Indian Journal of Agronomy **66** (5th IAC Special issue): S142–S162 (2021)

Organic farming research in India: Potential technologies and way forward

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ABSTRACT

The organic movement may have gained a place in the spotlight of the mainstream now, but it has not been like that for long. Since the 1950s, organic farmers operating at a grassroots level have devised, tested and shared production methods. Organic crop production in the organic farming system is gradually gaining momentum worldwide. For achieving sustainable food–livelihood–environmental security, an array of alternatives to chemical intensive agriculture is to be developed. Globally, 187 countries are involved in organic farming with 72.3 million ha land. The area of organic farming increased rapidly from 0.58 thousand ha in 2003–04 to 26.6 thousand ha in 2020–21, and many government schemes are initiated. Of the farmers involved in organic farming globally, 43.8% are from India, but currently India shares only 4.7% to global area. Therefore, technology development is going to play a critical role in enhancing the area, production and productivity. Integrated organic farming system models enhanced the system productivity and resulted in net returns ₹ 171,867/ha in Umiam, Meghalaya to ₹ 433,490/ha in Thiruvananthapuram, Kerala. Hence, organic farming endorses the one health approach to ensure healthy soil, plant, animal, human and environment. Organic farming improves the ecosystem services through regenerative approach for rehabilitation of food and farming systems. Therefore, it is an alternative viable option for sustainable and clean food production with minimum environmental pollution. Organic farming practices are suitable for small and marginal farmers, especially for their sustainable livelihood food security and to minimize the risk. Sustained efforts from research institutes, developmental organizations, progressive farmers, input dealers, processors and other stakeholders are warranted for better adoption of organic farming in horticultural crops in the long run. In this article, suitable location–specific organic farming technologies for agricultural and horticultural crops are focused.

Key words **:** Indigenous traditional knowledge, Organic farming technologies, Organic nutrient management, Organic pest management, Organic weed management

INTRODUCTION

The major problems of current agriculture are decline in agriculture growth rate, factor productivity, farm income, shrinkage in net cultivable area, depleting groundwater table, static or decline in food production as well increasing malnutrition, environmental pollution, cost of production and unemployment. During pre–green revolution period (up to 1960s) the rate of national agricultural growth was not able to keep pace with population growth and 'ship to mouth' situation prevailed. This was the major factor for introduction and large–scale popularization of the high–yielding varieties (HYVs) of crops, which were highly responsive to the chemical fertilizers and water use. As a result, the total foodgrain production increased phenomenally, from mere 50.83 million tonnes in 1950–51 to 303.34 million tonnes in 2020–21, indicating ~ 6 times increase (DES, 2021). This increase can be primarily attributed to large–scale adoption of HYVs, combined with other Green Revolution Technologies (GRTs) in cereal crops, expansion of gross irrigated area (22.56 million ha in 1950–51 to 94.46 million ha in 2014–15) and increase in fertilizer nutrient consumption (0.07 million tonnes in 1950–51 to 29.37 million tonnes in 2018–19) (DES, 2020). All of them put together have led to substantial increase in the productivity of crops, especially foodgrains (from 522 kg/ha in 1950–51 to 2377 kg/ha in 2020–21, DES, 2021) culminating into change the status of India from a food importer to net food exporter in many commodities. India's average fertilizer and pesticide consumption stands at 137.9 kg/ha and 0.60 kg a. i./ha, respectively, during 2018–19 (DES, 2021). It has been proved scientifically and convincingly that integrated use of organic manures with chemical fertilizers improves the

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use efficiencies of the latter owing to concurrent improvement of soil physical, chemical and biological properties (Panwar *et al.,* 2021). It is estimated that various organic resources having the total nutrient potential of 32.41 million tonnes will be available for use in 2025. To feed the projected population of 1.7 billion in 2050, 400 million tonnes of food need to be produced which is expected to require around 60 million tonnes of nutrients. Therefore, promotion of organic farming in the entire country will not be a viable option considering the difficulty in handling the bulky organic manures and its low–level nutrient contents. Conservative estimates indicate, around 15 million tonnes of nutrients can be shared through organic manures and other sources. Hence, niche area and crop approach for promotion of organic farming is considered to be a viable and efficient option for promotion of certified organic farming, while in other areas towards organic approach otherwise called as integrated crop management would better in achieving the targets of food production besides ensuring sustainability in agriculture.

GREEN REVOLUTION, INORGANIC FARMING AND ITS IMPACT ON CROP, SOIL AND HUMAN HEALTH

The glory of Green Revolution was on the basis of the use of high–yielding varieties (HYVs), chemical fertilizers, pesticides, and farm mechanization that led to unprecedented pressure on our natural resource base including natural way of controlling pest and diseases. Green Revolution has encouraged an increase in the production of mainly 2 crops, wheat (*Oryza Sativa* L.) and rice (*Triticum aestivum* L.), but the cost paid was in terms of destruction of other crops (especially coarse cereals and pulses) and over exploitation of precious water resources and fertile soils. The high dosage application of fertilizers deteriorated the physical, chemical and biological properties of soil on one side, but increased soil salinity and pollution of groundwater resources on the other side. The use of pesticides has been posing serious environmental and health problems.

Impact on soil health

Total factor productivity and growth rate of productivity of crops are decreasing year after year and deterioration of soil health is the major contributor for the same. In spite of 326 districts receiving more than 100 kg of nutrient (N, P and K)/ha, it has been found that, soils in majority of the districts are low in N (228 districts), P (170 districts) and K (47 districts) (FAI, 2014). Exhaustive cropping systems cause mining of soil nutrients far in excess of external supply. Rice–wheat–cowpea fodder system removes around 800 kg ha^{-1}. Further, wider nutrient application gap between recommended and farmers practice also adds to the problem. Across the major systems [rice/maize–based cropping system], farmers are applying 33.3, 38.8, 57.1 and 93% less application of NPK and micro nutrients, respectively as compared to recommended doses. Among the systems, rice–rice is having the minimum gap in application in terms of NPK (1.1, 12.6, 36.4% respectively). Continuous application of under doses of nutrients and wider NPK ratio (8.2:3.2:1 during 2012–13 reported by the Ministry of Chemicals and Fertilizers, 2013) (Theresa *et al*., 2019) to intensive systems like rice–rice, rice–wheat, and maize–wheat leads to decline in soil health. On the other hand, temporal decline in response of nutrients has been observed in many systems and across the systems; it has been observed that the response of 13.4 kg yield per kg of NPK in 1960 has come down to 2.7 kg per kg. Partitioning of yield between major (NPK) and micro–nutrients indicates, in case of cereal –cereal system, contribution of major nutrients such as NPK in bridging the yield gap is higher (72 to 86%) while micronutrients contribute to about 14 to 28%. However, in rice–green gram system [Vigna radiate (L.) R. Wilezek], the contribution is almost equal (52 and 48% respectively). During the initial years of introduction of the HYVs, only macronutrient deficiencies were discovered as an obstacle to their high yields. With passes of time, the situation has worsened with increasing use of high–analysis fertilizers free from secondary and micronutrients, decreasing use of organic manures and neglected recycling of crop residues. As a result, multi–nutrient deficiencies (macro + micro) are being observed in recent years. Among micronutrients, Zn deficiency is the most common soil disorder, accounting for nearly 48% of the soil samples analysed under the Indian Council of Agricultural Research (ICAR)–All India Coordinated Research (AICRP) on Secondary and Micronutrients and Pollutant Elements.

Impact on climate

With manufacturing of fertilizers and pesticides as the 2 major inputs of Green Revolution Technologies, an important point of consideration was the need for fossil fuels and/or expensive energy which are associated with serious environmental and health problems. This fact further got the attention of the world when the Intergovernmental Panel on Climate Change (IPCC) found that agriculture as practiced today (conventional agriculture, modern agriculture or GR agriculture) accounts for about one–fifth of the anthropogenic greenhouse effect, producing about 50% and 70%, respectively of the overall anthropogenic methane and nitrogen oxides emissions

(Charyulu and Biswas, 2010). Crop productivity has increased substantially through utilization of heavy inputs of soluble fertilizers – mainly nitrogen and synthetic pesticides. However, only very minimal was taken up by crops (approximately 17–22%). The remainder was lost to the environment. It is also observed that between 1960 and 2000, the efficiency of nitrogen uses for cereal production decreased from 80 to 30 % (Erisman *et al.,* 2008). High levels of reactive nitrogen (NH_4, NO_3) in soils may contribute to the emission of nitrous oxides and are main drivers of agricultural emissions. The excess fertilizers (not taken up by the plants) are often emitted into the waterbodies and the atmosphere. The emission of GHGs in CO_2 equivalents from the production and application of nitrogen fertilizers from fossil fuel amounted to 750 to 1,080 m t (1 to 2% of total global GHG emissions) in 2007. In 1960, 47 years ago, it was less than 100 m t. However, agriculture emits 10 to 12% of the total estimated GHG emissions per annum. Smith *et al.* (2007) documented those fertilizers alone contributes for 38% of GHG emissions (Nitrous oxide) from agriculture sector.

Reduction in genetic diversity and natural enemies

Diversity in crops was a key factor in agricultural systems in India during earlier years. It provided stability and resilience to the systems as well as economic security to the farmers. However, after the introduction of modern technology, more emphasize upon high–yielding varieties focused on single species. This resulted in the erosion of genetic diversity base of agro–ecosystems. Many research studies have proved that, reduction in genetic–diversity leads to more susceptibility to pests and diseases. The reduction in natural enemies due to chemical management was found to be 63 to 74% in various crops.

Contamination of food and decline in nutritive values

The widespread application of chemicals leads to genetic mutation of pests and develop resistance to these chemicals. According to Pimentel (1995), only 0.1% of pesticide actually reaches the target pests and the rest goes to non–target sectors. There was a significant decline (around 15 %) in the consumption of total pesticides in the country during 2012–13 compared to previous years. The reduction in the consumption may be due to the introduction of integrated pest management (IPM) technologies including bio–control and conduct of awareness programmes by the government. However, pesticide residue is major concern. In general, the more pesticides are applied in cotton (37 %) and fruits (grapes, 2 %) and vegetables (13%).

INSTITUTIONAL DEVELOPMENT FOR PROMOTION OF ORGANIC FARMING

Institutional development such as National Programme for Organic Production (NPOP) launched during 2001, followed by setting up of the National Centre of Organic Farming (NCOF) under the Ministry of Agriculture and Farmers Welfare and initiation of research through All India Network Programme on Organic Farming (AI–NPOF) under ICAR–Indian Institute of Farming Systems Research by the ICAR during 2004 laid the foundation for systematic development of technologies for organic farming in the country. Third party certification and in conversion cultivated area under organic farming reached to 2.66 million ha by March 2021 (Figs 1 and 2; APEDA, 2021), while around 0.73 m ha is brought under participatory Guarantee System (PGS). Therefore, currently around 2.4% of the net cultivated area is either under certified or

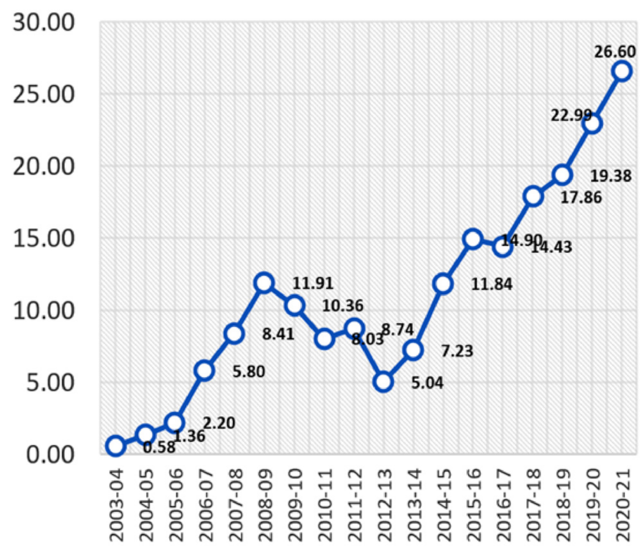

Fig. 1. Growth of cultivated area under organic certification in India

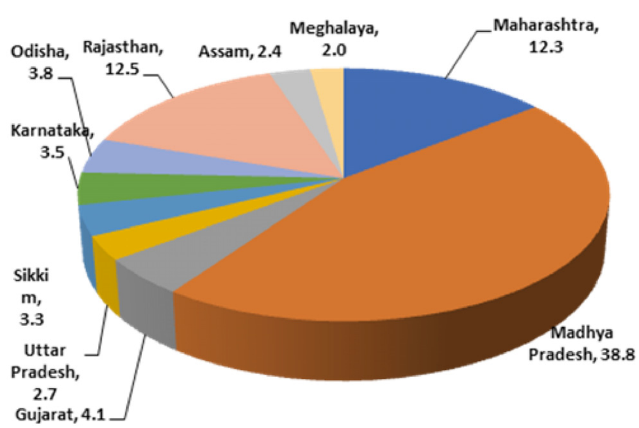

Fig. 2. Share in organic farm area (%) by top 10 States to total area in country (2019–20)

in conversion process of organic farming. Conducive policy, technological advancements, demonstrations, and farmer led innovations have contributed for increase in area. India is producing wide range of crops under organic management with oilseeds, sugar crops, fibre crops, cereals and millets and pulses occupy the large chunk of the basket. The Government of India has set a target of bringing minimum of 4% net cultivated area under organic farming by March 2026. However, organic farming promotion is constrained due to limitations in terms of yield, availability of inputs for nutrient, weed, insect and disease management among other factors.

India is now the ninth largest in terms of total arable land under organic farming and largest in terms of total number of organic producers in the world. India produces around 2.75 m t (2019–20) of certified organic products export volume and value of 0.6389 million tonnes, ‘ 46,860 million (689 million USD) respectively. Therefore, launch of All India Network Programme on Organic Farming (AI NPOF) by the ICAR helped significantly for promotion of organic farming practices in India. ‘Towards organic’ (integrated crop management) approach for input–intensive areas (food hubs) and ‘certified organic’ approach by integrating tradition, innovation and science in the de–facto organic areas (hill and rainfed/dryland regions) has been found to be better option for national food security, higher household income and climate resilience (Aulakh and Ravisankar, 2017) which will further enhance the safe food production and meet the social values.

CONCEPT, BRIEF HISTORY AND STRATEGIC IMPORTANCE OF ORGANIC FARMING

Organic farming is a holistic production/management system which promotes and enhances agro–ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes, the use of management practices in preference to the use of off and on farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system (FAO, 1999). The IFOAM defines “Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

Organic farming system relies on crop rotations, crop residues, animal manures, legumes, green manures, safe off–farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. In its simplistic form, organic agriculture may be defined as “a kind of diversified agriculture wherein crops and livestock are managed through use of integrated technologies with preference to depend on resources available either at farm or locally”. According to Auerbach *et al.,* (2013), the strongest benefits of organic agriculture are its reliance on fossil fuel independent, locally available resources that incur minimal agro–ecological stresses and are cost–effective. She describes organic agriculture as ‘neo–traditional food system’, which combines modern science as well as indigenous knowledge. Available records on grain yield of paddy under traditional farming practices indicates yield up to 2.95 t/ha in the first crop (Kuruvai) and 2.81 t/ha in the second crop (Thaladi) [1925–26] has been recorded by Lalgudi Sivagnanam Co–operative Agricultural Society in the Madras Presidency [Royal Commission on Agriculture in India report volume III, 1927]. Similarly in case of wheat, yield of 2.41 t/ha has been reported from West Bengal during 1970–71 [Report of National Commission on Agriculture, 1976]. The historical perspective and key mile stones of organic farming in world and India are given in Tables 1 and 2.

NON–CONVENTIONAL PRACTICES AND ITKS IN ORGANIC FARMING IN INDIA

Organic farming essentially excludes the use of many inputs associated with modern farming, most notably synthetic pesticides and fertilizers. To the maximum extent possible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off–farm organic wastes, mechanical cultivation, mineral–bearing rock powders and biological pest control. These components maintain soil productivity and tilth, supply plant nutrients and help control insects, weeds and other pests. Moreover, history of Indian agriculture shows that most of its farming community relies on traditional methods and ecological agriculture such as ‘Agnihotra’ and ‘Panchagavya’ the farming systems based on ancient techniques for soil and animal management (Subrahmanyeswari and Chander, 2013). Organic agriculture, the innovative farming system, can build–on and enhance the traditional knowledge and practices of local and indigenous communities. This means farmer’s knowledge of ecological systems; environment and their conventional wisdom has to play more role in making organic farming more sustainable.

Natural farming or organic farming is gaining importance in 21st Century in view of sustained agriculture and

Table 1. Historical perspective of organic farming

Oldest practice	10,000 years old, dating back to Neolithic age, practiced by ancient civilization like Mesopotamia, Hwang–Ho basin etc.
Ramayana	All dead things – rotting corpse or stinking garbage returned to Earth are transformed into wholesome things that nourish life. Such is the alchemy of mother Earth (interpreted by C. Rajagopalachari)
Mahabharata (5500 BC)	Mention of Kamadhenu, the celestial cow and its role on human life and soil fertility
Kautilya Arthashastra (300 BC)	Mentioned several manures like oil–cake, excreta of animals.
Brihad–Sanhita (by Varahmihir)	Described how to choose manures for different crops and the methods of manuring.
Rig Veda (2500–1500 BC)	Mention of organic manure in Rig Veda 1, 161, 10, 2500–1500 BC, is green manure in Atharva Veda II 8.3, (1000 BC). In Sukra (IV, V, 94, 107–112) it is stated that to cause healthy growth the plant should be nourished by dungs of goat, sheep, cow, water as well as meat. A reference of manure is also made in Vrksayurveda by Surpala (manuscript, oxford, No 324 B, Six, 107–164)
Holy Quran (590 AD)	At least one–third of what you take out from soils must be returned to it implying recycling or post–harvest residue

Source: Bhattacharya and Chakraborty (2005)

Table 2. Key milestones of organic farming in World and India

World		India	
1909	American agronomist F.H. King tours China, Korea and Japan, studying traditional fertilization, tillage, and general farming practices. Findings published in "Permanent Agriculture: Farmers of Forty Centuries"	1905–24	British botanist Sir Albert Howard, often referred to as the father of modern organic agriculture, worked as an agricultural adviser in Pusa and Bengal, where he documented traditional Indian farming practices, and came to regard them as superior to his conventional agriculture science.
1924	Rudolf Steiner's publishes "Spiritual Foundations for the Renewal of Agriculture" which leads to the development of "biodynamic agriculture"	1984	First conference of NGOs on organic farming in India by the Association for Propagation of Indigenous Genetic Resources (APIGR) at Wardha.
1939	The first use of the term "organic farming" is by Lord Northbourne. The term derives from his concept of "the farm as organism", which he expounds in his book, "Look to the Land"	1994	• Sevagram declaration for promotion of organic farming in India
1940	In Japan, Masanobu Fukuoka, develops "Fukuoka farming"	2001	• National Programme for Organic Production • National Standards for Organic Products and Processes and Accreditation of Certification Agencies
1943	Lady Eve Balfour published "The Living Soil", which led to the formation of a key international organic advocacy group, the Soil Association.	2004	• National Project on Organic Farming • National Centre of Organic Farming with 6 regional centres • Formulation of policy on Organic farming by Karnataka state • Network Project on Organic Farming was started by the Indian Council of Agricultural Research in India with 13 centres in 12 states • The Mizoram Organic Farming Act (First state in India to enact act)
1962	Rachel Louise Carson (1907 – 1964) a prominent scientist and naturalist, publishes "Silent Spring", chronicling the effects of DDT and other pesticides on the environment. A key factor for the federal government of the United States to ban the use of DDT in 1972	2007	Nagaland state declared intention to go organic and defined organic pathway and policy
1970	One Global goal of the organic movement is to encourage consumption of locally grown food. There is the promotion of this concept with slogans such as "Know Your Farmer, Know Your Food".	2010	Launching of Sikkim Organic Mission with the intention to covert entire state as organic by December 2015

Contd...

1972	In Versailles, France, creation of The International Federation of Organic Agriculture Movements (IFOAM)	2013	Network Project on Organic Farming in Horticulture crops started with 9 centres under the ICAR
1991	The European Union provides a legal framework for the organic agriculture designation	2014	Network Project on Organic Farming of ICAR was strengthened with addition of 7 new centres to cover niche areas and crops
2008	The IFOAM suggested the definition for Organic Agriculture: "Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."	2015	• Paramparaghat Krishi Vikas Yojana (PKVY) to promote traditional practices of agriculture including organic farming • Special scheme to promote organic farming in North Eastern states of India (MOVCD–NER) • Gujarat state joins as 9th Indian state to promote organic farming in default areas
		2016	• Sikkim State becomes first complete organic farming State in India

maintaining ecological balance. It lies in a simple principle of utilizing low-coast and local inputs with zero utilization of chemicals in any form like fertilizer, herbicide, pesticide, antibiotic, hormone etc.

SCIENTIFIC VALIDATION OF ITKS IN INDIA

Many agricultural products based on indigenous fermentation technologies are used in organic farming. Cowdung is an integral component of all these preparations and serves as a source of inoculum of beneficial microorganisms. Presence of naturally occurring beneficial microorganisms, predominantly bacteria, yeast, actinomycetes, and certain fungi have been reported in cowdung (Swain and Ray, 2009). Research related to isolation and characterization of the beneficial attributes of the bacteria present in biodynamic preparations are few (Sharma *et al.,* 2021). 'Panchagavya' (PG; Sanskrit for a blend of 'five products from cow') is a traditional product prepared in India by fermenting cowdung, cow urine, milk, curd and clarified butter (ghee) (Somasundaram *et al.* 2007). BD 500, a biodynamic preparation that is also called as horn manure and 'Cow pat pit' (CPP) are preparations from cow dung that are used in organic farming (Stalin, 2010). Biodynamic products are included in the list of materials and techniques permitted in organic farming by an EC regulation (834/2007). These contain macro– and micro–nutrients, amino acids, and growth–promoting substances like indole acetic acid, gibberellins and beneficial microorganisms. Beneficial effects of biodynamic preparations have been reported on lentil (Lens culinaris Medikus) and wheat (Carpenter–Boggs *et al.* 2000). Spraying a 3% solution of PG along with soil application of biogas slurry improved the yields of maize and sunflower (*Helianthus annuus*) (Somasundaram *et al.,* 2007). Biodynamic sprays increased the yields of cereals and vegetables, during the years when yields were low (Sharma *et al.,* 2021).

Here we are discussing important indigenous technical knowledge (ITK) practices prevalent in organic farming which have been validated scientifically. The important broad methods currently recommended and used in India are given in Table 4. Collection, documentation and validation of ITKs in different parts of India is being carried out by the ICAR– All India Network Project on Organic Farming (AINPOF) since 2004–05. More ITKs related to soil–health management, nutrient management, crop diversification, plant–growth regulation, pest and disease management, grain storage, liquid organic manures and herbal extracts have been documented.

ORGANIC FARMING RESEARCH AND TECHNOLOGIES FOR FIELD CROPS

Under All India Network Programme on Organic Farming, several options for nutrient, pest and weed management have been tested in multi–location trials which resulted in development of technologies for organic farming. Salient findings and technologies are:

STATE–WISE RECOMMENDED AGRICULTURAL CROPS AND VARIETIES FOR ORGANIC FARMING

Identified best suitable varieties for basmati rice, coarse rice, wheat, maize, chickpea (*Cicer arietinum* L.), groundnut (*Arachis hypogaea* L.), mustard [*Brassica juncea* (L.) zern.], soybean [*Glycine max* (L.) Merr.], tomato (*Solanum lycopersecum* L.), cauliflower (*Brassica oleracea* var. *botrytis* L.), pea (*Pisum sativum* L.), okra [*Abelmoschus esculentus* (L.) Moeneh], frenchbean (*Phaseolus vulgaris* L.), turmeric (*Curcuma longa* L.), black pepper (*Piper nigrum* L.) and cotton (*Grossypium hirsutum* L.) for organic farming in 12 states. These vari-

Table 3. Non–conventional practices and methods of organic farming in India

Method	Innovator/year	Constituents	Scope/ future	Other comments
Natueco–culture	Dabholkar, 1967. Mathematician in Sangli (Maharashtra) who inspired organic farming method	Mulching–no plowing; *Amrut Mitti*–a name given by Late OP Rupela; compost strips made for raising crops; *Amrut–Jal* fermented cow dung and urine with jaggary. Applied as nutrient liquid.	Has the potential for gardeners and orchardists. Not suitable for large scale farms.	Can partially contribute to food security. Fermented liquid is a variant of Kunapajala
Zero budget Natural farming	Palekar, 2005–06	Four key elements: *Beejamrita*–seed treatment, *Jevamrita* fermented microbial culture, *Achhadana* mulching, and *Waaphasa*; no irrigations	For small scale operations	Partial food security. Features similar to Kautilya, Dabholkar, and Kunapajala are present.
Rishi–Krishi	Deshpande,1970. Science graduate	Four steps: *Angara*–soil from Banyan tree trunk; *Amrit–Pani* [ghee, honey, cow dung in water; *Beej Sanskar* [seed dressing with paste of *Angara* and *Amrit–Pani,* and *Achhadana* (mulch).	Has similarities to methods of Dabholkar and Palekar. Suitable for small farmers.	Can contribute to partial food security. No fermentation.
Agnihotra/ Homa farming	Potdar Inspired and Paranjpe by "Sadguru". 1970 to 2000	Ghee, grains, milk, piece of dried cow dung burnt in copper pyramid. Smoke purifies the air around.	Can be practiced by individual orchardists or a village group.	Can contribute a little to food security. Smoke was prescribed in *Vrikshayurvedas*
Panchagavya	K Natarajan, 2003	Mixing 5 products of cow, coconut water and cane jaggery. Fermented for 30 days. Seed dip, soil drench, foliar paste.	*Panchagavya* has gained popularity with farmers in several states of India	Excellent potential to contribute to food security.
Krishi–suktis and *Vrikshayur veda*	Parashara [c.400 BCE], Kashyapa [c. 800 CE], Surapala [c. 1000 CE]	Sound practices for raising of crops. Animal dung manure to field crops and *Kunapajala* [KJ] mainly for perennial crops. KJ is a fermented liquid manure prepared from flesh, animal and plant wastes, and cow products.	*Kunapajala* has gained limited popularity is readily acceptable.	Excellent potential to contribute to food security. Also waste management.
Compost tea and *Bokashi* tea	Elaine Ingham, 1990s	Liquid extraction of nutrients and microbes from finished compost, molasses added.	Anaerobically composted animal and plant wastes, bran, inoculated with "effective microbes"	Has gained popularity in several countries. Can contribute to food security.
Biodynamic	Steiner, 1924.	Cow horn manure and cow horn quartz (silica)	Limited use	Complement the microbial activities and soil build up

Source: Nene (2017)

eties tend to result in higher yield under organic production system.

NUTRIENT MANAGEMENT PRACTICES IN ORGANIC FARMING

Supply of Sufficient Nutrient Through Organic Sources

Enough scope for production of sufficient organic inputs exists in India. Among different nutrient sources, livestock accounts for major share (nearly 40%) followed by crop residues (30%) and other sources (15%) which include the rural compost, vermi–compost and agricultural wastes. The issue of sufficient nutrient supply under organic production system can be addressed by adoption of rotational manuring in cropping systems, integrated organic farming systems and combination of sources.

Table 4. Important indigenous technical knowledge used by farmers and validated under All India Network Project on Organic Farming

Sl. No.	Name of ITKs	Description of ITKs	Scientific Validation	Reference
1.	Use of Panchagavya in organic farming	Farmers use Panchagavya in organic crop production, so effect of indigenous panchagavya with respect to concentration of Panchagavya and its stage of application was evaluated on blackgram and it was found that, application of Panchgavya 4% recorded maximum seed and stover yield of blackgram (801 kg and 1,735 kg/ha respectively) with maximum net returns (₹67,042/ha) and significantly increased the seed yield, stover yield and net return of black gram by 17.62, 14, 74 and 24% over the application of indigenous Panchgavya 2%. Application of Panchagavya at branching + flowering stage of blackgram significantly increased the seed yield (751 kg/ha), stover yield (1,617 kg/ha) and net returns (₹ 60,977/ha) by 18.26, 10.0 and 24.15% respectively, over the application of Panchagavya at branching stage and by 12.60, 11.40 and 17.10 per cent, respectively over the application of Panchagavya at flowering stage.	MPUAT, Udaipur	*Annual Report* 2015–16. AINPOF, MPUAT, Udaipur.
2.	Indigenous bio–pesticides for organic management of chilli anthracnose	Foliar application of neem oil (0.5%) recorded the lowest per cent disease index (28.9) and maximum per cent efficacy of disease control (62.2) as compared to the control.	MPUAT, Udaipur	*Annual Report* 2016–17. AINPOF, MPUAT, Udaipur.
3.	Management of anthracnose, *Alternaria* leaf spot, powdery mildew of organic blackgram	Farmers use neem oil for pest and disease management. This ITK was evaluated during 2017 and 2018 and was found that, application of neem oil @ 1 Y recorded significantly lowest PDI 28.63, 24.11 and 27.80 of Alternaria leaf spot, powdery mildew and *Anthracnose,* respectively, in black gram as compared to maximum of their respective PDI 72.95, 76.22 and 64.98 was observed in the control. On the other hand, concentrations with optimum dose and high dose were found to be significantly superior to lower dose.	MPUAT, Udaipur	*Annual Report* 2017–18. AINPOF, MPUAT, Udaipur.
4.	Use of Beejamrit and BD–501	Farmers use Beejamrit for seed treatment and biodynamic manure–501 for growth enhancement. Seed treatment of mung bean with Beejamrut + 1 foliar spray of BD–501 significantly reduced the *Alternaria* blight and powdery mildew and maximum seed yield of mung bean 2470 kg/ha (Average over 5 years)	MPUAT, Udaipur	*Annual Report* 2017–18. AINPOF, MPUAT, Udaipur.
5.	Use of Jeevamrut	The maximum grain, net return and B:C ratio was recorded under the 10% jeevamrut (41.19 q/ha, ₹ 145,709/ha and 2.08 respectively) during 2017–18 and 2018–19. The maximum grain yield, net return and B:C ratio (41.05 q/ha, ₹ 145136/ha and 2.07, respectively) was found with the application of jeevamrut at 75 and 90 days after sowing (DAS). It is clear from the data that, the effect of application jeevamrut at single time that is 60, 75 and 90 DAS had equal effect on grain yield of wheat. But the application of jeevamrut twice that is at 60 and 75 DAS as well as 75 and 90 DAS significantly increased the grain yield of wheat as compared to 1 time application of jeevamrut that either at 60, 75 and 90 DAS.	MPUAT, Udaipur	*Annual Report* 2018–19. AINPOF, MPUAT, Udaipur.
6.	Vermiwash	Farmers prepare Vermiwash from different organic sources and different methods. It was found that application of Vermiwash from 100% cow dung gave significantly maximum seed yield, net return and B:C ratio (861 kg/ha, ₹ 69,320/ha and 2.58 respectively) of blackgram.	MPUAT, Udaipur	*Annual Report* 2018–19. AINPOF, MPUAT, Udaipur.
7.	Herbal bio–pesticides (Dashparni) in cauliflower	Application of Dashparni (10%) at 30, 45 and 60 DAS + vermiwash (10%) at 30, 45 and 60 DAS + *Trichoderm*a (1%) at 30, 45 and 60 DAS resulted in significantly maximum curd yield (19,006 kg/ha) and net returns (₹ 330,962/ha) and B:C ratio (6.73) in cauliflower. Minimum downey mildew (PDI 14.41) in cauliflower was observed with application of Dashparni (10%) at 30, 45 and 60 DAS + Vermiwash (10%) at 30, 45 and 60 DAS + *Trichoderma* (1%) at 30, 45 and 60 DAS while maximum (PDI 44.50) was observed in the control.	MPUAT, Udaipur	*Annual Report* 2019–20. AINPOF, MPUAT, Udaipur.

8.	ITK for storage of maize grains and blackgram seed	Per cent grain damage by rice weevil, *Sitophilus oryzae* was resulted in grain treated with neem oil (3%) in maize crop and per cent grain damage by pulse beetle, *Callosobruchus chinensis* was 9.10 with neem oil (3%) in blackgram.	MPUAT, Udaipur	*Annual Report* 2019–20. AINPOF, MPUAT, Udaipur.
9.	Silica diatomous earth for storage of maize grain	Per cent grain damage by rice weevil, *Sitophilus oryzae* at 30, 60 and 90 days after storage period revealed that, the minimum mean per cent grain damage was 4.41 in grain treated with active silicon (4%) and it was at par (4.84) with the treatment of active silicon (3%) in maize.	MPUAT, Udaipur	*Annual Report* 2019–20. AINPOF, MPUAT, Udaipur.
10.	Silica diatomous earth for storage of soybean	Silica diatomous earth (4%) was found most effective treatment which caused 4.22% mean grain damage, and it was at par with silica diatomous earth (3%) which caused 4.61% mean grain damage in soybean.	MPUAT, Udaipur	*Annual Report* 2019–20. AINPOF, MPUAT, Udaipur.

Table 5. Recommended varieties in organic farming for various states

State	Season	Crop	Varietal group	Name of best performing varieties	Scientists involve in organic farming research
Chhattisgarh	*Rainy season (Kharif)*	Rice	Short grain, traditional aromatic rice (tall)	'Vishnu Bhog'	M.C. Bhambhri
	Winter season (Rabi)	Chickpea	HYV, Kabuli chickpea	'Vaibhav', 'RG 2009–01' 'PKV Kabuli', 'BGD 128'	
Gujarat	*Kharif*	Groundnut	General purpose	'GJG 17'	L.J. Desai
			HPS purpose,	'TG 37'	
	Rabi	Wheat	*Aestivum,* HYV	'GW 451', 'GW 496'	
	Summer	Greengram	HYV	'GM 4', 'GAM 5'	
Himachal Pradesh	*Kharif*	Okra	Improved variety	Perkins Long Green, Pusa Mukhmali	D.K. Parmar
	Rabi	Cauliflower	Hybrid	US–178	
			Improved variety	'PSBK 1'	
		Pea	Improved variety	'Azad P1'	
			Hybrid	'Ten Plus'	
	Summer	Tomato	Hybrid	Red Gol, RK–123	
Jharkhand	*Kharif*	Rice	HYV– Short duration	'BVD 203'	Mohd. Nayyar Ali
			HYV– Medium duration	'Lalat'	
			HYV– Long duration, Scented	'MTU 1010'	
	Rabi	Wheat	HYV– Timely sown	'K 0307'	
			HYV– Late sown	'GW 366', 'NW 2036'	
Karnataka	*Rabi*	Chickpea	HYV	'JAKI 9218', 'MABC 37'	U. K. Shanwad
		Wheat	HYV	'UAS 446' (DW), 'UAS 347' (BW)	
Kerala	*Kharif*	Turmeric	HYV	'Sugna', 'Pragati'	C.K. Thankamani,
Madhya Pradesh	*Kharif*	Soybean	HYV	'RVS 2002–4', 'JS 20–41'	A.B. Singh
		Maize	HYV	'Proagro 4212', 'Kanchan'	
	Rabi	Wheat	HYV	'GW 366', 'HI 8498'	
		Chickpea	HYV	'JG 130', 'RVG 203'	
	Kharif	Rice	Scented rice	'PS 3', 'PS 4'	
			Traditional and HYV	'IR 64'	
			Short duration	'MTU 1010'	
	Rabi	Wheat	Traditional	'C 306'	
			Partially irrigated	'JW 17', 'JW 3020'	
			High yielding	'HI 1500', 'HI 2987'	
			Durum wheat	'HD 2004', 'HD 4672'	

Meghalaya	*Kharif*	Maize	HYV	'RCM 75'	Jayanta Layak and
	Post *kharif*	Frenchbean		'RCM–FB 18'	Anup Das
Rajasthan	*Kharif*	Maize		'VL–Amber' popcorn, 'Sugar 75'	S.K. Sharma *et al.*
	Rabi	Wheat		'HI 8713', 'HI 8663'	
Tamil Nadu	*Rabi*	Rice	Traditional group	'IW Ponni', 'Mappilai Samba', 'Bhavani'	E. Somasundaram *et al.*
			Improved group	'CO 43', 'CO (R) 48', 'IR 20'	
Uttarakhand	*Rabi*		Medicinal and aromatic	'CB 05022', 'Red Kavuni'	
		Wheat	Normal sown	'UP 2565'	D.K. Singh
Uttar Pradesh	*Kharif*	Maize	HYV	'HQPM 1'	R.P. Mishra
	Rabi	Mustard	HYV	'NRCHB 506', 'DRMRIJ 31'	

Combination of Organic Nutrient Sources

Combining more than one organic source for supplying nutrients to crops has been found to be very effective as meeting the nutrient requirement by single source is not possible. For example, rice–wheat system requires around 30 t FYM/year to meet its nutrient demand. This can be very easily managed by adopting strategies of cropping systems involving green manures, legumes and combined application of FYM + vermicompost and neem cake. This type of management also helps in reducing the insect/disease incidences, as incorporation of neem cake in soil has been found too much effective. The FYM (partially composed dung, urine, bedding and straw), edible and non–edible oil cakes, enriched composts and effective microorganisms are some of the combinations which can be used for meeting the nutrient demand of crops. Identified nutrient–management packages for various cropping systems are given in Table 6.

The nutrient management in organic systems is aimed at optimizing the use of on–farm resources and minimize losses (Kopke, 1995). The philosophy is to 'feed the soil and not the plants' and it means giving back to the nature what has been taken from it (Funtilana, 1990). Plants use nutrients from organic sources through mineralization mediated by soil microorganisms which play an important role in the mobilization of nutrients in the soil and make a significant contribution to maintain a healthy soil system and consequently healthy plants (Veeresh, 1990). Supply of nitrogen (N) is one of the most important yield–limiting factors in organic crop production (Askegaard *et al.,* 2011). Nitrogen supply in organic agriculture systems relies mainly on organic soil nitrogen indirectly provided by inputs through legumes in the crop rotation intercropping or by recycling N through solid or liquid manure (Berry *et al.,* 2002; Ansari *et al.,* 2021). Leguminous green–manure crop fixes the atmospheric nitrogen in the soil in the available form, improves the soil health, prevents nutrient leaching and consumes excess soil moisture (Ansari *et al.,* 2021). Green manuring saves 45–120 kg N/ha (Ladha *et al.*, 1988). The recycling of crop resi-

Table 6. Identified combination of nutrient sources for different cropping systems

Location (State)	Cropping system (s)	Sources to meet nutrients
Coimbatore (Tamil Nadu)	Cotton–maize–green manure (GM) Chillies–sunflower–green manure	Farmyard manure (FYM) + non–edible oil cakes (NEOC) + panchagavya (PG)
Raipur (Chhatisgarh)	Rice–chickpea	Enriched compost (EC) + FYM + NEOC + Bio dynamic (BD) + PG
Dharwad (Karnataka)	Groundnut–sorghum Maize–chickpea	EC + VC + green leaf manure (GLM) + biodynamic and PG spray
Ludhiana (Punjab)	Maize–wheat–summer greengram	FYM + PG + BD in maize, FYM + PG in wheat and FYM alone in greengram
Bhopal (Madhya Pradesh)	Soybean–wheat Soybean–chickpea Soybean–maize	FYM + PG + BD
Pantnagar (Uttarakhand)	Basmati rice–wheat–green manure Basmati rice–chickpea Basmati rice–vegetable pea	FYM + VC + NC + EC + BD + PG
Ranchi (Jharkhand)	Rice–wheat–green manure	VC + *Karanj* cake + BD+ PG

Table 7. Identified cropping systems for reduced manuring under organic production system

State	Crop/cropping system
Chhattisgarh	Soybean–pea, soybean–chili
Himachal Pradesh	Okra–pea–tomato (Summer)
Jharkhand	Rice (Basmati type)–wheat
Karnataka	Greengram–sorghum
Madhya Pradesh	Soybean–wheat, soybean–Indian mustard, soybean–chickpea, soybean–linseed
Punjab	Green manure–basmati rice–chickpea
Uttar Pradesh	Green manure –basmati rice–Indian mustard
Uttarakhand	Green manure –basmati rice–vegetable pea + coriander (4 : 2 rows)

dues is an important aspect of organic farming systems because of their role in improving soil health and restrictions on their burning on organic farms. Crop residues have the potential to improve soil and water conservation, sustain soil productivity and enhance crop yields (Das *et al.*, 2003). Biofertilizers have the ability to fixed atmospheric nitrogen, solubilize/mobilize soil phosphorus and can also be used to enhance the decomposition of crop residues. They have been reported to increase the crop yields by about 6–25% (Dahama, 2003). The biofertilizer inoculation enhances the yield of chickpea by 13–76%, pigeonpea by 10–46%, green gram by 9–95%, mash by 32–54% and cowpea by 25–30% (Kler *et al.,* 2001). Combined application of the biofertilizer mixture (*Azotobacter chrocoocum*, arbuscular mycorrhizal fungi, and *Bacillus circulans*) with organic fertilizers enhanced maize growth, yield, and nutrient uptake (Gao *et al.,* 2020).

Reduced Manuring

Application of 75% nutrients only through combination of organics such as FYM, vermicompost, non–edible oil–cakes and other locally available sources + 2 innovative inputs such as cow urine, panchagavvya, *PGPR* with complete organic management suggested for 8 States and 11 cropping systems (Table 7).

Rotational Manuring

Application of 100% nutrients through combination of organics such as FYM, vermicompost, nonedible oil cakes with complete organic management suggested for following states and cropping systems and application of 100% can be rotated intermittently over the years (Table 8).

Towards organic approach (Integrated crop management)

Towards organic approach with 75% organic + 25% inorganic package and 50% organic + 50% inorganic package suggested for 9 cropping systems in 5 States (Table 9).

Resource–conservation practices

Resource–conservation practices under organic farming have been standardized for 4 cropping systems in

Table 8. Identified cropping systems for rotational manuring

State	Crop/Cropping System
Jharkhand	Rice (Basmati type)–potato, Rice (Basmati type)–linseed
Kerala	Black pepper
Maharashtra	Rice–groundnut
Meghalaya	Rice in sunken beds and French bean and tomato in raised beds
Punjab	Green manure–basmati rice–wheat; soybean–wheat
Uttarakhand	Green manure–basmati rice–chickpea + coriander (4:2 rows) Green manure–basmati rice–potato

Table 9. Identified cropping systems towards organic approach (integrated crop management)

State	Crop/cropping System
Himachal Pradesh	Blackgram–cauliflower–summer squash, cauliflower–frenchbean
Kerala	Turmeric
Maharashtra	Rice–Indian mustard, rice–*Dolichos* bean
Meghalaya	Rice in sunken beds and broccoli, potato and carrot in raised beds
Tamil Nadu	Green manure (GM)–beetroot–maize; GM–cotton–maize; GM–chili–sunflower

Table 10. Identified resource conservation practices for different cropping systems

Cropping System	Land configuration	Scientist's involved
Karnataka		
Soybean–wheat	BBF with crop residues	S.A. Gaddenkeri
Groundnut + cotton (2 : 1)	Conventional FB with crop residues	
Greengram–sorghum	Conventional FB without crop residues	
Soybean + pigeonpea (2 : 1)	BBF with crop residues	
Meghalaya		
Carrot– Okra	Raised bed	Jayanta Layak and Anup Das
Rice (Lampnah) –Pea	Sunken bed	
Uttarakhand		
Direct seeded rice –chickpea– green gram in BBF	Direct seeded rice with chickpea on broad bed (105 cm × 45 cm)	D. K. Singh

BBF: Broad bed furrow

Karnataka, 2 in Meghalaya and 1 in Uttarakhand (Table 10).

ORGANIC FARMING RESEARCH FOR HORTICULTURAL CROPS

India is blessed with wide range of agro–climatic conditions, which are suitable for cultivating various horticultural crops such as fruits, vegetables, flowers, spices, plantation crops and tuber crops. The production of horticulture crops in India was 311.71 million tonnes from an area of 25.43 million ha with the productivity of 12.25 t/ha during 2017–18 (GoI, 2018). Globally, India is the second largest producer of fruits and vegetables, largest producer of mango (*Mangifera indica* L.), banana (*Musa paradisuaca* L.), coconut (*Cocos nucifera* L.), cashew (*Anacardium occidentale* L.), papaya (*Carica papaya* L.) and pomegranate (*Punica granatum* L.) and largest producer and exporter of spices. A total of 1,596 high–yielding varieties and hybrids of horticultural crops (fruits, 134; vegetables, 485; ornamental plants, 115; plantation and spices, 467; medicinal and aromatic plants, 50; and mushrooms, 5) were released for maximizing productivity of horticultural crops (ICAR, 2021). Improper farming practices such as monocropping, imbalanced fertilization, poor soil organic matter management, soil contamination, soil compaction, mining of soil nutrients, waterlogging, depletion of groundwater, decline in soil biodiversity and changing pest and disease complex and application of imbalanced NPK fertilizers in the ratio of 7.9:3:1 as against ideal of 4:2:1 are the major factors for soil degradation (Purohit and Gehlot, 2006). In view of the adverse effects of indiscriminate use of chemical fertilizers and synthetic inputs, importance is being given to promote organic farming in major agricultural and horticultural crops. The component of production technologies of organic farming in horticultural crops is given in Table 11.

PRODUCTION TECHNOLOGIES OF ORGANIC FARMING IN HORTICULTURAL CROPS

Organic farming resulted in 10–20% higher yield in tropical tuber crops, viz., elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson], white yam, greater yam (*Dioseorea alata* L.), lesser yam [*Dioscorea esculenta* (Lour.) Burkill], dwarf white yam (*Dioscorea rotundifolia* Poir.) and Chinese potato [*Coleus rotundifolius* (Poir) A. Chav. & Perrot] i.e., 20, 9, 11, 7, 9

Table 11. Components of organic production technologies in horticultural crops

1. ***Improved varieties:*** High–yielding with quality traits, resistance to biotic and abiotic stresses, nutrient use efficient, local market demand
2. ***Agronomic/cultural practices:*** Summer ploughing, mulching, crop rotation, intercropping/ border cropping, cropping system/ farming system, field hygiene, season of planting, spacing
3. ***Nutrient management:*** Cover cropping with green manure/leguminous crops, green leaf manure, crop residues, oil–cakes, farmyard manure, composts (different types), biofertilizers/ PGPRs, liquid organic fertilizers (Beejamrithum, Jeevamrutham, Panchagavya), enriched organic manure (cocopeat, vermicompost etc.),
4. ***Water management:*** Drip irrigation, half–moon terracing/ full moon terracing, planting across the slope, mulching
5. ***Weed management:*** Cover cropping, mulching with crop residues, use of geotextiles, weed control ground cover, mechanical weeding (use of harrow, heel hoe, tools), organic herbicidesGoals: 1, Safe food; 2, Enhancing productivity and profitability; 3, Sustainability; 4, Doubling farmers income

and 10.5% respectively (Suja and Sreekumar, 2014). Cost:benefit analysis indicated that, the net profit under organic farming was 20–40% higher over state package of practices (POP) in tuber crops (Suja *et al.,* 2016). The ICAR–Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh, has experimented and validated production technologies in major horticultural crops in collaboration with the ICAR Institutes/SAUs through Network Project on Organic Farming. The successful production technologies of organic farming in major horticultural crops (Ravisankar *et al.,* 2017) are given in Table 12.

Integrated Organic Farming Systems

One acre Integrated Organic Farming System (IOFS) models, suitable for marginal farmers, have been established in Gujarat, Kerala, Meghalaya, Rajasthan, Sikkim and Tamil Nadu (Table 13) which provides scope to generate more than 80% of inputs required for organic farming within the farm, thus reducing the cost of production.

INSECT AND DISEASE MANAGEMENT IN ORGANIC FARMING

In general, the incidence of pests and diseases are comparatively low under organic production system compared to inorganic systems owing to several factors such as application of oil–cakes having insecticidal properties, use of green leaf manures such as *Calotropis* and slightly higher content of phenols in plant parts under organic management. Further, organic management also increases

Table 12. Production technologies of organic farming in horticultural based cropping system

Sl. No.	Name of the cropping system/ varieties	Production technologies for organic farming	Mean yield (t/ha)
1.	Soybean (JS–335) – Onion (Nasik Red)	• Rhizobium @ 500 g/ha, phosphobacteria @ 500 g/ha, *Trichoderma viride* @ 500 g/ha, FYM @ 2 t/ha, vermicompost @ 0.8 t/ha, neemcake @ 0.2 t/ha, rockphosphate @ 0.27 t/ha, hand weeding and mechanical weeding by cycle weed hoe	1.88
		• FYM @ 5 t/ha, vermicompost @ 2 t/ha, neem cake @ 0.5 t/ha, rock phosphate @ 0.27 t/ha, 6–8 irrigations, manual weeding and interculture	11.83
2.	Maize ('Girija') – garlic ('GHC 1')	• FYM @ 16 t/ha, vermicompost @ 12 t/ha, rockphosphate @ 60 kg/ha, cow urine (10%) @ 60 L/600 L water, Panchagavya (3%) @ 18 L/600 L water, vermiwash (10%) @ 60 L/600 L water, 4–5 irrigations, manual weeding	4.60
		• FYM @ 22 t/ha, vermicompost @ 16 t/ha, rockphosphate @ 0.1 t/ha, cow urine (10%) @ 60 L/600 L water, Panchagavya (3%) @ 18 L/600 L water, vermiwash (10%) @ 60 L/600 L water, 5–6 irrigations, manual weeding and interculture	8.04
3.	Cauliflower ('Hybrid Swati') – pea ('Azad P 1') – Tomato ('Hybrid 7730')	• FYM @ 22 t/ha, Trichoderma viride @ 3 kg/ha, Pseudomonas fluorescence @ 3 kg/ha, vermicompost @ 16 t/ha, rock phosphate @ 0.1 t/ha, cow urine (10%) @ 60 L/600 L water, Panchagavya (3%) @ 18 L/600 Lwater, vermiwash (10%) @ 60 L/600 L water, 4–5 irrigations, manual weeding and interculture	8.85
		• FYM @ 4.34 t/ha, Trichoderma viride @ 3.75 kg/ha, Pseudomonas fluorescence @ 3.75 kg/ha, vermicompost @ 3.2 t/ha, rock phosphate @ 87 kg/ha, cow urine (10%) @ 60 L/600 L water, Panchagavya (3%) @ 18 L/600 L water, vermiwash (10%) @ 60 L/600 L water, 2–3 irrigations, manual weeding	8.93
		• FYM @ 17.4 t/ha, Trichoderma viride @ 3.75 kg/ha, Pseudomonas fluorescence @ 3.75 kg/ha, vermicompost @ 12.8 t/ha, rock phosphate @ 0.1 t/ha, cow urine (10 %) @ 60 L/600 L water, Panchagavya (3%) @ 18 L/600 Lwater, vermiwash (10%) @ 60 L/600 L water, 3–4 irrigations, manual weeding and interculture	10.41
4.	Rice ('Birsamati') – potato ('Kufri Ashoka')	• FYM @ 5.33 t/ha, karanj cake @ 0.67 t/ha, Azolla @ 1 kg/m2, vermicompost @ 2.67 t/ha, Panchagavya @ 10–12 L/ha mixed in 500–600 L water, hand weeding and summer ploughing	2.72
		• Phosphobacteria/*Azotobacter* @ 250g/10 kg of seeds, FYM @ 8 t/ha, karanj cake @ 1 t/ha, vermicompost @ 4 t/ha, 4–5 irrigations, hand–weeding and stale seed–bed technique	17.83
5.	Chili (Byadagi Kaddi, Byadagidabbi, Dyvanur) – Cotton (Jayadhar)	• Seed treatment with Azospirillum @ 250 g, phosphobacteria @ 250 g and Trichoderma viride @ 10 g; enriched compost @ 4.2 t/ha, vermicompost @ 3.3 t/ha, green leaf manure @ 6.7 t/ha, neem cake @ 250 kg, foliar spray of cow urine @ 10% and Panchagavya @ 3%, deep tillage, stale seed–bed technique, intercultivation with hoes and mechanical hand–weeding	0.45

		• Cow urine (25%) @ 50 l/ha for seed treatment, Azospirillum @ 0.5 kg/ha, Phosphobacteria @ 0.5 kg/ha, enriched compost @ 3.3 t/ha, vermicompost @ 2.7 t/ha, green leaf manure @ 5.3 t/ha, neemcake @ 0.25 t/ha, cow urine (10%) @ 100 l/ha, Panchagavya (3%) @ 30 l/ha	0.56
6.	Turmeric ('IISR Prathibha', 'IISR Aleppy Supreme') – fallow	• FYM @ 20 t/ha, neem cake @ 2 t/ha, enriched compost @ 5 t/ha, vermicompost @ 2 t/ha, ash @ 0.5 t/ha, micronutrient mixture (turmeric specific) @ 5 g/l, mulching with locally available materials viz., coconut leaf, paddy straw for weed management	18.74
7.	Ginger ('IISR Varada', 'IISR Rejatha', 'IISR Mahima') – fallow	• FYM @ 20 t/ha, enriched compost @ 4 t/ha, vermicompost @ 2 t/ha, ash @ 0.5 t/ha, micronutrient mixture (ginger specific) @ 5 g/l, mulching with locally available materials viz., coconut leaf @ 5.4 t/ha, paddy straw @ 6 t/ha and green leaf @ 7.5 t/ha for weed management	13.6
8.	Black pepper ('Karimunda', 'Panniyur 1') – fallow	• Trichoderma harzianum @ 50 g mixed with 2 kg compost per vine per year, FYM @ 10 t/ha, neem cake @ 1 t/ha, enriched compost @ 1 kg/vine/year, vermicompost @ 2 t/ha, ash @ 1 t/ha, micronutrient mixture (black pepper specific) @ 5 g/l, mulching with locally available materials viz., coconut leaf @ 5.4 t/ha, paddy straw @ 6 t/ha and green leaf @ 7.5 t/ha for weed management	1.2
9.	Rice ('Shahsarang 1', 'Lampnah') – carrot ('New Kuroda')/ tomato ('Rocky', 'Avinash 2', 'Mega Tomato 3')	• Azospirillum @ 100 g/10 litres of water for seedling treatment, FYM @ 15 t/ha, neem cake @ 0.1 t/ha, rock phosphate @ 0.15 t/ha, vermiwash (10%), Panchagavya (3%), hand weeding and cono weeding	4.05
		• Phosphobacteria @ 1.5 kg/ha, vermiwash @ 50 litres/ha, hand weeding	12.45
		• Trichoderma viride @ 100 g/10 litres of water for seedling treatment, FYM @ 20 t/ha, rock phosphate @ 200 kg/ha, neem cake @ 0.15 t/ha, Panchagavya (3%), hand weeding	23.81
10.	Maize ('Prabhat') – potato ('Kufri Chandramukhi') – summer greengram ('SML668')	• FYM @ 4.25 t/ha, vermicompost @ 2.75 t/ha, non edible oil cakes @ 1.65 t/ha, 5 irrigations, hand weeding	4.63
		• Vermicompost @ 4.25 t/ha, 7 irrigations, hand weeding	16.67
		• Rhizobium @ 0.5 kg/ha, FYM @ 1.25 t/ha, vermicompost @ 0.25 t/ha, 4 irrigations, hand weeding	1.24
11.	Turmeric ('Pb Haldi 1') – onion ('Pb Naroa')	• FYM @ 10 t/ha, vermicompost @ 3.25 t/ha, rice straw mulching @ 10 t/ha, one hoeing, 15 irrigations	32.88
		• FYM @ 6.75 t/ha, vermicompost @ 2.25 t/ha, 12 irrigations	15.25

Table 13. Components of integrated organic farming systems

State	IOFS model composition	Area (ha)	Total net returns (₹)
Kerala	Spices–based system [turmeric, ginger, cassava, taro, vegetable cowpea and fodder grass) + livestock (2 cows)]	0.40	173,396
Meghalaya	Field and horticulture–based system [cereals + pulses + vegetables +fruits + fodder) + dairy (1 cow + 1 calf) + fishery + vermicompost]	0.43	73,903
Tamil Nadu	Field crop–based system (green manure–cotton–sorghum; Okra + coriander–maize + cowpea (fodder), desmanthus, 1 milch cow, 1 heifer and 1bull calf + vermicompost + boundary plantations (*Gliricidia, coconut*)	0.40	127,169

the natural enemies in the farm. Natural enemies of crop pests and diseases such as Coccinellids, syrphids, spiders, *Micromus*, *Chrysopa* and *Campoletis* were higher under organic management compared to integrated and inorganic management. Coccinellids, which naturally reduce the hoppers and leaf folders were found to be 2 to 3 times higher under organic management in cotton, groundnut, soybean, potato and maize crop fields. Similarly, spiders which also control the pests are found to be twice higher under organic management compared to inorganic management. The diversity of arthropod population in soil, viz. *Collembola*, *Dipluran*, *Pseudoscorpians*, *Cryptostigmatids* and other mites' population was also found to be higher under organic management compared to integrated and chemical management.

Biological Control

The term 'Biological control' is restricted to the use of insect pathogens and natural enemies to manage the pests and diseases infesting crops. Predators, parasitoids and biopesticides play significant role in achieving sustainable organic pest management by maintaining pest population below economic threshold level (ETL) (Singh *et al*., 2012). Inundative release of *Trichogramma* sp. @ 40,000 to 50,000 eggs/ha, *Chelonus blackburni* @ 15,000 to 20,000 /ha and *Chrysoperla* sp. @ 5,000/ha managed pest problems under organic cultivation (Srijita, 2015). Efficacy of *Acerophagous papayae* in the management of papaya mealybug was well documented by Mani (2017). Biopesticides derived from fungi, bacteria, viruses, nematodes and protozoa and also some other compounds produced directly from these microbes such as metabolites are main microbial pest management agents in organic agriculture (Rabindra and Grzywacz, 2010).

The most commonly used bacterial product available to the organic growers is Bacillus thuringiensis (Bt). This bacterium produces an insecticidal protein that provides effective control for many pest insects and has very little effect on non target insects and natural enemies. *Bacilllus thuringiensis, Phoebiosis gigantean and Agrobacterium radiobacter* are to be used repeatedly as and when required as that of chemical control (Gupta and Dikshit, 2010). Biopesticides like *Trichoderma viridie, T. harazianum and Pseudomonas fluorescence* @ 4g/kg seed either alone or in combination reduce seed–borne and soil–borne diseases. Similarly, entomopathogenic fungi, viz. *Beauveria bassiana, Metarhizium anisopliae, Nomuraea rileyi, Lecanicillium lacanii, Hirsutella thompsoni and Paecilomycis* sp., popular in India are used successfully to protect crops from a variety of insect pests (Rupela *et al*., 2005). Biopesticides based on baculoviruses, *viz.* nuclear polyhedrosis virus (NPV) and granulosis (GV) virus are ideally suited in integrated pest management under organic agriculture. Spraying of NPV of *Helicoverpa armigera* or *Spodoptera litura* @ 250 larval equivalents (LE) are highly effective in organic pest management (Elamathi *et al*., 2012). Entomopathogenic nematodes (EPN) are microscopic, soil–dwelling worms that are parasitic to insects./ *Heterorhabditis*/ and/ *Steinernema*/ are examples of commercially available EPN in the management of soil insect–pests (Stuart *et al*., 2008).

Botanical Pesticides

Botanicals are naturally occurring chemicals extracted from plants or minerals. These are potential alternative to chemical pesticides and are eco–friendly. Azadirachtin, pyrethrum, rotenone, sabadilla, ryania, limonene and linalool are example of natural pesticides derived from plants and were reported to be effective against wide range of insect–pests and diseases. Among the botanicals, neem alone was found to be effective in the management of approximately 200 species of insect–pests, disease-causing organisms and nematodes (Subbalakshmi *et al.,* 2012). Studies demonstrated that, insecticidal oil obtained from plants and fish–processing industry are effective on wide array of pests and safer to the non–target organisms (Koul *et al*., 2008)

Bio–rational Insecticides

Bio–rational insecticides are also called as insect-growth regulators (IGRs), which interfere with the growth, development and metamorphosis of insects. It includes synthetic analogues of insect hormones, viz. ecdysoids, juvenoids and non–hormonal compounds such as precocenes and chitin–synthesis inhibitors (Goldammer, 2017).

Organically Acceptable Chemical Alternatives

Though use of synthetic chemicals is prohibited in organic pest management, certain chemical alternatives can be used in organic farming under exceptional circumstance as the last resort. Spinosad produced from the micro–organism *Saccharopolyspora spinose,* Mertz & Yao is effective both as contact and stomach poison. It is approved for use in organic farming and recommended for the control of caterpillars, leaf miners, thrips and foliage feeding beetles. Spinosad provides excellent control of many caterpillar species, but they are less efficacious on piercing–sucking insects such as stinkbugs and plant bugs. Formulations of spinosad are labeled for a wide array of crops, viz. potatoes, brinjal (*Solanum melongena* L.), tomatoes, cucurbits, cole crops, groundnut and rice (Karthikeyan *et al*., 2008). Avermectins discovered from soil microorganism *Streptomyces avermitilis* are effective against lepidopterous pests and less toxic to non–target organisms and environment. Abamectin is a broad spectrum acaricide acting on mites of Tetranychidae, Eriophyidae and Tarsonimidae and less toxic to beneficial arthropods.

Indigenous Technical Knowledge (ITK)

Insect herbal repellants such as ginger, garlic (*Allium sativum* L.) and green chili (*Capsicum annuum* L.) extract (3 G) @ 5% and 5 leaves herbal extract @ 10% are popular among the organic farmers of Tamil Nadu. Farmers of Madhya Pradesh treat ginger (*Zingiber officinale* Roscoe) and turmeric (*Curcuma longa* L.) seed rhizomes in the solution of fresh cowdung for the management of soil and seed–borne disease and better germination. Betelvine (*Piper betle* L.) growers apply sesame (*Sesamum indicum* L.), Indian mustard and neemcake for the management of soil–borne disease. Chickpea seeds (30 kg) treated with 5 g of asafetida (*Ferula ass–foetida* L.), 200 g salt mixed in

1 litre of butter milk protected chickpea crop from wilt disease. Pulse seeds are treated with cow urine to protect them from soil–borne fungal pathogens and for better growth. Cultivation of marigold (*Tagetes erecta* L.) with solanaceous vegetables is effective in the management of bacterial wilt. Mixing of dried neem leaves and seed powder of custard apple with wheat grains and mustard oil or ash with pulses are practiced to protect from storage pests (Tripathi *et al*., 2020).

WEED MANAGEMENT IN ORGANIC FARMING

Weeds are major problem under organic management and almost 43% of organic growers expressed; that low and no–cost–weed management techniques should be identified for successful practicing of organic farming. Slash weeding is to be done between the plants. Weeds under the base of the plants can be cleaned and put as mulch around the plant base. The weeded materials should be applied as mulch in the ground itself. Stale seed–beds, hand and mechanical weeding are the other options available for managing weeds under organic management. Further, effective crop rotation, mixed and intercropping is also essential for reducing the weeds. Few identified weed–management practices for various locations and cropping systems are given in Table 14.

CROP PRODUCTIVITY AND ECONOMICS UNDER ORGANIC MANAGEMENT

Long–term results of organic management clearly establish that the scientific Package of Practices (PoPs) for organic production of crops in cropping systems perspective should be adopted for keeping the crop productivity at comparable or higher level than chemical farming. Under ICAR–All India Network Programme on Organic Farming (AI–NPOF), 51 location–specific package of practices for organic production of crops in cropping systems, suitable to 12 states, have been developed which can be practiced for getting optimum productivity under organic management.

Current organic agriculture performs well in several

Table 14. Recommended weed–management packages of different cropping systems under organic production (11 cropping systems for 11 States)

State	Cropping system	Recommended management package	Scientist's Involve
Chhattisgarh	Sweet–corn – tomato	Stale seed–bed + reduced spacing (up to 25%) + mulching with paddy straw + hand–weeding at 20 DAS	M.C. Bhambhri
	Rice–Indian mustard	Conoweeder with square planting for rice Stale seed–bed for Indian mustard	
Himachal Pradesh	Blackgram–cauliflower–summer squash	Stale seed–bed technique (standing water for 3–4weeks) + reduced spacing up to 25% + mulching with wheat straw + 1 hand–pulling at 20 DAS	D.K. Parmar
Jharkhand	Rice–wheat	1 mechanical weeding at 25 DAS + 1 hand–weeding (HW) at 50 DAS	Mohd. Nayyar Ali
Kerala	Turmeric	Dried coconut leaf application at the time of planting, hand–weeding at 45 and 90 DAP	C.K. Thankamani
Karnataka	Groundnut	Spray of *Cassia* and *Prosipis juliflora* as post–emergent	H.B. Babalad
Madhya Pradesh	Maize–Indian mustard	Cotton seed cake 15 days before planting/sowing @ 5 t/ha + 1 hand–weeding at 40 DAS	A.B. Singh
Maharashtra	Rice–groundnut	Stale seed–bed + reduced spacing up to 25% + mulching with previous crop residue + 1 HW at 30 DAS	S.B. Bhagat
Meghalaya	Maize +soybean	1 HW at 35 DAS + soybean intercropping	Jayanta Layak
	Maize (green cob)–Indian mustard	Mulching with fresh Eupatorium/ Ambrosia @ 10 t/ha (after earthing up)	Anup Das
Punjab	Basmati rice–wheat–green manure	High–density planting + hand weeding at 25–30 DAT	C.S. Aulakh
Rajasthan	Sweet corn–fennel	Stale seed–bed preparation + plastic mulch at sowing	S.K. Sharma
Tamil Nadu	Tomato	Mulching with dried mango leaves @ 5 t/ha followed by 1 HW on 45 DAT	E. Somasundaram
	Rice–black gram–green manure	2 HW + spray of aqueous leaf extract at 3–4 leaf stage of weeds	Siddeswaran
Uttarakhand	Rice–wheat	*Sesbania* + 2 mechanical weeding at 20 and 40 DAT in rice and 2 HW in wheat	D.K. Singh
Uttar Pradesh	Maize–mustard	Soil solarization + 1 HW	R.P. Mishra

DAS, days after sowing; DAP, days after planting; DAT, days after transplanting sustainability domains, like animal welfare, farm profitability and low pesticide use, but yields are commonly lower than in conventional farming (Roos *et al.,* 2018). The organic crop yields on an average are reported to be 80% (De Ponti *et al.,* 2012), 66–95% (Seufert *et al.,* 2012) or 81% (Ponisio *et al.,* 2015) of conventional yields. In general, in European countries, grain yields of organic agriculture wheat are 30 – 70% of conventional production (David *et al.,* 2012). Surekha (2007) reported a gradual increase in grain yield of rice with the use of organics over a period of time. Ramesh *et al.* (2008) reported a decrease of 5–15% in rice grain yield and 35–58% in wheat grain yields with FYM as source of nutrition. Higher yield reduction in wheat could be due to slow release of nutrients from FYM during cool winters. In sugarcane 10 t FYM/ha and 10 t vermicompost/ha were 75% and 100%, respectively, as effective as application of 150 kg N, 60 kg P and 60 kg K/ha (Singh *et al.,* 2007). Yadav *et al.* (2002) reported lower yields of rice and wheat compared with conventional farming during the first 4 years of study.

Higher maize, soybean and wheat yields were obtained under organic farming than chemical farming with green–manuring and application of FYM 10 t/ha to maize and 5 t/ha to soybean in rainy season (*kharif)*, 15 t/ha to wheat in the winter season (*rabi)* and crop–residue incorporation of all the crops (Walia, 2004). Hazra *et al*. (2014) reported the lower sustainable yield indices in cereals under organic production due to unstable yield in wheat crop. Vegetables are highly responsive to organic sources of nutrients and application of FYM at 10 t/ha and poultry manure at 5 t/ha significantly increased number of branches/plant, leaf–area index, and dry weight/plant in tomato (Samawat *et al.,* 2001).

Among different organic farming treatments in rice–wheat system, incorporation of crop residues + green–manuring + phosphorus–solubilizing microbes + poultry manure 5 t/ha + neemcake 0.2 t/ha, resulted in higher yield and net returns than inorganic treatments (Yadav *et al*., 2009). Nima *et al*. (2020) reported that, crop productivity was 33.9% higher in organic than chemical farming, resulting in higher net returns under green manuring based organic farming in north–western India. The profits of organic farms are 22–35% higher compared to conventional farms owing to organic premium prices (Crowder and Reganold, 2015). Despite such advantages and opportunities, there are some challenges faced by small–scale farmers to switch to organic system, including low yield, nutrient–management difficulties, certification and market issues as well as educational and research needs. Low yield is among the most important issues in this regard. Nevertheless, and given the controversial results on the organic farming yields, this aspect still needs further investigations in which the yields resulted from different organic farming practices could be compared in the long–run. Regarding regional priority for organic farming, different studies reveal that, organic farming can result in the highest profitability in dry, water–scarce and least–developed regions (Te Pas and Rees, 2014).

CONCLUSION

Organic farming systems are very much native to India as traditionally crops and livestock are reared together and as of today also, present in more than 85% of the farm households. India's average fertilizer and pesticide consumption stands at 128.3 kg/ha and 0.31 kg a.i/ha and many of the states have lower than the national average consumption of these synthetic inputs. In spite of technological advancements, the nutrient–use efficiency is still on lower side (33% for N; 15% for P; 20% for K and micronutrients). It is estimated that various organic resources having the total nutrient potential of 32.41 m t will be available for use in 2025. Since integrated approach of crop management including inter/mixed cropping (is also considered as **"towards organic"**) is found to increase the use efficiency of all costly inputs especially fertilizers and water, it would be appropriate to adopt the integrated crop management in the states contributing major share to the food basket. Organic production of niche crops (crops which yield higher under organic condition and have market demand) can be considered in the hilly and rainfed areas. It will also add to the increase in overall food production of the country. However, organic farming technologies need to be fine–tuned and updated to further enhance the yields. Farmer friendly certification policies and demand driven supply chain management is essential for the growth of organic farming in the country. It can be concluded that **"towards organic"** (integrated crop management) approach for intensive agricultural areas (food hubs) and **"certified organic farming"** with combination of tradition, innovation and science in the de–facto organic areas (hills) and rainfed/ dryland regions will contribute for safe food security in future besides increasing the income of farm households and climate resilience. This approach will also positively contribute to the cause of human, livestock and eco–system health.

WAY FORWARD FOR ORGANIC FARMING

Organic agriculture includes several aspects starting from crop husbandry to livestock to horticulture with complimentary activities on the farm. Presently, in India, several schemes have been formulated and implemented to promote the organic agriculture which have resulted in many–fold increase in area and export over the years, but still lot has to be done. The salient recommendations for penetration of organic farming in the country are:

- Organic farming growth is constrained due to several factors, such as a decline in yield in the initial years of conversion, insufficient availability of organic manures within the farm to meet out the nutrient demand, slow release of nutrients from organic manures leading to mismatch between crop demand and soil supply, difficulty in handling the bulky manures, and inadequate certification and marketing infrastructure. Hence an integrated strategy of addressing all these issues is essential.
- The main problem of organic growers is lack of continuous and reliable supply of certified inputs (such as seeds, bio–agents, bio–fertilizers, manures) and economically viable marketing of organic farm produce. Hence, steady and reliable input–output chains need to be established in potential organic clusters. The organic input production units established in public/ private sectors, under various developmental schemes in the country, should be linked up with suitable marketing channels to improve upon their capacity utilization and make them responsible and viable. Establishment of certified organic input–marketing channels is the need of the hour for expansion of organic farming in the country.
- To exploit high–end domestic and international export markets, potential organic agriculture zones need to be identified on the lines of "Special Economic zone" and be named as "Special Organic Agriculture Systems Zone". For example, potential exists for creation of "Organic Spice" zone in Kerala; "Organic Coconut Zone" in Nicobar district of Andaman and Nicobar Islands, "Organic Basmati Rice Zones" in Uttarakhand, Western Uttar Pradesh, Haryana and Punjab, "Organic Cotton Zones" in Madhya Pradesh, Gujarat and Maharashtra; "Organic Seed–Spices Zones" in Rajasthan and Gujarat. Similarly, several specialized organic zones may be identified for production and marketing of different vegetables and fruits within the well–established horticultural belts in different states. These zones can also be made as Agro–ecotourism centres for attracting the nature loving tourists. Tax holidays for those private investors, who will invest in establishing organic input production/ processing and packing units within the zone, may be considered. The zone should be planned in such a manner that all requirements of inputs, certification, processing and packing are met within the zone itself.
- Wide–spread existence of crop + livestock farming system is the strength for organic India. This should be considered a great opportunity for establishing integrated organic farming system in all the niche areas, which should serve as research–cum–demonstration unit. Cluster of villages must be encouraged for organic farming systems depending on the niche.
- Organic farming package adoption and its promotion for individual crops should be done away with the system approach should be adopted. Cropping and farming system approach of providing required nutrient and other inputs are proved to be successful. "Model Organic Farm" in farming system mode for marginal and small farmers should be developed in each district of identified and potential states.
- The approach of "Towards Organic" should be adopted instead of immediately switching over to organic from inorganic in the high–intensive agricultural areas to have safe food security in the country. This approach will reduce the immediate heavy yield losses during the conversion period and also will contribute for increased use efficiency of fertilizers and water. Government schemes of Integrated Nutrient Management, Plant Protection and Water Management needs to be amalgamated so as to get desired output.
- The guidelines of national standard for organic production are having the equivalence with European Union and other important countries. It is good for the export. However, the domestic standard which also follows the export standards for organic production and certification needs to be reviewed. As **"safe food for all"** is possible through **"towards organic"** approach which includes integrated crop–management practices. The domestic standard can consider the production practices of integrated approach with prescribed maximum use of nutrients (can be up to 50%) in the form of chemical fertilizers. However, the pest–disease and weed–management practices should be as per the export standard. This recommendation also holds well in the light of the argument that regardless of sources including organic, plants absorb nutrients in the form of inorganic.
- **"Certified organic farming"** with combination of tradition, innovation and science in the de–facto organic areas (hills) and rainfed/ dryland regions will contribute for safe food security in future besides increasing the income of farm households and climate resilience. This approach will also positively contribute to the cause of human, livestock and eco–

system health. Hence, organic farming should be promoted in niche areas and crops.

- Farmer Producer Organizations (FPO's) should be involved in production, processing and marketing of organic produces in the country. In fact, linking with assured market will be very important for organic promotion. Anand pattern which was successful in dairy should also be explored for organic farming expansion in the country.
- On the line of Minimum support price, the organic produces should also have premium minimum support price to ensure the better profitability to organic growers. This can be done by accounting environmental services from the system. Support for organic seed production with seed–production chain of arable crops, green manures, viz. (dhaincha [*Sesbania bispinosa* (Jacq.) W. Wight; syn. S. aculeate (Willd.) Pers.]/sunhemp [*Crotalaria juncea* L.]) should be given thrust.
- Establishment of sufficient and accessible laboratories for testing of products mainly for pesticide residues to maintain the quality of organic produce and inputs are essential.
- The North–Eastern Region of India is having very good potential for organic farming considering the fact that the use fertilizers, chemicals etc. are negligible especially in hills. They should be given preference and infrastructure support especially for input production and output storage, branding and marketing. At least 1 cold storage facilities/godown should be considered for each hub/cluster to store organic produce and get adequate benefit for the farmers.
- Networking of academic, research institutions, markets, certifying agencies and NGOs in the South Asia Association for Regional Cooperation (SAARC) nations are essential for sharing of technologies and harvest the benefit of complementarity. Authentic web–enabled information system for an organic agriculture system in the SAARC nations are essential.

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