
3.	Ascorbic acid (mg $100g^{-1}$ fruit)	197.03	231.38	312.50	462.50
4.	Reducing sugar (%)	4.30	4.70	2.23	2.54

acids than their conventional counter parts (Palupi et al., 2012; Rahmann et al., 2017). Moreover, organic milk contains more conjugated linoleic acids (CLA) (Rahmann et al., 2017). The French AFSSA paper (Lairon, 2010) mentioned the presence of more minerals (Fe, Mg) and more antioxidants like phenols and salicylic acids in organic plant products, as well as more poly–unsaturated fatty acids in organic animal products, apart from less nitrate in 50% of the products, 94-100% of the products without pesticide residues and equal amounts of mycotoxins.

Rembialkowska et al. (2008) reported that the consumers of organic foods assessed their health status as being significantly better than that of the consumers consuming non-organic foods. Gill and Prasad (2009) noted improvement in some quality parameters in horticultural crops for example, spices [ginger (oleoresin and oil content), turmeric (oleoresin, starch, curcumin), black pepper (oleoresin), chillies (ascorbic acid)], and vegetables [Fe, Mn, Zn, and Cu) in tomato, French bean, cabbage, cauliflower, pea, garlic]. Study conducted by Pathak et al. (2010) indicated better fruit quality in respect of total solids (TSS), ascorbic acid, acidity and reducing sugars (**Table 6**).

Economic Appraisal of Organic Farming Technology and Market Opportunity

Economic Appraisal

Organic agriculture is based on local resources and recycling of nutrients. Therefore, most of the organic farmers use considerably less inputs than the conventional farmers depending on situation (Singh, 2006; Suresh and Kunal, 2004). The challenge for organic farming is the system being labour-intensive, but the opportunity is generation of more employment.

Bhattacharyya et al. (2005) reported that the cost of cultivation was lower under organic cultivation because no fertilizers and pesticides were used. Initially yields in organic farming are lower up to third year of farming, but the yields of organic farming after 6th year compare with those obtained under conventional agriculture. Due to premium of 20%, the net income increases progressively fourth year onwards under organic farming. A study by Ramesh et al. (2010) on certified organic farms in India indicated 11.7% reduction in the cost of cultivation on organic farms when compared to the conventional farms. But owing to availability of premium price (20-40% higher) for organic produce in most cases, the average net profit was 22% higher in organic compared to the conventional farming (Ramesh et al., 2010).

Market Challenge

A survey conducted by the International Competence Centre for Organic Agriculture (ICCOA) in 2005 (Kishore Rao et al., 2006) indicated that there is already a ready market for organic products in the country and the focus of organic foods will be on the urban market because of higher purchasing power of urbanites (Kishore Rao et al., 2006; Singh, 2006). In fact, commercial organic agriculture is in the whirlpool of large and niche market (Bhattacharyya, 2017). Organic trade has continued its expansion, albeit at slower rate, despite the recent economic and financial crisis (Aertsens, 2011). The current value of global organic market is 100 billion US $ (FiBL & IFOAM, 2019).

The organic market in India is catching up fast both for domestic and export (Bhattacharyya, 2017). At present, the market is highly regulated. The nature of products sold in the broad organic market include: certified, natural, in conversion, chemical free, pesticide free, eco-friendly, healthy and truthfully labelled organic products. Supermarkets, hyper markets, consumers' cooperatives, food processing industries are playing key role in trading of the organic products.

While developed countries have so far registered the highest organic sales, domestic markets in developing countries including India are expanding rapidly. Only 10% of the total organic production of India is exported; rest is consumed domestically. Indian Government is encouraging small farmers to adopt Participatory Guarantee System (PSG) of the Ministry of Agriculture with Secretariat as the National Centre on Organic Farming, Ghaziabad in small villages to prepare themselves for third party certification operated by Ministry of Commerce, GOI with Secretariat at APEDA to enter the mainstream market.

In 2017-18, India produced around 1.70 Mt of certified organic products which included all varieties of food products namely oilseeds, sugarcane, cereals, millets, cotton, pulses, medicinal plants, tea, fruits, spices, dry fruits, vegetables, coffee etc. (APEDA. 2017). According to World Organic Agricultural Report of 2018, India produced 30% of total organic products, but accounted for only 2.59% of total cultivable area (Buragohain, 2020).

Excellent achievements have been made in the organic tea sector. Total world production of organic tea was 9 million kg (9,000 t) in 2001 out of which India produced 3,150 t and production from China was 4,500 t. Last two decades have witnessed a dramatic rise in organic tea production in the world In 2015, world organic tea production was 50,000 t, with China contributing 70% (35,000 t) and India 22% (11,000 t). In India, organic tea constituted 2% of the total organic products exported in 2012-13 (Bhattacharyya 2017). In fact, only 1% of the total tea produced in India is organic tea.

India's organic mangoes have high demand in the Netherlands, UK and Germany and their export might fetch good amount of income to the country. USA, EU, and Japan are three major pineapple importing countries and offer tremendous export potentialities. European Commission have granted Equivalent Status to Indian organic certifying agencies.

The total value of export during 2017-18 was 4.58 lakh t, while monetary realization was around Rs. 3453 crores (515.44 million US$). India exported organic products to USA, Europe, Canada, Israel, South Korea, Japan and Vietnam. Maximum exports include oilseed (47.6%), cereals – millets (10.4%), tea/ coffee (9%), spices (7.5%) and others. Export of organic products from India and export value realization (Indian Rupees/Million US$) have been presented for a period of 2011-12 to 2018-19 in **Table 7**. Export of total agricultural products (including cotton) during 2018-19 was US$ 38.5 billion. Against it, organic export share was 0.896%. Share of agricultural products exported in 2018-19 was 11.7% in total merchandise export of US$ 330.1 billion in India.

Risks Ahead

At present, the world population is 7.8 billion and it will reach 9.7 billion by 2050. Context to this, India's current population is 1.37 billion which will touch the figure of 1.70 billion by 2050. Country will need about 400 Mt of food grains by 2050 to feed these 1.7 billion mouths. The global food grain production which is currently about 2.2 Bt will have to witness higher growth. This is a big challenge for both practices, be these chemical or organic. The issue is, especially, more critical in the case of organic farming. Although many farmers, for example, Padma Shri Bharat Bhushan Tyagi, Bulandshahar, UP or few NGOs like F.I.A.M, Raigunj, Uttar Dinajpur, West Bengal are satisfied with the production pattern under organic cultivation and the same has been supported by many research data, but simultaneously several reports have cautioned that the production in the organic farming system is lower in the initial years of conversion and takes time to get settle. When most of the farmers of the country belong to small and marginal category, the situation becomes more alarming.

The second issue on organic farming is how to generate resources for recycling the nutrients. A question is often raised whether on-farm produced agricultural inputs are sufficient to meet the demand of nutrients. The organic standards do not allow off-farm inputs for use in organic cultivation unless it is tested. Is it possible to get tested these bio-organic inputs on regular basis by poor farmers (even progressive farmers) from accredited laboratory who charges are exceptionally high?

More use of organic residues, green manure crops, compost and biodegradable wastes may add greater amounts of CO_2 in nature as major fraction

Table 7. Export of organic products from India and export value realisation in crores of Indian rupees / million US dollars (Source: Anonymous, 2019)

Year	Export of organic products		
	Quantity (Metric tonnes)	Values in crores of rupees	Values in million US dollars
2011-12	1,47,799	1866.33	358.42
2012-13	1,56,262	2106.81	-
2013-14	1,94,087	2428.00	403.09
2014-15	2,85,663	2099.00	327.00
2015-16	2,63,687	1975.87	298.00
2016-17	3,09,767	2478.17	370.00
2017-18	4,58,339	3453.00	515.00
2018-19	6,14,090	5151.00	757.00

of added carbon is mineralised to CO_2 under tropical climate of India. Further, GHG emissions increase several fold during anaerobic conditions created during storage and handling of cattle dung either in heap or in slurry form (Sharma and Singh, 2004).

The availability of green manures is not sufficient and farmers are apathetic towards legume cultivation. Further, the quality maintenance of bio-organic inputs is a matter of serious concern. In fact, the quality of bio-fertilizers and bio-pesticides as available in the market is also a big question. Poor quality and inconsistent responses are still the major challenges (Bhattacharyya and Mishra, 1994).

The certification system, either for third party certification (operated by APEDA) or PGS certification (operated by NCOF) and documentation pattern in this regard is getting complicated with every single day passing. The system is also highly expensive and sometimes requires subsidy from the Government. Recently, the intervention of FSSAI (Food Safety Standard Authority of India) for getting *Jaivik Kheti* logo has added to the problem which may be beyond the reach of poor and uneducated farmers.

Some fraud agencies or persons are taking the advantage of organic sentiment of the people including farmers, Already, these have come to be known as "Organic Mafia" group. Such agencies or people are cheating farmers with products in the name of organic stimulants and are also making business at the cost of poor farmers' financial load.

Bias towards chemical farming has compelled policy makers and some scientists to pay little attention to the organic farming.

Issues of Sustainability

Organic agriculture, developed as a holistic, eco-system based approach, has been conceived as an alternative to what proponents see as the ecologically unsound practices of conventional agriculture. With respect to issue of ecological sustainability, organic agriculture has positive impacts on soil fertility, water quality, biodiversity conservation, pollution reduction, landscape improvement, climate protection. As regards economic sustainability, chemical agriculture poses greater long-term economic risks than organic farming. A vast number of small scale farmers ran into a debt trap after few years of Green Revolution based on chemical farming. Against this backdrop, organic farming is safe. Further, the scope of export is a big opportunity for organic farmers. Organic farming generates employment scope as it focuses on labour-intensive activities.

Conclusion

Organic agriculture is now a mass movement in India. Many farmers, agencies, environment protectors, researchers are involved in this movement. Task Force on Organic and Non-chemical Farming constituted by Government of India (2016) have pointed out that the data related to organic farming in the country should be fully streamlined for getting a comprehensive, authentic and accurate picture and reviewing the progress. This documentation once prepared will hopefully serve the purpose. It is disheartening that most of the policy makers and even scientists vehemently undermine the inherent strength of organic farming. Many plants (Jamun, Ashoka etc.) on roadside or hillside or on desert or forest have been surviving with huge biomass years after years without use of any fertilizers or pesticides. Alvares (2014) reported that all jackfruits grow under completely natural conditions without fertilizers and pesticides and irrigation. Production of jackfruits in volumes is approximately 1.5 Mt in India and it is greater than the entire organic export of all commodities put together out of India to the European Union.

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