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Editors
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ORGANIC FARMING AND SUSTAINABILITY

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Preface

Environmental preservation, resource conservation and assuring of food quality for the ever growing population had been the major challenges in agriculture during the last two decades. Growing awareness among consumers for safe and healthy food grown in tandem with nature has triggered the growth of another food segment across the world. Organic farming was found to be the most viable and effective option to address all these concerns and to address the consumers need. Although modern organic agriculture has its roots in consumers' desire for safe and healthy food and has emerged from western developed economies, of late it has also caught the attention of sustainability promoters and has been found to address all the global concerns. Organic farming in its modern form is not only productive enough to meet our growing demands but is also resource conserving and continuously contributing to the improvement of soil health and fertility. Ardent promoters of organic farming consider that present day organic agriculture, which is a mix of traditional wisdom and modern science and technology, can meet emerging demands and become the means for complete development of rural areas, especially in the developing countries like India where large chunk of farmers are small, with limited resources and with limited access to water, mainly through seasonal rains.

With increasing hazards caused by the use of synthetic chemicals in agro ecosystems, organic farming provides an alternative option, not only for sustaining productivity and retaining soil health but also promising chemical residue free food. Today, organic farming is a well-researched science that combines the knowledge of soil fertility, plant pathology, entomology, and other biological and environmental sciences.

Globally organic agriculture is being adopted by more than 162 countries and more than 37.2 million ha of land is registered under organic certification process. This does not include the traditional and/or default organic areas which remained untouched from green revolution era and may comprise of three times the certified area, located mainly in Africa and India. Besides this approximately 32.5 million ha of wild harvest collection area is also registered for organic certification. India is the second largest producer of organic agriculture commodities in Asia after China. As per the latest survey conducted by FiBL and IFOAM (2014) India's share in the global market for organic food is although less than 1% but there is tremendous scope to increase it. Hopefully, India can soon become the leader in organic agriculture and accelerate the growth towards a sustainable future.

In India, agriculture has been practiced for thousands of years, which was essentially organic, is also the repository of traditional wisdom and genetic germplasm. Civil society organizations and innovative farmers have developed technologies which are not only effective and productive, but are also explainable and accepted by the modern science. Many farmers with their farms are acting as centres of learning and serves as source of inspiration to thousands of upcoming organic agriculture enthusiasts.

Organic farming has many advantages such as energy efficiency, preservation of traditional knowledge, eco-friendliness, profitability, reduction and mitigation of Carbon emissions, etc. However, there are various queries regarding its contribution in sustaining food security and nutritional quality, adoptability, organoleptic quality, certification, economic feasibility and the resistance capacity of organic produce towards pests and diseases, etc.

This book contains lead papers from distinguished experts, policy makers and dedicated researchers. Efforts have been made to compile the latest information on the present status of organic agriculture in India and other major practicing countries. Efforts were also made to record initiations in organic agriculture by the various governments, farmers, non-government organizations and other stakeholders. We hope that this book will be of immense help to researchers in planning their future line of research, for policy makers to take rational decisions on organic agriculture for the benefit of farmers as well as consumers and for students and the general public to obtain a wealth of information on organic agriculture in India. It must be mentioned here that while the scholarly papers included in this volume do help enrich the readers' understanding on the issues related to organic agriculture, the views expressed by the authors in their respective papers are their own and the editors do not necessarily subscribe to them.

We thank all the contributors of this volume and are grateful for their valuable contributions. Our sincere thanks to Dr V S Ramamurthy, Director, National Institute of Advanced Studies and Dr Parveen Arora, Sc-`G'/Advisor, Department of Science and Technology, Government of India for their support and encouragement at every stage of its preparation. We are grateful to Ms I S Shruti, Mrs V B Mariyammal, Shri Krishna Prasad, Shri N R Shetty, Ms G F Aiyasha and Mr Thomas K Varghese for their support and involvement.

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India’s Organic Farming Movement

Claude Alvares

The story of how India’s organic farming movement started – and grew – till its significance became so overpowering that even the Central Government was forced to get involved – has not really been told. As far as my own personal knowledge goes, the first meeting about reviewing what we were doing to our farms and fields was held under the auspices of the newly formed Association for the Propagation of Indigenous Genetic Resources (APIGR) at Wardha in 1984, and it focused on genetic resource depletion in the form of loss of seed varieties – a critical issue with the organic farming movement. APIGR survived for some years. It called meetings annually during which people came together over specific issues including conservation of rice varieties, Indian breeds of cattle, water scarcity and green revolution, etc. It also published a series of booklets on these deliberations. APIGR was followed in the mid-1990s with the arrival of ARISE. The initiative for this came from Bernard deClercq, one of India’s most insightful organic farmers who lives and works in Auroville. ARISE was even registered as a national society, but the exercise eventually faltered.

Then we come to the third avatar of the organic farming movement in the country, the Organic Farming Association of India (OFAI) set up in 2002 in Bangalore. A majority of those attending were organic farmers from across the country. OFAI was formally registered in 2006, but is actually now ten years old. This has now remained the main association, with most organic farmers of all hues and various state level organic farming associations as a part of its membership. It has biennial conventions at different places in India – which are sort of university conventions – where farmers come to exchange techniques, participate in seed exchanges and make presentations on discoveries.

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So it is confirmed that the organic farming movement was not initiated by either scientific institutions or the government which – from 1966, in fact – became increasingly addicted to a strategy of agricultural production based on chemical fertilisers and dangerous poisons called pesticides. Of course, in the 1940s and 1950s, when no chemical fertilisers were yet available with the kind of power they exercise nowadays, the official establishment in India – symbolised by trained British agricultural expert, Albert Howard – did nothing but good organic farming! The books written by Howard are still very influential, from 'An Agricultural Testament' to 'Soil and Health', the latter released only last year (2013). Both books are organic farming classics the world over, as well known as Rachel Carson's 'Silent Spring' or Japanese agricultural scientist, Masanobu Fukuoka's 'One Straw Revolution.'

In the developed countries like the USA and Europe as well, the organic farming movement was initiated by farmers and members of civil society organisations. It was their growing strength which led to the formation of the International Federation of Organic Farming Movements (IFOAM), the world's apex body of organic agriculture. Last year, the Asia-level groups set up IFOAM-ASIA. OFAI deputed one of its members to the new organisation which elected him as the first Vice-President of the new executive board.

The need to pay more attention to farming by organic methods received a huge stimulus in India with the introduction of stricter standards for food imported into Europe from the Indian subcontinent. Export consignments to Europe with pesticide residues in excess of norms were returned. This is when the Government of India, under strong pressure from the export lobby, turned to support organic farming, purely in order to shore up exports and launched the National Programme on Organic Production (NPOP) for installation of standards based quality assurance system during the year 2000 under Ministry of Commerce and Industry. This explains also why – till date – the entire production and export of organic food is in the hands of the Commerce Ministry, and not the Ministry or Department of Agriculture! And it has remained there since!

For the purpose of preparing organic farming standards, the Indian Government – as usual – called in persons associated with IFOAM and other NGOs in Europe. These standards were later adopted as the National Standards on Organic Production (NSOP). APEDA was asked to set up an organic farming section to administer such exports. Agencies to accredit certification inspectors were notified. Much later, GOI decided to bring in an organic certification scheme for the domestic market under the AGMARK regime. For the purposes of organic production, the GOI redesignated the National Centre for Biofertilisers into the National Centre of Organic Farming (NCOF), and their regional offices as well became regional centres of organic farming (RCOF). This enabled it to keep the mainstream agricultural research and extension infrastructure actively linked exclusively with green revolution technology.

The export-oriented organic certification schemes were terribly expensive at first, since they relied upon European inspectors (some still do). Later, these were replaced by Indian inspectors under accredited Indian agencies. Nevertheless, the cost of certification remained high. Any extra income the farmer could get on his organic produce was being eaten up by the inspectors. Disgusted with the huge costs of certification, the Govt of India, FAO, and groups like OFAI, sat together in an unprecedented series of meetings and drew up a new organic quality assurance guarantee in the form of the Participatory Guarantee System (PGS) first evolved by the organic farming community in Brazil, South America. This low-cost scheme has been entirely successful and it has led to the registration under the Societies Act of the PGS Organic Council (PGSOC) run purely by NGOs servicing sustainable agriculture. There is also now an NCOF-run PGS system. More than 5,000 farmers are presently registered as successful organic farmers under the private PGS label.

At the state level, several state governments – notably Karnataka, Kerala, MP, Bihar, Maharashtra, etc., – have announced their own individual organic farming policies to promote and support conversion of farmers to organic agriculture. Large amounts have been allocated in some state government budgets to promote organic agriculture. This brings us to the consumer side of the organic farming movement which is not at all well organised. Organic stores – which two decades ago were approximately one or two per city at the most – have now shot up to more than 500 across India, and there are some superchains as well, including Morarka, Namdhari's and 24 Letter Mantra. A few organic food restaurants have also been started.

Consumers now know what organic food is. But somehow at the moment, only the very poor and the very rich have access to it: the poor because they grow it for themselves, the rich because they can afford the high rates of organic farmers who grow for the market. The middle class finds organic food more expensive than conventionally grown food and it does not see why it should pay the difference in price because it is still to be health conscious with determination. Why organic food is sold at a higher cost especially since organic farmers do not use costly chemical fertilisers or synthetic pesticides or GM seeds, which cost a bomb because they are fully controlled by multinationals like Monsanto? But that is a fact of life today. It can only change when more and more farmers begin to raise crops organically, and more of it is sold directly to consumers, as is done in some areas today in the form of green bazaars.

The scientific basis of organic agriculture: Today organic farming is done under various labels: organic farming is also natural farming, zero-budget, Low External Input Sustainable Agriculture (LEISA), biodynamic or ecological agriculture. Permaculture, another form, is also regaining ground. Local idioms refer to organic farming as *jaivik kheti*, or *naisargic kheti* or *shendriya sheti*. The defining feature of all is the absence of reliance on chemical fertilisers, pesticides and GM seeds (which are, besides being another form of pesticide, a form of unorganic or unnatural input into a system that is based almost entirely on natural principles). Use of GM seed is expressly forbidden in organic agriculture.

In my view, some basic aspects of India's agriculture need to be highlighted first. Historically speaking, there are only three significant ways in which we human beings have ensured the supply of food needed for our survival and our other necessities: a) The first looks at nature as a direct source. Nature is the most experienced farmer there is, and of course, it follows principles (example, selection) which have evolved over millions of years. Nature remains today the largest producer of biomass, fruit and flower, and a host of other things we cannot even begin to enumerate so we have to concede that we can never match either the scale, the efficiency, or the energies employed in that department; b) The second is the way we have learnt recently under the influence of Western advisers, which is largely to substitute natural processes with industrial inputs like chemical fertiliser and pesticides based on a wholly reductionist (NPK) view of the plant. This system, also called the green revolution (GR) – but now turning increasingly brown – is only 50–60 years old in India; it has only a little earlier origin (but not more than a hundred years) worldwide, notably in those countries which have by now almost wholly industrialised their agriculture; c) The third way is one that developed between these two other ways. It is still subsisting widely today and is often referred to as indigenous or traditional agriculture, which is based on culture and natural resources, but in most cases, takes advantage of natural principles and bases its practices on those.

The implication or assumption in most educated and scientific circles is that the green revolution system is the result of science, it is modern, and therefore certainly an advance on both: farming according to natural principles or indigenous agriculture. Now this, in my opinion, is what the organic farmers of the world have refuted to a large extent because of a better scientific explanation or theory of how plants and soils work. And this will be the focus of the rest of my presentation here, because I expect that it will be appreciated by people who work with – and are committed to – the idea of scientific agriculture. Ecological agriculture is a contribution of organic farmers to human knowledge. It is quite awesome in nature and if we are intent on using labels – we could confidently called it the most modern practice of farming available in our times.

First and foremost, no form of food production which emerges as a result of natural biological principles at play can be labelled either unscientific or not scientific. This is important to establish at the start, because very often, the move to farm away from a system based on industrial chemicals is seen not just as a move away from a more efficient and productive agriculture, but as a move away from science, rationality, etc., and all that goes with the mental baggage associated with those terms. When the forest produces fruits and we (and birds and animals) eat that fruit or the honey or the flowers, the produce we eat is a result of natural biological principles in operation. They do not come into existence by any process that is against science or is unscientific or pre-scientific in any way. It would in fact be an absurd proposition to claim that natural processes are contrary to science, because science is nothing more than our understanding of the functioning of nature at various levels and in various fields.

So anything that grows according to natural principles cannot be in anyway contrary to science. In fact, since modern scientific methods are only a few centuries old, and are yet to scratch the surface in many areas, natural methods that evolved over millions of years have stood the test of time which is the most important test there is. We need to keep that in mind. Just to give you a simple example: with all the scientific knowledge available to us, we simply cannot regenerate natural forests. All natural forests emerge by themselves and each is a unique community. We may even understand them, but we cannot create or duplicate them. This brings us to indigenous agriculture or agriculture that has continued to produce food even after the introduction of the GR. This is also often among the educated and scientific community seen as a technology of stagnation, of low productivity, and incapable of meeting the demands of growing populations.

Again this is untrue, because traditional agriculture, in contrast with modern agriculture, has kept all cultures alive and well, in times of peace and war, for several thousands of years. So it cannot really be that bad or inefficient. It met the needs of societies at the appropriate time. If it didn't, societies would not have survived and we all would have long ceased to exist. There are in fact features of indigenous agriculture that are not so well known and which one should keep in mind, in addition to the fact that it was (and is, because much of it still exists) 'default' organic.

One important feature of traditional agriculture, for example, is the inherent biodiversity implicated in its cropping systems which is often as impressive as that found in natural biodiversity-rich areas. It is well recognised that traditional systems are biodiversity-based, whereas conventional modern agricultures are principally monocultures. But it is when we examine the nature of the biodiversity that the scientific contributions of indigenous cultures appear staggering in their achievements. Among rices alone, for example, we in India had at one stage more than 300,000 varieties, all these prior to the advent of the GR. In fact, the GR reduced that diversity sharply to a few handfuls of so called successful varieties that can survive only on chemicals and copious quantities of water. The CRRI (Central Rice Research Institute) had 60,000 varieties. The Madhya Pradesh Rice Research Institute (MPRRI) under Dr R H Richharia – when he was alive – had 19,000 varieties collected by him only from that state. So we need to seriously review our perceptions of non-GR technologies.

Different approaches to plant nutrition: What then is the difference between traditional/natural agriculture and conventional agriculture, and how has this difference been highlighted and exploited by the organic farming movement? This is a very interesting question, and needs some introduction to botany fundamentals. Standard texts in botany highlight the following principal sources for the nutrition of plants. These are conveniently set out in the table below:

Sources of plant nutrition:

I. **Elements from the atmosphere**: These represent 92 to 98% of a plant's dry weight

- 4 vital elements (all constitutive): carbon, oxygen, hydrogen, nitrogen

II. **Elements from the soil**: They represent 2–5% of a plant's dry weight

- 12 vital elements of which: 2 are non-constitutive – Potassium and chlorine 10 are constitutive – phosphorous, boron, Calcium, magnesium, sulphur, iron, manganese, molybdenum, copper and zinc
- 18 secondary micro-nutrients (of which the function of some is not fully understood), of which 4 are non-constitutive – lithium, sodium, rubidium and cesium and 14 are constitutive – fluorine, silicon, selenium, cobalt, iodine, strontium, barium, aluminium, vanadium, tin, nickel, chromium, beryllium and bromine

Source: Claude Bourguignon, 'The Regeneration of the Soil,' Other India Press, Goa.

Thus 95–97% of the plant's nutritional needs or constituents is met by the atmosphere, and is therefore never sourced from the soil or the ground through the root system. The root system is responsible for intake of some mere 3–5% of the plant's constituents, including some nitrogen, vital minerals, which by their nature, cannot come from the atmosphere since they come from rock. It is important to highlight here how the plant draws these from the soil.

Principally this process is controlled by soil microbes, who through natural chemical processes, transform the minerals into forms that can be absorbed by the plant's roots. For example, it is they who do the conversion of sulphur into sulphates or phosphorus into phosphates. (Some plants like legumes are masters in fixing atmospheric nitrogen directly in small nodules on their roots: this is commonly known.) Older agricultures procured minerals from tank silts or from rivers overflowing their banks, and microbes from cowdung and composts (adding to the microbes already found in the soil).

Some of these minerals are non-constitutive elements of the plant, and include potassium and chlorine, lithium and sodium, among others: the plant returns them to the soil after its life. Others – constitutive elements – like phosphorus, boron, sulphur, etc., are exported from the soil with the plant when it is removed (with the harvest). This is how soil deficiencies progressively occur, because little or no effort is made to replace the elements that are exported from the soil with the crop. In other words, we begin mining the soil and since we are dealing with limited physical quantities, soil micro-nutrient deficiencies and exhaustion is inevitable, leading to plant disease of all kinds. Thus our organic farmers found that if they reintroduced soil microbes in large quantities into the soil through recipes like *panchagavya* or *jeevamrut* and then created conditions for those microbes to survive and work – for example, providing a good mulch – their need for external inputs declined rapidly to such an extent that on the best organic farms today, almost no external input, even addition of microbes, is any longer necessary. These farmers have come very close to how a forest system maintains itself, with absolutely no inputs from human beings. These lessons have come from hard-working and intelligent farmers who found they had to develop these techniques, after close analysis of traditional ways and close observations of forests, to develop a new agriculture of permanence and sustainability. That learning took place outside the walls of agricultural universities and science institutions.

Now this almost natural mimicry is exactly what is displaced by modern agriculture of the green revolution. NPK are supplied in soluble form, after being produced in vast industrial units. Since these salts cannot be absorbed by the plants directly, they have to be conveyed to the roots through water, demanding huge dams and irrigation canals. Therefore irrigation is required not for the plants' natural thirst, but as a mechanism to convey industrial salts to the root system. Since the plants are genetically not equipped to absorb all the salts, most of these are conveyed by the same waters to the river, tanks and sea. The efficiency in uptake of chemical fertiliser is therefore extremely poor.

But more important are the effects of these salts on the soil flora: termites, earthworms and soil microbes perish or migrate because they are unable to survive the inhospitable environment created by these chemicals. The soil becomes sterile and the dependence on chemicals increases, soon leading to the law of diminishing returns. This becomes the new ground for looking for deadlier technologies like genetically modified (GM) seed which fundamentally speaking cannot improve the yield potential of a seed (like hybridisation or crossing sometimes does, because of hybrid vigour) but can only promise to protect existing crop yields from destruction.

Agriculture at crossroads: Agriculture has always worked within the seasons and for that reason has remained sustainable. Sustainability is a measure of 'how long', whether the practices of one generation survive or can survive, into the next and then the next. Traditional agriculture has lasted thousands of years, which is a great measure of success in evolutionary terms. In contrast, GR agriculture is undoubtedly already in the throes of a crisis of monumental proportions. In fact, the failings of the first GR – the use of dangerous, but increasingly ineffective pesticides which severely compromise the food we eat – are now exploited to further the cause of the so-called second GR, based on GMOs. One of the primary arguments used to push GMOs is their purported ability to reduce the use of toxic pesticides.

There is really no paradigm shift involved, so calling it a second GR will not help. The approach – heavy or exclusive reliance on external inputs, each one more expensive than the last – is the same: a methodological approach that departs needlessly from the natural principles governing plant growth, and which seeks to use fast-depleting non-renewable resources (petrochemicals) to provide substitute nutrition for something which can always be provided by nature free of cost. That's how our forests run in any case. That's how most of our vegetation survives, but not our agriculture, which operates within an artificial box.

There is one argument continuously made in defence of industrial agriculture: that earlier we imported food, now we produce it ourselves. But this does not acknowledge the fact that we now import the petrochemicals needed to grow that food, and without that critical industrial input, organised agriculture would face collapse. In fact, the era of cheap oil is gone. Oil production has peaked. Now industrial culture has moved into fracking which has even greater environmental consequences than the extraction of oil. To carry out agriculture on such a base is to build a house on sand. This is a completely unsustainable operation by any definition.

The majority of the organic farming community do not accept the idea that inputs for farming must come from outside the farm: getting into that situation, or remaining in that relationship of dependence, is taken as a measure of defeat. How directly opposite is this approach to official agriculture which strongly insists on enhancing dependence on more and more expensive tools (including GMOs), not just from outside the farm, but outside the country's laboratories and oilfields as well!

That thrust, we must concede, is the natural consequence of permitting the wholesale invasion of agriculture by industrial elements. Industrial agriculture furthers the interests of those who supply industrial inputs: fertiliser plants, agricultural research laboratories, pesticide manufacturers, and now multinational seed monopolies like Monsanto and Bayer. This means industrial agriculture begins and extends with continuous dependence on external inputs into the foreseeable future.

One important final observation about the organic farming movement in India needs to be made. In quantitative terms India is still the largest producer of organic in the world. This is not so if one goes by official data, but the official data are completely unintelligent and unreliable in this respect (Table 1).

Table 1: Some strange statistics about organic farming, India and worldwide

Jackfruit	1.5 million tonnes per annum (pa)	No chemicals used	Locally consumed
Jackfruit: Karnataka alone	2,35,000 tonnes pa	Value: INR 12,718,00,000 /–	Locally consumed (70% wasted)
Jackfruit: Assam alone	1,75,000 tonnes pa	Not available	Locally consumed
Ber	0.9 million tonnes pa	No chemicals used	Locally consumed
Mahua	60 million tonnes pa	No chemicals used	Locally consumed
Total export of certified organic from India	1,65,262 tonnes (2012–13)	1155.81 cr	Exported
Beef export India	1.52 million tonnes/pa	Free range browsing/ agricultural residues	Part of what is locally consumed
Beef export Australia	1.40 million tonnes/pa	Artificial feeds, antibiotics and hormones	All exported
Organic beef export Australia	17,533 tonnes/ pa (of which, 8,000 tonnes to Europe)	12 million ha organically certified pastures, which comprise 97% of organic production of Australia.	Small part of total beef export
India organic production (official)	780,000 ha	0.43% of total arable land	400.551 farmers
Australia organic production (official)	12 million ha	2.93% of total arable land	2,129 farmers

In India, millions of farmers have been growing organically for several centuries. But since they do not do it the way the Europeans do organic farming today, or follow the organic standards laid down by Europe, we presumably cannot call them certified 'organic'; in fact, we call them 'default' organic i.e. organic by default. The presumption is, if the farmers had the cash and the water, they too would have gladly used chemicals. Since these limiting factors are operating practically in all dryland areas, with little or no irrigation and where chemical fertilisers cannot be used, we turn that situation into one of profit, and sell the produce as 'default' organic. The idea is not to improve default organic to the status of intended organic, but to take advantage of the situation. So if you look at world figures of organic production, you see that Australia is the world's leading producer of certified organic. You may then ask what it is that Australia produces. 97% of Australia's certified organic produce is pasture grass, which is not even for the direct consumption of human beings! So, simply because of nonsensical and arbitrary definitions, Australia leads India trails. The problem is that such defining exercises do have huge policy implications which we should critically examine.

Why would one say that India is the largest organic producer in the world? Well, just take any one food item (say, jackfruit) at random. All jackfruits grow without fertilisers and pesticides and irrigation, completely naturally. Production in volumes is approximately 1.5 million tonnes, which is greater than the entire organic export of all commodities put together out of India to the European Union. Take Mahua flowers, for instance, of which production is some 60 million tonnes or Ber, which is 0.9 million tonnes. Or wild produce, like rock honey. If I have to enumerate the number of things that human beings eat in India and which are not produced with the use of chemicals, pesticides or irrigation, I would need several pages for a listing. If we certified all the naturally growing grass our animals eat from hillsides and plains, Australia with its 12 million ha organic pastures would be quite far behind. Put the entire organic production from India together, and it will clearly out total the organic production of the rest of the world. This is in fact our strength, but for some convoluted reason, we are determined to undermine this inherited capacity for ecological agriculture and chase dangerous chemical fixes based more on industry than science without a second thought. It's time we help redress these conceptual and policy grievances, so that we can reclaim our rightful position as the largest producer of organic in the world.

Future Sustainable Food Security of India through Organic Farming: Myth or Reality

Ashok Kumar Yadav

During last fifty years, global agricultural production has witnessed phenomenal growth averaging 2.3 percent per year and ensured consistent availability of food for the increasing and wealthier global population. High yielding varieties and breeds, synthetic inputs, mechanization, better plant protection and health care systems and good management practices have boosted crop yields and livestock productivity. Aquaculture supplies an increasing share of total fish consumption and the real price of food has declined over the long term.

However, rapid population growth and increased human activities have resulted in the overexploitation of the environment and natural resources, and have started to threaten the ability of the agriculture sector to provide food and income for the people. Multitude of challenges and problems associated with the present day agriculture due to exploitation and deterioration of natural resources include, loss of soil fertility, strong decline of agro-biodiversity, pollution of water (Badgley *et al,* 2007; Singh 2000), and health problems associated with the use of synthetic plant protection products (Pimental 1996). There are increasing concerns that the agricultural production system during next four decades may exceed the environment's 'carrying capacity' or the ability to support human activities. The available scientific evidence suggests that business as usual may lead to a future in which economic growth will be constrained by natural resource limits, putting the security of food supplies at risk. Therefore there is an urgent need to identify good practices and good policies, to overcome impediments and embracing opportunities to implement policies that may move food and agriculture on to a sustainably productivity pathway. First decade of twenty first century has witnessed introduction of many comprehensive

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system-oriented approaches which are gaining momentum and are expected to better address the difficult issues associated with the complexity of farming systems in different locations and cultures (IAASTD 2009).

Food security and agricultural productivity: Food security is generally defined as a condition where 'all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. Therefore, ensuring sustainable food security is not simply a question of producing enough food to meet the demand; it is influenced by various factors, including production, trade, policies, prices and support structures by Governments. Increased food supply does not automatically mean increased food security for all. Therefore, in spite of phenomenal growth in agricultural productivity and country being surplus in food production, food security to all is still a dream. The conventional wisdom for food security is that, we need to double food supply and to achieve that we need to redouble the modern agriculture. Such a strategy has been successful in the past. But now there are doubts about the capacity of such systems to reduce food poverty. The great technological progress in the past half century has not led to major reductions in hunger and poverty in developing countries.

Arguably the most sustainable choice for agricultural development and food security is therefore to increase farm productivity *in-situ*, in the developing countries including India that are the most in need for greater food supplies. Therefore attention needs to be focused on the following: a) The extent to which farmers can improve food production and raise incomes with low-cost, locally available technologies and inputs; b) Whether they can do this without causing further environmental damage and excessive resource exploitation; c) The extent of farmer's ability to trade and; d) Define policies, strengthen innovation system and ensure adequate investment to facilitate level playing field for such practices to happen.

Sustainability in agriculture: Many different expressions have come to be used to imply greater sustainability in agricultural systems. These include biodynamic, community based, eco-agriculture, ecological, environmentally sensitive, farm-fresh, free range, low input, organic, permaculture etc. However, highly sustainable agricultural systems can be taken to mean those that aim to make the best use of environmental goods and services while not damaging the five assets namely, natural, social, human, physical and financial. The key principles to sustainability are: 1) Integrate biological and ecological processes such as nutrient recycling, nitrogen fixation, soil regeneration, allellopathy, competition, predation and parasitism in production processes; 2) Minimize the use of those non-renewable inputs that cause environmental damage or that harm the health of farmers and consumers; 3) Make good use of knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly external inputs; 4) Make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as pests, watershed, and irrigation, forest and credit management.

If sustainable agricultural systems are those that aim to make the best use of environmental goods and services while not damaging the five assets – particularly natural, social and human capital, then an integrated organic farming system can be considered inherently sustainable. Unlike the conventional intensive agricultural systems, organic farming represents a deliberate attempt to make the best use of local natural resources. The aim of organic farming is to create integrated, humane, environmentally and economically viable agricultural system that relies to the greatest extent on: (i) local or on-farm renewable resources, and (ii) the management of ecological and biological processes, while use of external inputs, whether inorganic or organic is reduced as far as possible.

Organic agriculture: The concept of organic agriculture builds on the idea of the efficient use of locally available resources as well as the usage of adapted technologies (e.g. soil fertility management, closing of nutrient cycles as far as possible, control of pests and diseases through management and natural antagonists). It is based on a system-oriented approach and can be a promising option for sustainable agricultural intensification in the tropics, as it may offer several potential benefits (Kilcher 2007; Valkila 2009; Eyehorn *et al*, 2007; Mendez *et al*, 2010) such as: (i) A greater yield stability, especially in risk-prone tropical ecosystems, (ii) higher yields and incomes in traditional farming systems, once they are improved and the adapted technologies are introduced, (iii) an improved soil fertility and long-term sustainability of farming systems, (iv) a reduced dependence of farmers on external inputs, (v) the restoration of degraded or abandoned land, (vi) the access to attractive markets through certified products, and (vii) new partnerships within the whole value chain, as well as a strengthened self-confidence and autonomy of farmers.

There may by differing management approaches for organic cultivation under different climates, locations and cropping systems but one thing they all have in common is the desire to develop a method of production capable of generating safe and healthy food and fiber, with minimum or no adverse effects on the environment and resources. Over the years it has been scientifically proven, beyond doubt, that organic farming systems are most productive environment-friendly system of growing crops, promising environmental preservation, protection of variety and species, protecting the soil, keeping the water clean and reducing the impact of agriculture on the atmosphere. The system may not be emphasizing on maximization of yields and profits from one or two particular crops but ensures that the total productivity and benefits (including environmental and resource conservation) from the farm as a whole are far more than the productivity and economic benefits from one single crop.

Critics contend that organic agriculture is associated with low labor productivity and high production risks (Trewavas 2002; Nelson *et al,* 2004), as well as high certification costs for smallholders (Makita 2012), but, the main criticism reflected in the scientific literature is the claim that organic agriculture is not able to meet the world's growing food demand, as yields are on average 10% to 25% lower than in conventional agriculture (de Ponti *et al,* 2012; Seufert *et al,* 2012). It should however be taken into account, that yield deviations among different crops and regions can be substantial depending on system and site characteristics. In a meta-analysis by Seufert *et al* (2012) it was shown that yields in organic farming systems with good management practices can nearly match conventional yields, whereas under less favorable conditions or under simple nutrient replacement models they cannot. Reganold (2012) pointed out that while making comparisons productivity is not the only goal that must be met in order for agriculture to be considered sustainable: The maintenance or enhancement of soil fertility and biodiversity, while minimizing detrimental effects on the environment and the contribution to the well-being of farmers and their communities are equally important and need to be given due importance while making such comparisons. Abstract details of some of the studies published in recent years, underlining the potential of productivity in production, profitability and soil health improvement are being described in following paragraphs.

Organic agriculture and productivity: Since the advent of organic farming in the recent years there had been concerns on the production potential of the system. But the results of long term experiments released during the last 10 years from world over have eliminated all fears. Under irrigated conditions organic farming may be yielding 5–12% less than their conventional counterparts but under rain-fed and water deficit conditions organic system yields 7 to 15% more.

Six years experimenting, comparing two models of organic management with only chemical input and chemical + organic under 4 crop husbandry systems at ICRISAT (Rupela 2006) revealed that although, maximization of yields can be achieved by the combined use of chemical fertilizers and organic inputs/practices (integrated agriculture), but this combination may not be affordable for small and marginal farmers in rainfed areas (Figures 1 and 2).

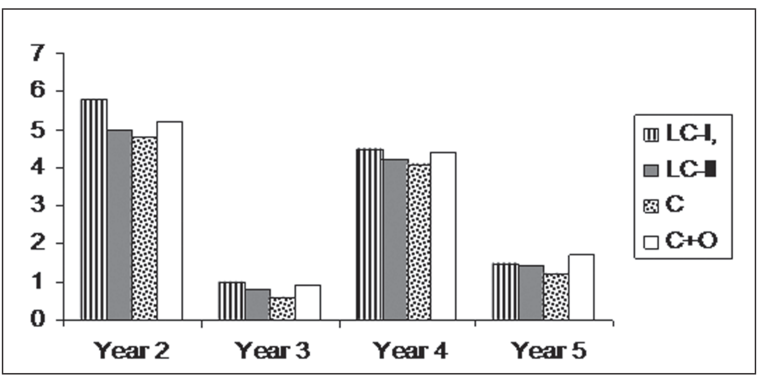

Figure 1. Yield (total economic mass) t/ha

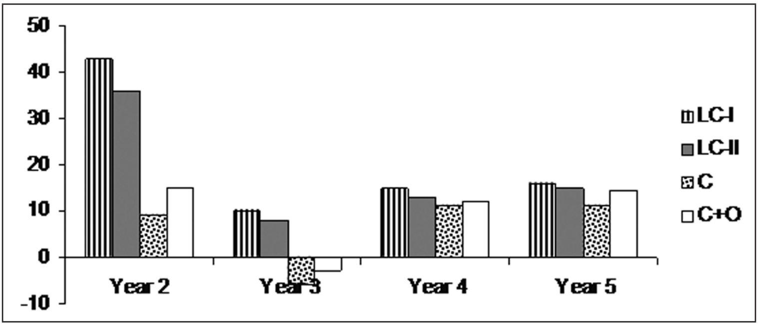

Figure 2. Net Income (thousand rupees)

LC–I and LC–II = Organic model I and organic model II, C = Conventional where only chemical fertilizers were used, C+O = Integrated application of chemical fertilizers+organic manures

The low cost organic approaches can be an attractive choice, particularly when their strategic application results in yield levels at par with conventional system. The two organic models studied in the experiment yielded comparable results, but were 25% more profitable than conventional system. Pest and disease management was also effective and low cost with biological approaches. Soil fertility and soil nutrient balance was certainly on significantly higher side in organic system and offer longer sustainability and suitability of the approaches under Indian conditions, typical of small and marginal farmers.

Reviewing 154 growing seasons' worth of data (Halwell 2006) on various crops grown on rain-fed and irrigated land in the United States, University of California –Davis agricultural scientist Bill Liebhardt found that organic corn yields were 94 percent of conventional yields, organic wheat yields were 97 percent, and organic soybean yields were 94 percent. Organic tomatoes showed no yield difference. More importantly, in the world's poorer nations where most of the world's hungry live, the yield gaps completely disappear. University of Essex researchers Jules Pretty and Rachel Hine looked at over 200 agricultural projects in the developing world that converted to organic and ecological approaches, and found that for all the projects –involving 9 million farms on nearly 30 million hectares – yields increased an average of 93 percent. A seven-year study from Maikaal project in Khargone District in central

India (Eyehorn *et al,* 2009) involving 1,000 farmers, cultivating 3,200 hectares found that average yields for cotton, wheat, chili, and soybean were as much as 20 percent higher on the organic farms than on nearby conventionally managed ones. Farmers and agricultural scientists attributed the higher yields in this dry region to the emphasis on cover crops, compost, manure, and other practices that increased organic matter (which helps retain water) in the soils.

A study from Kenya found that while organic farmers in 'high-potential areas' (those with above average rainfall and high soil quality) had lower maize yields than non-organic farmers, organic farmers in areas with poorer resource endowments consistently out yielded conventional growers. (In both regions, organic farmers had higher net profits, return on capital, and return on labour). The study carried out in the Central Valley of California (Drinkwater *et al*, 1995) showed that tomato yields were quite similar in organic and conventional farms. However, significant differences were found in soil health indicators such as nitrogen mineralization potential and microbial abundance and diversity which were higher in the organic farms. Nitrogen mineralization potential was three times greater in organic compared to conventional fields. The organic fields also had 28% more organic Carbon.

One of the longest running agricultural trials on record (more than 150 years) are the Broadbalk Experiment at the Rothamsted Experimental Station in the United Kingdom. The trials compare a manure based fertilizer farming system (but not certified organic) to a synthetic chemical fertilizer farming system. Wheat yields are shown to be on average slightly higher in the organically fertilized plots (3.45 tonnes/hectare) than the plots receiving chemical fertilizers (3.40 tonnes/hectare). More importantly though, soil fertility, measured as soil organic matter and nitrogen levels, increased by 120% in the organic plots, compared with only 20% increase in chemically fertilized plots (Leigh and Johnston, 1997).

Another trial's result from Sustainable Agriculture Farming Systems project (SFAS) at University of California, Davis (Clark *et al*, 1999) showed that organic and low-input systems had yields comparable to the conventional systems in all crops which were tested – tomato, safflower, corn and bean, and in some instances yielding higher than conventional systems. Initially tomato yields in the organic system were lower in the first three years, but reached the levels of the conventional tomatoes in the subsequent years and had a higher yield during the last year of the experiment (80 t/ha in the organic compared to 68 t/ha in the conventional). In one such study at South Dakota in Midwestern United States shows the higher average yields of soybeans (3.5%) and wheat (4.8%) in the organic compared to conventional farming system (Welsh, 1999). 21 year study compared plots of cropland grown according to both organic and conventional methods at Institute of Organic Agriculture and the Swiss Federal Research Station for Agroecology and Agriculture found that Organic yields were less by about 20% but Fertilizer, Energy and Pesticide use were less by 34%, 53% and 97% respectively as compared to conventional (Maeder *et al*, 2002). Also organic soils housed a larger and more diverse community of organisms. The study at Iowa State University assessed (Delate and Cambardella, 2004) the agro ecosystem performance of farms which found initially the yield was slightly lower (Organic corn and soybean yield averaged 91.8% and 99.6% of conventional respectively) in organic plots but in fourth year organic yield exceeded conventional for both corn and soybean crops (Delate *et al*, 2002). 30 Years Farming System Trial (FST) at Rodale Institute showed organic corn yields 31% higher than conventional in years of drought (Pimentel *et al*, 2005). These drought yields are remarkable when compared to genetically engineered 'drought tolerant' varieties which saw increases of only 6.7% to 13.3% over conventional (non-drought resistant) varieties. Corn and soybean crops in the organic systems tolerated much higher levels of weed competition than their conventional counterparts, while producing equivalent yields. This is especially significant given the rise of herbicide-resistant weeds in conventional systems, and speaks to the increased health and productivity of the organic soil (supporting both weeds and crop yield).

The study conducted by ETC Organic Cotton Programme in the district of Karimnagar, Andhra Pradesh India showed organic cotton yielded on par at 232 Kg seed cotton/acre vs. conventional cotton at 105 Kg/acre. The pest control expenses was observed about Rs. 220 and Rs. 1624 per acre for organic and in conventional cotton respectively (Daniel *et al*, 2005). Study at Washington State University compared yields, economics, soil quality, and other factors resulting from apples grown using organic, conventional, and integrated methods. After combining all of the sustainability indicators, the organic system ranked first (Reganold, 2006) in overall sustainability, the integrated second and conventional at last.

Research findings released from UAS, Dharwad, Karnataka under Network Project on Organic Farming (ICAR) reported results from six year long experiment comparing yields and net returns from organic cultivation, chemical farming and integrated nutrient management (INM). The results for three crop combinations are as follows (Table 1):

Table 1: Yields and net returns of three crop combinations

Crop combination	Yield kg/ha	Yield kg/ha	Returns Rs/ha
Groundnut-sorghum	Groundnut yield	Sorghum yield	Net returns
Organic	2975	1166	48345
Chemical	2604	1043	40790
INM	2842	1155	46090
Soybean-Wheat	Soybean yield	Wheat yield	
Organic	1769	1081	21120
Chemical	1521	933	16313
INM	1733	1062	19929
Chilli-Cotton	Chilli yield	Cotton yield	
Organic	447	662	19502
Chemical	427	559	14176
INM	445	681	19540

(Source: UAS Dharwad, 2011)

Organic agriculture and profitability: Recently a study was conducted in Maharashtra to study the impact of organic farming on economics of sugarcane cultivation in Maharashtra (Kshirsagar, 2007). The study was based on primary data collected from two districts covering 142 farmers, 72 growing Organic Sugarcane (OS) and 70 growing Inorganic Sugarcane (IS). The study finds that organic cultivation enhances human labour employment by 16.90 per cent and its cost of cultivation was lower by 14.24 per cent than conventional farming. Although the yield from organic was 6.79 per cent lower than the conventional crop, it was more than compensated by the lower cost and price premium received and yield stability observed on organic farms. The organic farming gives 15.63 per cent higher profits and profits were also more stable on organic farms than the conventional farms.

Tej Pratap and Vaidya (2009) in a nationwide survey of organic farmers suggest that 'The cost-benefit analysis indicates favourable economics of organic farming in India. Farmers in 5 out of 7 states are better placed, so far as organic farming is concerned. The returns are higher in Himachal Pradesh, Uttaranchal, Karnataka, Maharashtra and Rajasthan. In Karnataka organic farmers had 4–35% higher returns than inorganic farmers. In Kerala the differentials ranged between 4–37% in favour of inorganic farmers. In Maharashtra the difference in net profit was more than 100% in case of organic soybean. Organic cotton farmers were enjoying comfortable profit margin. The profit differential in Rajasthan ranged from 12–59% in favour of organic farmers. In Tamil Nadu organic farmers were better placed with two crops, while inorganic farmers were at slight advantage in other two crops.

In another study by Ramesh *et al* (2010), it has been reported that on an average, the productivity of crops in organic farming is although lower by 9.2% compared to conventional farming. There was a reduction in the average cost of cultivation by 11.7% compared to conventional farming. However, due to the availability of premium price (20–40%) for organic produce in most cases, the average net profit was 22.0% higher in organic compared to the conventional farming. In traditional rainfed agriculture (with low external inputs), organic agriculture has shown the potential to increase yields and profits. The economics of organic cotton cultivation over a period of six years indicated that there is a reduction in cost of cultivation and increased gross and net returns compared to conventional cotton cultivation in India.

Recently a study by Forster *et al* (2013) presents agronomic and economic data from the conversion phase (2007–2010) of a farming systems comparison trial on a Vertisol soil in Madhya Pradesh, central India. A cotton-soybean-wheat crop rotation under biodynamic, organic and conventional (with and without Bt cotton) management was investigated. Authors observed a significant yield gap between organic and conventional farming systems in the 1st crop cycle (cycle 1: 2007–2008) for cotton (−29%) and wheat (−27%), whereas in the 2nd crop cycle (cycle 2: 2009–2010) cotton and wheat yields were similar in all farming. In contrast, organic soybean (a nitrogen fixing leguminous plant) yields were marginally lower than conventional yields (−1% in cycle 1, −11% in cycle 2). Averaged across all crops, conventional farming systems achieved significantly higher gross margins in cycle 1 (+29%), whereas in cycle 2 gross margins in organic farming systems were significantly higher (+25%) due to lower variable production costs but similar yields. Soybean gross margin was significantly higher in the organic system (+11%) across the four harvest years compared to the conventional systems.

Organic agriculture and soil health: Organic farming while relying on use of crop rotations, mixed crops, crop residue and manures, not only helps in improving nutrient balance in soil but also accelerates various microbiological processes leading to continuous improvement in fertility and health index. Long term experiments comparing productivity and soil health parameters at ICRISAT have demonstrated that organic practices produced yields comparable to conventional plots, without receiving any chemical fertilizer; they actually showed increase in the concentration of N and P compared with conventional. In years 3 and 4 of adopting organic management this increase was 11–34% in total N and 11–16% in total P over conventional plots. Among different soil biological properties, the soil respiration was more by 17–27% in organic plots then in conventional, microbial biomass Carbon was 28–29% higher, microbial biomass nitrogen was 23–28% more and acid and alkaline phosphates were 5–13% higher in organic compared to conventional (Rupela *et al* 2005, 2006). In another similar study conducted under Network Project on Organic Farming of ICAR, (Gill and Kamta Prasad 2009) appreciable improvements in yield levels under organic system were noted in the initial years with yields attaining comparable outputs by 4th and 5th years. Improvements of different magnitudes were also recorded in respect of soil organic carbon, available-P, available-K, bulk density, and microbial count under organic systems as compared to chemical farming.

In another study by Ramesh *et al* (2010) it has been reported that the bulk density of soil is less in organic farms which indicates better soil aggregation and soil physical conditions. Improvement in soil organic matter decreased the bulk density by dilution of the denser fraction of the soil. There was a slight increase in soil pH and electrical conductivity in organic farms compared to conventional farms. On an average there was 29.7% increase in organic Carbon of soil in organic farms (1.22%) compared to the conventional farms (0.94%). Dehydrogenase, alkaline phosphatase and microbial biomass Carbon were higher in organic soils by 52.3%, 28.4% and 34.4% respectively compared to the conventional farms. In general, increase in microbial biomass Carbon in organic manure amended soils was due to increased availability of substrate-C that stimulates microbial growth, but a direct effect from microorganisms added through the compost is also possible. In organically managed soils, both macronutrients (N, P and K) and micronutrients (Zn, Cu, Fe, Mn) were available in larger quantities compared to the conventional soils. It is well documented that there is a significant positive correlation between organic matter and micronutrient cation availability and is best exploited under organic management strategies.

Epilogue

Organic farming as we see today is not the age old traditional agriculture, it is a science based intensive cropping system based on efficient management of resources, soil health, sun energy harvesting and judicious use of natural resources. Experiments world over has proved the productivity potential. Under irrigated and intensive cultivation conditions organic farming may be 5–12% less yielder but under rainfed, water stressed conditions and in marginal land areas it is 7–15% higher yielder. Besides productivity the present day organic farming system not only ensure safe and healthy food, but also promise sustained soil health, fertility and better profitability. As it is natural resource based system close to nature it also offers viable organic solutions for integration into conventional agriculture for better future and sustained growth of agriculture in the country.

As food security is not only a component of increased productivity and encompasses other issues of polices, trade, prices and environmental and resource use optimization, organic farming provides solution to all the issues. Organic farming in its modern version, equipped with local resources, strengthened with modern science and supported with mechanization is ready to take challenges in the field of environment preservation; resource optimization, comparable productivity and soil health build up. Besides, the adoption of organic farming in group and desire of the organic farmers to enter into direct trade as entrepreneurs is also contributing to social, physical and financial capital build up. All these put together indicates that if policies are made favorable and level playing field is ensured through comparable financial support, organic agriculture can play its role in furthering the cause of food security in the country.

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Current Status and Relevance of Organic Farming in Indian Agriculture

P Ramesh

The impact of Green Revolution on the global food grain production, especially on Indian agriculture was highly commendable. This happened mainly due to the introduction of high yielding varieties (HYV's), extension of irrigated area, use of high analysis fertilizers and increase in cropping intensity, which propelled India towards self-sufficiency in food production. In the process, relative contribution of organic manures as a source of plant nutrients *vis-a-vis* chemical fertilizers declined substantially (NAAS, 2005). With increase in cost of production inputs, inorganic fertilizers became increasingly more expensive. Another issue of great concern is the sustainability of soil productivity as land began to be intensively tilled to produce higher yields under multiple and intensive cropping systems. Water logging and secondary salinization have been banes associated with excess and irrational irrigation. Ground water table declined sharply as deeper bore wells were drilled. Recharging of ground water has also been reduced due to severe deforestation. Indiscriminate use of chemical pesticides to control various insect pests and diseases over the years has destroyed many naturally occurring effective biological control agents. An increase in resistance of insect pests to chemical pesticides has also been noticed. Health hazards associated with intensive modern agriculture such as pesticides residues in food products and ground water contamination are matter of concern. The occurrence of multi-nutrient deficiencies and overall decline in the productive capacity of the soil due to non-judicious fertilizer use has been widely reported. Such concerns and problems posed by modern-day agriculture gave birth to new concept in farming, such as organic farming (Ramesh *et al*, 2005).

Concept of organic farming: Organic farming is one among the broad spectrum of production methods that are supportive

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of the environment. Organic production systems are based on specific standards precisely formulated for food production and aim at achieving agro ecosystems, which are socially and ecologically sustainable. It is based on minimizing the use of external inputs through the use of on-farm resources efficiently compared to conventional agriculture. Thus the use of synthetic fertilizers and pesticides is avoided. The basic principles and aims of organic farming are as follows: 1) Organic farming is a holistic production management system, which promotes biodiversity and biological activity. It actually promotes and enhances ecosystem health, while at the same time producing food. It is based on the low use of external inputs and non–use of artificial fertilizers and pesticides. It also takes into account the fact that regional conditions require locally adapted systems; 2) Organic farming develops a system that ensures that all forms of life, from microbes to livestock, are conserved, productively utilized and are also treated with respect and concern, keeping in view their health, safety and natural behavioral needs; 3) Organic farming as far as possible employs farm inputs which can be reused or recycled, are generated on-site and which cause minimal pollution in the local external environment. It specially excludes all products and processes of genetic engineering and related technologies; 4) Organic farming produces food diversity that is free from toxins and of high nutritional value and good shelf life in adequate quantities and of a quality suitable for direct consumption and small scale processing; 5) Organic farming protects and promotes all forms of diversity, social, cultural (the biodiversity knowledge base inclusive of arts, crafts, music etc.) along with systems of organizational and political governance especially at local level.

According to Codex Alimentarius Commission (FAO, 1999), a joint body of FAO/WHO, ‘Organic agriculture is defined as a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-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.’

According to National Programme for Organic Production (NPOP) of Agricultural and Processed Products Export Development Authority (APEDA) of India (APEDA 2008), 'organic farming is defined as a system of farm design and management to create an eco system, which can achieve sustainable productivity without the use of artificial external inputs such as chemical fertilizers and pesticides'. Organic products are grown under a system of agriculture without the use of chemical fertilizers and pesticides with an environmentally and socially responsible approach. This is a method of farming that works at grass root level preserving the reproductive and regenerative capacity of the soil, good plant nutrition, and sound soil management, produces nutritious food rich in vitality which has resistance to diseases.

Current status of organic farming

World scenario: According to the latest FiBL–IFOAM (FiBL and IFOAM, 2013) survey on certified organic agriculture worldwide (2011–12), data on organic agriculture are available from 162 countries. There are 37.2 million hectares of organic agricultural land (including in-conversion areas). The regions with the largest areas of organic agricultural land are Oceania (12.2 million hectares, 33 percent of the world's organic agricultural land) and Europe (10.6 million hectares, 29 percent). Latin America has 6.9 million hectares (18.4 percent) followed by Asia (3.7 million hectares, 10 percent), North America (2.8 million hectares, 7.5 percent) and Africa (1.1 million hectares, 3 percent). The countries with the most organic agricultural land are Australia (12 million hectares), Argentina (3.8 million hectares), and the United States (1.9 million hectares). Currently 0.9 percent of the agricultural land of the countries covered by the survey is organic. By region, the highest shares of the total agricultural land are in Oceania (2.9 percent) and in Europe (2.2 percent). In the European Union, 5.4 percent of the farmland is organic. However, some countries reach far higher shares: Falkland Islands: 35.9 percent; Liechtenstein: 27.3 percent; Austria 19.7 percent. In ten countries, more than ten percent of the agricultural land is organic. There were 1.8 million producers in 2011. Thirty four percent of the world's organic producers are in Asia, followed by Africa (30 percent), and Europe (16 percent). The countries with the most producers are India (5,47,591), Uganda (1,88,625 in 2010), and Mexico (1,69,570).

In spite of the slowdown in the global economy, international sales of organic products continue to rise. *Organic Monitor* estimates organic food and drink sales reached almost 63 billion US dollars in 2011. The market has expanded by 170 percent since 2002. Demand for organic products is mainly in North America and Europe; these two regions comprise more than 90 percent of sales. Although organic farming is now practiced in every continent, demand is concentrated in these regions. Production of organic foods in other regions, especially Asia, Latin America and Africa is mainly export-geared. The organic food sector in some countries is almost entirely dependent on exports. In 2011, the countries with the largest organic markets were the United States, Germany, and France. The largest single market was the United States. The highest per capita consumption was in Switzerland, Denmark, and Luxemburg. The highest market shares were reached in Denmark, Switzerland and Austria.

Indian scenario: Currently, India ranks 33rd in terms of total land under organic cultivation and 88th position for agriculture land under organic crops to total farming area. The cultivated land under certification is around 4.43 million hectares (2010–11) (APEDA, 2012). The Government of India has implemented the National Programme for Organic Production (NPOP). The national programme involves the accreditation programme for certification bodies, norms for organic production, promotion of organic farming etc. The NPOP standards for production and accreditation system have been recognized by European Commission and Switzerland as equivalent to their country standards. Similarly, USDA has recognized NPOP conformity assessment procedures of accreditation as equivalent to that of US. With these recognitions, Indian organic products duly certified by the accredited certification bodies of India are accepted by the importing countries. India produced around 3.88 million tonnes of certified organic products which includes all varieties of food products namely Basmati rice, Pulses, Honey, Tea, Spices, Coffee, Oil Seeds, Fruits, Processed food, Cereals, Herbal medicines and their value added products. The production is not limited to the edible sector but also produces organic cotton fiber, garments, cosmetics, functional food products, body care products, etc.

India exported 86 items last year (2010–11) with the total volume of 69837 MT. The export realization was around 157.22 million US $ registering a 33% growth over the previous year. Organic products are mainly exported to EU, US, Australia, Canada, Japan, Switzerland, South Africa and Middle East. Oil Crops (except Sesame) leads among the products exported (17966 MT). The commodity-wise export from India is presented in Table 1.

Table 1. Commodity-wise Export from India (APEDA, 2013)

Product Category	Export Volume (million tonnes)	Percent Share
Oil Crops (except Sesame)	17966	25.73
Cotton and Textiles	17363	24.86
Processed Food	8752	12.53
Basmati Rice	5243	7.51
Tea	2928	4.19
Sesame	2409	3.45
Honey	2409	3.45
Rice	1634	2.34
Dry Fruits	1472	2.11
Cereals	1348	1.93
Spices and Condiments	1174	1.68
Medicinal and Herbal Plants/Products	627	0.90
Coffee	320	0.46
Vegetables	167	0.24
Aromatic Oils	39	0.06

Relevance of organic farming in Indian agriculture

Production and Productivity: Conversion to organic farming affects the crop productivity, and the yields depend upon the farming situation: 1) In intensive farming systems, organic agriculture decreases yield, the range depends on the intensity of external input use before conversion (Stanhill, 1990); 2) In the green revolution areas (irrigated lands), conversion to organic farming usually leads to almost identical yields (Rajendran *et al*, 2000); 3) In traditional rain-fed agriculture (with low external inputs), organic farming has shown the potential to increase yields (Huang, 1993).

In general, the productivity of crops in organic farming is lower compared to the conventional chemical farming. This raises the issue whether India can afford to adopt organic farming? However, field experiments conducted in the last few years on the productivity of crops in organic farming (Ramesh *et al,* 2006; Ramesh *et al,* 2007; Ramesh *et al,* 2008; Ramesh *et al,* 2008; Ramesh *et al,* 2009; Ramesh *et al,* 2009) and the data obtained from the survey of certified organic farms in India may give certain answers in this direction. The results of the long-term experiments at Bhopal, Madhya Pradesh (Ramesh *et al*, 2009) revealed that the productivity of soybean under organic manuring is lower (7.8 and 5.3% less) in the initial two years (2004 and 2005) compared to chemical fertilizers, but in the subsequent years (2006 and 2007), the productivity was improved by 10.6 and 11.1%. Similar results were also reported with reference to the productivity of crops such as wheat, mustard, chickpea and isabgol. It is also reported that a suitable combination of organic manures as nutrient source is better for sustaining crop productivity under organic nutrition compared to chemical fertilizer application (Ramesh *et al,* 2009).

Soil quality and fertility: Long-term application of organic manures for the production of crops in organic farming is known to improve the soil quality and fertility. Experiments conducted at Bhopal, Madhya Pradesh revealed that organic manures application significantly improved the soil physical, chemical and biological parameter compared to the chemical fertilizer application in different cropping systems (Ramesh *et al,* 2006; Ramesh *et al*, 2008; Ramesh *et al*,2008; Ramesh *et al,* 2009; Ramesh *et al*, 2010; Ramesh *et al*, 2009; Panwar *et al*, 2010). In a survey conducted on certified organic farms in India (Ramesh *et al*, 2010) showed that, on an average there was 29.7% increase in organic Carbon of soils in organic farms (1.22%) compared to the conventional farms (0.94%), which is a good indicator of soil quality as it works as a sink for all nutrients and known for improving all soil physical and biological properties of soil. Soil quality indicative enzymes like dehydrogenase, alkaline phosphatase and microbial biomass Carbon were higher in organic soils by 52.3, 28.4 and 34.4% respectively compared to conventional farms.

Crop/Food quality: There is a growing demand for organic food driven primarily by the consumer's perception of the quality and safety of these foods and to the positive environmental impact of organic agricultural practices. The 'organic' label is not a health claim, it is a process claim. It has been demonstrated that organically produced foods have lower levels of pesticides and veterinary drug residues and in many cases lower nitrate contents (Woese *et al*, 1997). No clear trend have, however, been established in terms of organoleptic quality differences between organically and conventionally grown foods.

Economics of organic farming: Studies have shown that the common organic agricultural combination of lower input costs and favorable price premiums can offset reduced yields and make organic farms equally and often more profitable than the conventional farms (Hansen *et al* , 1997). Studies that did not include organic price premiums have mixed results on profitability (Welsh, 1999). A survey on the certified organic farms in India showed that on an average, there was a reduction in the cost of cultivation by 11.7% compared to conventional farming. However, due to the availability of premium price (20–40%) for organic produce in most cases, the average net profit was 22% higher in organic compared to the conventional farming (Ramesh *et al*, 2010).

SWOT analysis of organic farming in India: The SWOT analysis of organic farming (Table 2) (Kumara *et al*, 2010; Sikka *et al*, n.d.) which reveals that the global competitiveness for organic food exports from India is marked with number of weaknesses, whereas lot of opportunities does exist in the domestic and international market. The major threats are from that of global warming and competition for which area-specific varieties are to be developed. Government and other institutions should come forward to overcome the weaknesses such as infrastructure, market linkages, information, capacity building etc.

Scope and future prospects of organic farming in India: India's long tradition of ecological agriculture, in many different forms has been rooted in farmer's approaches. It is for this reason that the farmers and the private enterprises took the lead in understanding the competitive advantages of organic agriculture. World over, organic farming is rated among the sunrise industries. Where unlocking the nature's capital is the aim, organic serves the best tool for that. It is only later that when

Table 2. SWOT analysis of organic farming prospects in India

Strengths
• Wide variety of fruits and vegetables and other commodities can be grown organically.
• Very less consumption of chemicals in India as compared to developed nations. These areas can be turned into organic.
• Organic pockets existing in different parts of the country.
• Differentiation can be easily created
• Farmers as well as Government interests are rising in organic
• Various niches in fruits and vegetables can be created
• Indian corporate investing in agribusiness especially in organic farming
	Weaknesses
	• Short shelf life varieties
	• Lack of farmer awareness about agricultural practices, products and technologies for organic farming
	• Quality not competitive in the domestic and international market
	  • Price competitiveness
	  • Lack of market information and intelligence
	• Global marketing research lacking
	• Inadequate post harvest management and related specialized infrastructure to support organic food production
	• R and D base in organic food production lacking
	• Unavailability of inputs used in system
	• Certification and labeling
	• No access to international market

Opportunities • Favorable government vision • WTO offering global opportunities • Price -premiums in different markets • Export opportunities in new product/market(section) • USA, Europe and Japan are rising markets • Branding offers new opportunities for differentiation • Rising demand for organic products • Big retail stores/chains opening up • New developments in post harvest technologiesNew products and technologies ushering in Private sector keen to join organic chain value chain.	**Threats** • Competition from domestic industry • Threat from imported products • Non-tariff barriers may be imposed by developed nations. • High cost of organic food. • Costly and complex organic certification process • Most of the fields are contiguous and problem of contamination. • Lack of infrastructure facilities and certification bodies. • Low awareness about organic inputs.

the potential benefits of organic agriculture are becoming clearer, one for positioning Indian agricultural exports with advantage and two for bringing benefits to small and marginal farmers, that the government agencies are participating more actively. Indications of this trend are seen in several state level initiatives about promotion of organic agriculture (Export-Import Bank of India, 2003).

The elements of a successful strategy for India will need to include a two pronged approach:

i. **To increase the efficiency and sustainability of production**: Organic farming can help to reduce production costs (especially where labor is cheap compared to input costs) and to increase or stabilize yields on marginal areas and small farming communities. This is especially relevant for small holders in marginal areas where Green Revolution agriculture has lead to a depletion of soil fertility and to high debts because of increase in input costs. It can focus on food security and health and environmental benefits that are intrinsic to the organic systems.

ii. **To increase product value**: In areas where farmers have access to established organic markets within the country or abroad, products can achieve a higher price compared to the conventional market. Especially in the trend of decreasing prices for agricultural products, this can be an important way to stabilize or even increase incomes. In order to boost trade in Indian agricultural products and capture a significant share of market, it is an imperative that India becomes home to such organic products which give it a competitive edge in global market, namely organic cotton, spices, essential oils and medicinal plants, fresh fruits and vegetables.

What is seen in India presently are two kinds of strong undercurrents of organic farming; from limited to rapidly increasing certified organic farms, mainly producing for a premium price in the domestic or export market, and the large number of those non-certified organic farms which produce for their own households accessing local markets only, if there is surplus. In India, the Government is promoting organic farming which can be a profitable strategy to raise the income level of small and medium farmers. Some of its states such as Sikkim have already declared themselves as completely organic. There are many areas where the production is by default organic. Uttaranchal is one such state, where in hilly areas, negligible amount of chemicals is used. The farmers are also turning to organic production because of the high premium commanded by organic products. Some of the organic manufacturers associations have also emerged in the country. Realizing the potential existing in organic farming, corporates are also ready to invest in this area. The domestic market for organic food is yet to develop as most of the Indian population belongs to the lower middle class stratum of society, hence cannot afford the high-priced organic products. The only option left for organic food industry is to target elite domestic customers and large export markets.

India, being an agriculturally dominated country, has a vast scope in exports of raw and processed organic food. It has already established itself as a major agricultural exporter. These include cereals, fruits and vegetables, spices, herbs, tea etc. There is very less use of chemicals for farming in India as compared to the developed nations. The pesticide use is even less in case of the food items which is imported. Most of the pesticides are used on cotton. There are few pockets in the country where no chemicals are used and traditional farming is practiced. The produce from developing countries including India is preferred among the global communities for containing fewer chemicals. So the country has opportunities in exporting the items such as tea, fruits, vegetables, spices, coffee, etc., the processed organic forms of these commodities can also be made available in the global markets.

India can take advantage of the growing opportunities in the organic farming, making use of its varied agro-climatic conditions and traditional organic resources and farming practices. There are certain challenges to be met before India takes on to the world organic markets. The Indian produce has to create a competitive niche in global markets. The challenges in international marketing of organic food are standardization of products according to the customers' tastes and preferences, certification, consumer education, branding and promotion.

Production of organic products also face challenges with regard to availability of right and quality inputs, research and dissemination of appropriate technologies, processing, certification, production information and infrastructure support and also policies of the government need to be revisited to fulfill its objectives to tap global organic markets.

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Policies, Programs and Institutional Initiatives on Organic Farming in India

K Ramakrishnappa

In India health and environmental hazards arising out of modern agriculture production systems have led to a growing interest in alternate farming practices that avoid the use of synthetic fertilizers and pesticides, minimize air, soil and water pollution and optimize crop biodiversity. Consequently, organic farming as a means to increase sustainability in agriculture by maintaining farm diversity and simultaneously enhancing income opportunities for small and marginal producers has made credible advancements during the past decade with the combined efforts of farmers, NGOs, Governmental interventions and market forces.

The Government of India has initiated a number of steps to promote organic farming and regulate production and marketing of organic produce in the country. In March 2000, under National Program for Organic Production (NPOP), the country has launched the National Organic Logo 'India Organic' and announced the NSOP standards comprising the details of growing crops and the permissible use of natural minerals and biological pest and disease control measures under organic farming. The Central Government through APEDA has also prepared and approved criteria and procedures to accredit agencies for organic certification, announced inspection and certification procedures and short listed agencies for certification. Presently, 24 accredited certification agencies are looking after the requirement of certification process and the products certified by them are accepted in many countries including European Union and USA. The Director General of Foreign Trade has laid down rules and regulations for export of organic products from India. To look after promotional and capacity building activities, a National Project on Organic Farming (NPOF) was launched under Ministry of Agriculture during 2004, which

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is being operated by one National Centre of Organic Farming (NCOF) at Ghaziabad and six Regional Centres (RCOFs) located at Bangalore, Nagpur, Jabalpur, Panchkula, Bhubaneswar and Imphal. To address domestic certification issues, requirements of NPOP were notified under Agriculure Grading and Marking Rules and a new logo 'Agmark India Organic' was launched exclusively for domestic market. Recently Minitsry of Agriculture has also launched a farmer group centric certification system under PGS-India programme.

Karnataka state policy on organic farming: The Government of Karnataka, realising the importance of organic agriculture as early as in 2003 has set up a Mini Mission on organic farming with a mandate to study the existing agriculture situation and to recommend strategies for sustainable farming. The Mission after a series of meetings, visits and consultations, has submitted the report on the status of agriculture in Karnataka. The highlights of the paper indicates that like in other states of India, agriculture productivity in Karnataka is stagnated on account of heavy soil erosion, loss of soil fertility, salinisation of soils, declining ground water and genetic erosion of indigenous species. The other important observations of the mission include: a) high cost of production (b) young members of the farming families quitting agriculture in favour of petty jobs at urban locations (c) agro-chemicals reaching the soil and aquifer and threatening the very survival of useful micro flora (d) high levels of pesticide residues in food and water, threatening human and animal health and (e) high risk of nutrition, quality and safety of food.

The Mini Mission with the above observations has recommended to quickly overcome the knowledge gap in the existing agriculture production system and proposed to promote organic farming as a potential means to enhance agriculture production and to protect deteriorating agro-eco system. The Government of Karnataka has constituted a high level committee under the Chairmanship of the Development Commissioner cum Agriculture Production Commissioner to examine the proposal and on the recommendations of this committee, the Government announced the Karnataka State Policy on Organic Farming in March 2004.

Salient features of the policy: (i) Promoting organic agriculture as a sustainable, safe and healthy method of farming independent of special price advantages; (ii) The approach adopted in promotion of organic farming shall be farmer centered and the programs shall create conditions for conversion and efficient use of locally available resources; (iii) Central and State Governments to provide interventions to instill confidence in the minds of farmers during conversion and learning phase; (iv) Resolving often extreme distress in rural farming communities resulting from high input cost, low returns, increased debt etc.; (v) Developing land and crop management to compensate for more adverse and more variable weather conditions; (vi) Introduce participatory approaches in promotion of organic farming by involving all stakeholders at all decision making levels, facilitated largely by the Government.

Strategies: a) Integration of all land based activities like Agriculture, Horticulture, Animal Husbandry, Sericulture, Apiculture, Aquaculture, Forestry and other land use activities in policy making and at implementation levels; b) Reliance on locally available, affordable and environment friendly inputs to be produced on farm; c) Promoting self reliance through inclusion of local seeds, manures and indigenous practices for plant protection; d) Encouraging mixed farming aimed at household food security while conserving biodiversity and local cultural values; e) Preparing farmers for competitive marketing through value addition, e.g. through partial processing, development of specialty products, good presentation and maintaining quality and safety; f) Creating consumer awareness about respectful natural farming and safe food; g) Empowering people by establishing organizational structures like Farmers Associations, PCs etc. and provide institutional support.

Specific activities: a) Production of green manure seeds in sufficient quantities to be used by every holding and promotion of multi-purpose tree species on farms; b) Creation of infrastructures to facilitate grading, processing, packing and marketing of organic produce locally with transparent pricing and benefit distribution; c) Documentation of existing sustainable organic farming practices and to develop packages of practices by involving Research Organisations/Government Departments/

NGOs; d) Creating awareness in the use of organic produce among consumers, large scale production by small producers of truthful organic produce certified by local agencies/ NGOs /Farmers Associations need to be encouraged; e) Creation of infrastructure for testing organic inputs and outputs (products) with effective and economic methods, test centers and sampling mobile labs; f) Supporting organic food processing industries and encourage good farmer-buyer relationships; g) Creating new market opportunities in export markets through development of value added organic products.

Interventions under National Horticulture Mission: The Government of India in the year 2005–06 has initiated National Horticulture Mission, a centrally assisted scheme to provide holistic approach for development of Horticulture in the country and organic farming has been given a major thrust under the program. The focused activities under NHM include: a) Creating awareness on the ill effects of intensive farming and to disseminate knowledge on eco-friendly organic farming by organising awareness and training programs in association with local organic farmers group; b) Facilitating farmers to produce required inputs on farm by providing financial support for creation of low cost infrastructures for production of inputs like Vermicompost, Jeevamruth, Digester extract etc; c) Supporting farmers in the initial stages of conversion from chemical/ traditional into organic; d) Encouraging farmers/ Farmers groups in collection, grading, value addition and marketing of organic products; e) Facilitating farmers groups involved in promotion of organic farming to adopt Internal Control System (ICS) and Participatory Guarantee System in organic production system to bring in transparency, traceability and accountability; f) Organising Trade shows and exhibitions in collaboration with organic farmers associations, to establish linkages between consumers and producers for marketing of organic products in domestic and export markets; g) Encouraging Farmers and farmer's organizations involved in scientific validation of local practices for the benefit of organic community.

Institutional support for organic farming in Karnataka

Organic village program: As per the recommendations of the state policy on organic farming, organic village programs were initiated in all the districts of Karnataka since 2004–05.

One of the main components of this program was to convert 100 hectares of contiguous area into a model organic site on a holistic approach involving all land based developmental sectors like Agriculture, Horticulture, Watershed Development, Animal husbandry, Sericulture, Forest, besides Universities of Agricultural Sciences. This program since its inception was helpful in conversion of more than 1lakh hectares into organic agriculture in the state.

Biocentre as a resource organization: Biocentre, a certified organic centre, under the Department of Horticulture in Karnataka has been serving as a knowledge centre in promotion of organic farming in Karnataka. The centre organizes regular training and capacity building programs to farmers, extension personnel and policy makers, validate scientifically the local practices, conduct demonstrations on production and utilization of organic inputs on farm and provide analytical services to organic farmers for their inputs and outputs. The Biocentre is the largest producer and distributor of certified organic seed and planting material, and involved in conservation and development of local/traditional varieties of vegetables, medicinal and aromatic plants and heritage horticulture crops of Karnataka. Some of the important activities of the biocenter towards holistic and sustainable agriculture are:

a) Conservation, development and GI registration of heritage crops: One of the priority programs of Biocentre is to conserve and develop Karnataka's rich horticultural diversities through identification, characterization, documentation and registration of Geographical Indications of the genetic resources under fruits, vegetables, plantation, spices, medicinal and aromatic and flower crops. Nanjangud Rasabale, Mysore betel vine, Coorg orange, Mysore Jasmine, Udupi jasmine, Hadagali mallige are the earlier crops brought under GI Registry in Karnataka. Later on Kamalapur red banana, Devanahally pummelo, Bangalore rose onion, Sagar appe midi and Udupi Mattugulla have been given Tag.

b) Organic seed and planting material: The pace of progress in organic farming largely depends upon the pace with which good quality seed and planting material of superior varieties are multiplied and made available to farmers. In this context, organic seed and planting material of local/traditional varieties would play a major role in reducing the cost of production and improving the income of the farmers. The Bio center has been organizing training and capacity building programs to farmers and technicians on seed production techniques of open pollinated vegetable varieties. To create farmers interest, demonstration plots of screened varieties are being established at the centre by following different crop combinations, raised bed cultivation, in situ green manure production and pest and disease management

c) Bio-digester – an innovation for organic farming: Bio-centre has taken up scientific validation of farmer traditional practices and developed different models for sustainable cultivation of horticulture crops. Bio-digester is one such innovation of the Biocenter wherein the traditional knowledge on preparation of manure in pits has been validated scientifically by seeking interactive ideas from Grape farmers of Athani, Belgaum District of Karnataka.

Jaivik Krishik Society: Jaivik Krishik Society (JKS) is a federation of organic farmers' and organic farmers groups established in 2003 under Karnataka Society's Registration Act of 1960. It was established mainly to cater to the needs of organic farmers in providing interventions for production, quality control, group certification and creation of market infrastructure through promotion of socio-economic, ecological values and fair trade practices in agriculture production system. The Society extends services for establishment of organic farmers associations /groups and to enroll them as its members. It also provides services in setting up of Internal Control System (ICS) and Participatory Guarantee System through local associations and creates model organic outlets at consumer points. While the farmers have benefited from the trainings, certification support, processing and value addition support in addition to marketing support lent by JKS, even for many Karnataka consumers, JKS has been the main medium for awareness-creation on the benefits of organic produce, through the many melas and fairs it has organized and the media outreach it undertook.

Organic farming is a knowledge and labour intensive agriculture production system rather than capital intensive.

Organic farming has the potential to produce sufficient food of a high quality at a low cost on a sustainable basis. Therefore, organic agriculture is particularly well suited for rural communities that are facing the problems of low income and high production cost and breakdown in the sustainable food supply chains. However, the future of organic farming lies in meeting the challenges such as maintaining the social structure of the organic farmer groups, developing sites specific business models, creating required infrastructures for processing, handling, marketing, quality control and regulation of organic products. The establishment of Farmers Producers Company could play a key role in making organic farming a socially accepted and economically viable agriculture production system.

Organic Livestock Production in India: Why, How and Road Ahead

Mahesh Chander

With growing literacy, education, awareness coupled with rising incomes, consumers are becoming more quality conscious. Moreover, the food scares like food borne diseases are alerting people of harmful consequences of consuming food laced with chemicals and harmful residues of pesticides and antibiotics. Many chronic diseases which are on the rise are being attributed to life style including food habits, making the sustainability of chemical based farming and intensive livestock production questionable. As an alternative, therefore, organic agriculture is rapidly growing around the world (37.2 Million ha in 162 countries) with 1.8 million producers including significant number of organic farmers in developing countries like India. Considering the growing export demand alongside potential environmental benefits of organic production and its compatibility with integrated agricultural approaches to rural development, organic agriculture is being considered as a development vehicle for developing countries like India (Ramesh *et al*, 2005).

While organic farming is rapidly gaining ground in developing countries the research and development (R&D) activities in organic animal husbandry is confined only to EU and a few other developed countries in North and Australia. There are opportunities as well as challenges in organic livestock production which need to be addressed. It is important here to understand, why organic livestock production is relevant for India, how it can be done sustainably and what are its implications for livestock economy of India? This paper attempts to analyse an Indian perspective to organic livestock production, why it is important and how sustainability in livestock production can be achieved through organic principles and practices. The organic livestock development opportunities in India can be enhanced

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while harnessing natural advantages with more scientific research in organic livestock production under local conditions.

Livestock production: the global challenge: The food systems encompass activities related to the production, processing, distribution, preparation and consumption of food; and the outcomes of these activities contributing to food security. The interactions between and within bio-geo-physical and human environments influence both the activities and the outcomes (Figure 1). It is projected that by 2050, the global demand for animal food products can be met only by raising twice as many poultry, 78% more small ruminants, 58% more cattle and 37% more pigs, without further damaging natural resources (Rivera and Lopez, 2012). Hence, sustainable development based on balance of ecology, economics, norms and values are to be considered at various levels of the scale: between food and farming systems, regions, nations and continents (Zipp, 2003).

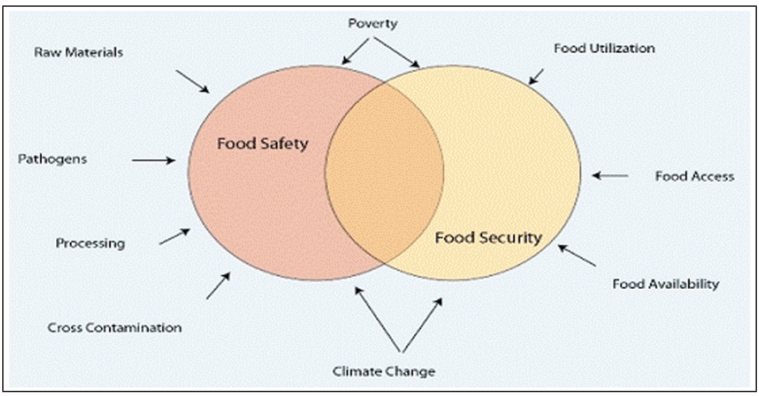

Figure 1: Interrelationship of food safety and food security (Hanning *et al.*, 2012).

This is where the real challenge lies: producing more food of good quality without further damaging or stressing the environment. For instance, FAO's (2006) report 'Livestock's Long Shadow' concluded that directly and indirectly, 18 per cent of the global Greenhouse Gas (GHG) emissions could be linked to animal-based production. Not only GHG but also there are several factors which are making intensive livestock production questionable from sustainability standpoint. To deal with this complex issue of livestock in relation to sustainability vis a vis climate change and food security issues, some of the options being studied and tried at different levels to reorient the existing farming systems as per the principles and practices of Conservation Agriculture, Climate-smart agriculture, Sustainable Agriculture, Precision Livestock Farming and Organic Livestock Farming.

Conservation agriculture: Conservation agriculture is an approach to manage agro-ecosystem for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It is characterized by three linked principles viz. Continuous minimum mechanical soil disturbance, permanent organic soil cover and diversification of crop species grown in sequence or associations (FAO, 2012). Mechanized soil tillage allows higher working depths and speeds and involves the use of such implements as tractor-drawn ploughs, disk harrows and rotary cultivators. This initially increases fertility because it mineralizes soil nutrients and makes it easier for plants to absorb them through their roots. In the long term, however, repeated ploughing and mechanical cultivation breaks down the soil structure and leads to reduced soil organic matter and loss of soil nutrients. This structural degradation of soil results in compaction and the formation of crusts, leading to soil erosion. Farming systems that successfully integrate crop and livestock enterprises stand to gain many benefits that can have a direct impact on whole farm production. Ruminant animals are especially desirable due to their ability to convert forages, browse and crop residues high in cellulose to useful food and fibre products. Such animals provide for: system diversification; recycling of nutrients; soil enhancing rotation crops; power and transportation; and act as biological 'savings accounts" for farmers during periods of stress.

Climate-smart agriculture: Climate-smart agriculture seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing Carbon storage on farmland. The climate-smart agriculture includes proven practical techniques in many areas, especially in water management but also innovative practices such as better weather forecasting, early warning systems, and risk insurance. It is about getting existing technologies into the hands of farmers and developing new technologies such as drought or flood tolerant crops to meet the demands of a changing climate. Achieving Climate-Smart agriculture needs an integrated approach, tackling productivity and food security, risk and resilience, and low Carbon growth together, but integration and institutional coordination remains a challenge in many countries (World Bank, 2011).

Sustainable agriculture: There is a need for 'rapid and significant shift from industrial monocultures and factory farming towards mosaics of sustainable production systems that are based on the integration of location-specific organic resource inputs; natural biological processes to enhance soil fertility; improved water-use efficiency; increased crop and livestock diversity that is well adapted to local conditions and integrated livestock and crop farming systems' (IAASTD, 2009). Producing more crops from less land is the single most significant means of jointly achieving mitigation and food production in agriculture, assuming that the resulting 'spared land' sequesters more Carbon or emits fewer GHGs than farm land (Robertson *et al*, 2000). This 'land sparing' effect of intensification is uneven in practice and requires policies and price incentives to strengthen its impacts (Angelsen and Kaimowitz, 2001). More efficient use of inputs, more sustainable alternatives and breeding for efficiency will be required to reduce the Carbon intensity (emissions per unit yield) of products, as well as reduce land areas and inputs that damage environmental health (Tillman *et al*, 2002).

Precision livestock farming: Spilke and Fahr (2003) stated that Precision Farming aims for an ecologically and economically sustainable production with secured quality, as well as a high degree of consumer and animal protection with specific emphasis on technologies for individual animal monitoring. Precision farming is based on information technology, which enables the producer to collect information and data for better decision making. This concept is considered by some as the future of agriculture and allied sectors. This concept is also called as spatially prescriptive farming; computer aided farming; farming by satellite; high-tech sustainable agriculture; soil-specific crop management; site-specific farming; and precision farming. The main objectives of precision farming are maximizing individual animal potential, early detection of disease, and minimizing the use of medication through preventive health measures. Although, vast research has been conducted on precision agriculture, but livestock sector has negligible studies on precision farming. International studies have also shown slow adoption rates of precision farming (Batte and Arnholt, 2003) due to small farm size, farmer age, education level, computer illiteracy etc. The advantages posed by the technology are often not immediately apparent and they require more management expertise along with an investment of time and money to realize (Bell, 2002).

Organic livestock farming: Organic animal husbandry has been defined as a system of livestock production that promotes the use of organic and biodegradable inputs from the ecosystem deliberately avoiding the use of synthetic inputs such as drugs, feed additives and genetically engineered breeding inputs, while ensuring the welfare of animals (Chander *et al*, 2011; Chander *et al*, 2013; Chander and Subrahmanyeswari, 2013). There are four principles of organic farming viz; principle of ecology, principle of health, principle of fairness, and principle of care, which organic systems must always take into consideration. In order to achieve the animal welfare, environmental protection, resource-use sustainability and other objectives, certain key principles are adhered to under organic livestock production systems. Subrahamanyeswari and Chander (2008) found that majority of the livestock production practices of the farmers in Uttarakhand were in line with what the organic standards recommend, and thus, are compatible to organic systems. Since, majority of the animal husbandry practices followed by the farmers were favourable to or closer to the recommended organic livestock production standards which is a clear indication of becoming organically certified by effective interventions. In this context, public and private organizations have a major role to make livestock farmers more compatible with the organic standards and also act as an effective solution for the changing climatic conditions.

According to the International Federation of Organic Agriculture Movements (IFOAM), the organic animal husbandry has multiple objectives, which are: 1) To raise animals in a system that takes into consideration the wider issues of environmental pollution, human health on consumption of animal products allowing them to meet their basic behavioral needs and reduce stress. 2) Diversify in keeping as many types of livestock on the holding as each furnishes different nutrients at the household level. For example, special attention should be given to rabbits and poultry as income generated from this enterprise goes directly to the disadvantaged segments of the population e.g. women and children. Their nitrogen rich manure is used to increase vegetable production in the kitchen gardens, thus, improving the family diet. Others like donkeys are useful in transport thus, reducing the consumption of non-renewable sources of energy e.g. petroleum based fossil fuels. 3) Exploit the natural behavior of animals in their production systems to reduce stress e.g. chicken like perching at night and perching rails should be provided for this purpose. They should also be raised in deep litter system that allows them to scratch for ants and worms and dust bathe. Dark secluded nest should be provided as they like lying in dark secluded places. Goats being browsers in nature like having their forage suspended high enough so that they can attain an upright posture. Pigs have rooting tendency, for which water and mud facilitate their natural rooting behavior. 4) Use of low external input which lessen the cost of production and allow for a sustainable system of production since most materials can be recycled in the farm and also locally available. 5) Bridging of nutrients gap in soil, crops and animals i.e. animals feed on crops and cultivated crops by-products. The animals' waste in the form of farmyard manure is composted and taken back to the soil to replenish the lost soil nutrients through cultivation. This ensures the completion of nutrient cycle in the ecosystem.

In order to achieve the animal welfare, environmental protection, resource-use sustainability and other objectives, certain key principles are adhered to under organic livestock production systems, which include management of livestock as land-based systems so that stock numbers are related to the carrying capacity of the land and not inflated by reliance on 'purchased' hectares from outside the farm system, thus, avoiding the potential for nutrient concentration, excess manure production and pollution. As such, landless animal husbandry prevalent in India is not ideally suitable for organic livestock farming; unless, the landless livestock keepers go for land leasing; reliance on on-farm or locally-derived renewable resources, such as biologically-fixed atmospheric nitrogen and home-grown livestock feeds, thereby reducing the need for non-renewable resources as direct inputs or for transport; reliance on feed sources produced organically, which are suited to the animal's evolutionary adaptations (including restrictions on use of animal proteins) and which minimize competition for food suitable for human consumption; maintenance of health through preventive management and good husbandry in preference to preventive treatment, thereby reducing the potential for the development of resistance to therapeutic medicines as well as contamination of workers, food products and the environment; use of housing systems which allow natural behaviour patterns to be followed and which give high priority to animal welfare considerations, with the emphasis on free-range systems for poultry; use of breeds and rearing systems suited to the production systems employed, in terms of disease resistance, productivity, hardiness, and suitability for ranging.

Animal health and well-being through better living conditions, improved welfare measures and good feeding practices are ensured through a set of standards and the maintenance of written records by organic livestock farmers. Better management practices and prevention of illness are emphasized over treatment. Thus, the primary characteristics of organic livestock production systems are: well-defined standards and practices which can be verified, greater attention to animal welfare, no routine use of growth promoters, animal offal, prophylactic antibiotics or any other additives, at least 80% of the animal feed grown according to organic standards, without the use of artificial fertilisers or pesticides on crops or grass. Against the background given above, we have to analyse strength, weakness, opportunities and threats, pertaining to organic livestock production in India, so as to understand its relevance for Indian farmers, consumers and economy on the whole.

Strengths: Integrated crop-livestock farming system predominant in India with well diversified livestock population in terms of species and breeds is ideal for organic livestock production. Besides, limited external input use including for animal production and maximum on-farm reliance brings it further closer to organic systems. The livestock production being largely extensive or semi-intensive, animal welfare too is not much compromised compared to factory type of animal production common in Western developed nations. The Indigenous Technical Knowledge (ITK) and ayurvedic medicines for health care are effective substitute for allopathic medicines, giving India an edge over western countries in the matters of organic livestock production. The concerned agencies under Government of India are actively pursuing the development of Indian National standards for organic livestock and poultry production, to bring it under regulation – a welcome move which might boost organic livestock production.

Weaknesses: Feed and fodder: The inadequate supply of required organic feed and fodder may be a limiting factor while promoting organic livestock farming, since under organic livestock systems, animals are expected to be fed species specific organic diet in sufficient quantities. Besides, the feed and fodder requirement has to be met on farm or locally and it has to be grown following organic crop production methods. The fodder cultivation area in India has remained more or less static for many years and it is concentrated mostly in irrigated areas or so called green revolution belt of the country. Looking at the deficit in green and dry fodder in country, massive efforts are needed to ensure feed and fodder to livestock in required quantity, while considering organic animal husbandry.

Sanitary conditions: Prevention of diseases is paramount in organic systems, so that the medicine interventions like antibiotics etc are minimized to the extent possible. To minimize diseases, sanitation is important, for which the efforts are needed on massive scale to improve hygiene and sanitary conditions especially at production, processing and packaging stages. Looking at the prevailing conditions at production sites, processing units dealing with, India needs to do a lot so as to be eligible for organic livestock producing country.

Existence of diseases: Among others, the prevalence of Foot and Mouth Disease (FMD) in various parts of India is one limiting factor for export of livestock products, so its control is number one priority for India. The Disease Free Zones (DFZs) may be created, where; organic livestock production may be encouraged.

Traceability: Unlike in Western countries, milk and meat is sourced from numerous small farmers in India making the traceability a difficult option. Nevertheless, appreciably, Indian government has introduced a web-enabled application – Tracenet system for organic products being exported from India. Considering the logistic problems, small farms, farmers' educational levels, how far traceability mechanism will be feasible makes it a bit skeptical in case of animal products.

Table 1. Maximum number of animals per hectare (Draft Indian standards)

Species/Class	Maximum no. per hac.
Equines over six months old	2
Calves	5
Other bovine animals less than one year old	5
Male bovine animals from one to less than two years old	4
Female bovine animals from one to less than two years old	4
Male bovine animals two years old or over	2
Dairy Cows	2
Female breeding rabbits	100
Sheep	14
Goats	14
Piglets	74
Breeding Pigs	7
Pigs for fattening	14
Chicken	580
Laying Hens	230

Small farms: In India, livestock production is mainstay of landless and small scale farmers. However, the landless animal husbandry is not allowed under the organic systems, unless they go for land leasing to raise livestock. Contract farming may be a potential solution where many small farmers may contract out their farms to companies, which may produce organic food products on consolidated holdings with required expertise and resources. Here it would be pertinent to quote the number of animals which can be raised in 1 ha land, organic livestock production system as per the prescribed standards making it nearly impractical for Indian farmers. Even when farmers own land, the number of animals to be maintained per hectare are far too less (Table 1), considering 80% holdings in India are <1 ha and per farmer land ownership is going down due to division of land in the expanding families. This requirement is a serious limiting factor having potential to hinder the development of organic animal husbandry in India, unless it is properly negotiated at international level.

Lack of knowledge, training and certification facilities: Easily accessible information in local languages, locally available training and certification facilities at an affordable cost to small farmers is not available in many parts of the country, restricting Indian farmers to switch over to organic production especially when there is weak domestic market and current poor prospects for exports in case of livestock products.

Opportunities: It is expensive for intensive livestock producers to convert to organic production, but converting extensive, pasture-based systems could become economically more attractive, if price premiums could be captured for organic meat and livestock products (Scialabba and Hattam, 2002). India may follow experiences of developing countries like Argentina, Brazil and Namibia which could export organic livestock products. India exports certified organic honey, which may be extended initially to small ruminants, for organic textile/ garments including the materials like hides, leather and wool. The Indigenous Technical Knowledge (ITK) of farmers may provide effective option for veterinary care through proper validation, as also the negligible use of agro-chemicals especially in drylands and hilly regions, makes favourable environment for organic livestock production. Grass based extensive production systems prevalent in parts of India have good potential for conversion into organic animal husbandry. Moreover, Indian livestock breeds being less susceptible to diseases and stress, need less allopathic medicines/antibiotics. With rising literacy and the consumers' awareness and concern about animal welfare issues and health foods, domestic consumption of organic foods including of animal origin is likely to get a boost. The organic agricultural products including of livestock origin are gaining increasing popularity. The farmers can cash upon this growing interest in eco-friendly, animal welfare oriented, safe, nutritious and tastier meat products (as perceived by consumers of organic products). The eggs and meat obtained from such venture can be promoted as specialty item to restaurants; hotels and ethnic food jaunts fetching higher returns, better when local/*deshi* birds are raised, which can better perform in free range system. Poultry can utilize the grazing lands/plantation areas (Rubber, coffee, coconut etc) by feeding on earth worms, small insects, green grass etc, while fertilizing the land with manure.

The free range poultry systems or pastured poultry is a sustainable agriculture technique that calls for the raising of laying chickens, meat chickens (broilers), and/or turkeys on pasture, as opposed to indoor confinement, inhuman treatment, the perceived health benefits of pastured poultry, in addition to superior texture and flavor, are causing an increase in demand for such products, which are believed to be having medicinal value, rich in antioxidants and least in chemical, medicinal or hormonal residues. Therefore, the growing interest in organic farming and meat and eggs drawn from free range systems might offer an attractive option in the form of market premiums for livestock farmers to venture into organic production.

The growing consumer interest in good quality food products in India signals the need for developing domestic market for local consumption of organic foods. With rising literacy, income and awareness on food quality generated by the mass media like print, radio and TV, people are increasingly becoming quality conscious. Also, they are increasingly showing their willingness to pay for good quality products. For example, people readily pay extra money for unadulterated milk, which is not necessarily organic milk *per se.* This trend indicates that there is good potential for organic livestock products for local consumption. The enterprising farmers are now ready to experiment on new ideas on production and marketing, wherein organic livestock products like milk, meat, poultry and fish ideally fit. Just like marketing of FMCG and other industrial products market segmentation can be done by the farmers by supplying products to different categories of consumers with varying prices. The growing interest in eating out especially by visiting ethnic food jaunts, looking out for something unique, local and something which is natural and healthy while being environmentally safe offers hope for the production and supply of organic livestock products for domestic consumers. The domestic market development is the key for the development of organic animal husbandry and poultry farming in India. The growing market for organic cereals, vegetables, fruits, spices, pulses in Indian metros can be successfully extended to organic livestock and poultry products too.

Educating consumer and producer both is important to promote organic livestock production. Consumers need to be told that the safe milk and meat that they are looking for is the certified organic milk and meat, while farmers need to be made aware of this demand to be able for them to translate it into the new market opportunity! Also, there is a small but very concerned section of the society who does not consume livestock products owing to issues of animal cruelty, ill-treatment with them etc. The organic rearing of the farm animals sincerely addresses these issues and the certifiers approve that the due care has been taken in the process of production. These standards ensure that animals are kept free or never tied without specific purpose, allowed to express their physiological behaviour, fed with chemical free fodder, are not given hormonal injections and are reared in a completely stress free atmosphere. The information gap with respect to organic animal husbandry at the level of producers and consumers need to be bridged by suitable extension education interventions and encouraging the farmers, milk brands, cooperatives to enter this market on one side and consumers at the other end.

Threats: The international trade in organic livestock products from the developing world is considered a risky business due to poor sanitary conditions, existence of diseases, traceability problems as also the self sufficiency in importing countries, which might discourage producers in India too. But rich segments among the Indians might offer market niche for organic livestock products, which can be tapped.

The producers in India need to overcome the weaknesses and harness the strengths and opportunities, while developing their capacity in terms of knowledge, skills, infrastructure, animal feeding, hygiene, sanitation, disease control and assured certified supply chain required for organic livestock production. Large-scale commercial farms usually undertake most organic livestock production in industrialized countries; whereas, the

The Road ahead....

If 0.5% of India's enormous human population of 1.21 Billion decides to turn organic in next 5–10 years, it would have huge implications for the way food is produced and processed, considering the elaborate requirements and standards for organic production. Let us assume, roughly only 50% of the Indian population consumes meat, even then the requirement would be far more than what is being consumed in industrialized countries with very thin population, where, organic meat products are currently consumed. Going by the global trends indicating preference for good quality, health foods, animal welfare and environmental concerns, it looks quite likely that growing number of consumers would demand organic products of animal origin in India too. Already, the demand for good quality milk and milk products is getting stronger and the Indian consumers are willing to pay or even paying upto Rs 80/liter for pure milk and Rs 1200/kg for ghee, not necessarily organic per se, but unadulterated. This emerging trend makes it imperative that serious attention is to be paid not only on production, processing and marketing sectors but research in organic livestock production too need attention of the policy planners and other stakeholders like livestock research institutions.

Organic Animal Husbandry presents a formidable task, considering the stringent principles, guidelines, practices and standards of organic livestock production, as well as the mandatory certification procedures for such production systems. To benefit from this emerging system of food production, farmers in India must build their capacity and take into account their natural advantages.

small scale producers are having limited resources and low risk bearing ability dominate Indian livestock sector. Nevertheless, they may cater to domestic consumers, if not exports currently. The emerging need of the quality conscious high end consumers in metros is required to be met by producing organic animal products locally. The local organic milk, meat and egg production may substitute import (if any) while generating employment, reducing foreign exchange demand, stimulating innovation, and making the country self-reliant in critical areas like food. Organic livestock production may be encouraged initially for domestic consumption, through research and development efforts including establishment of model organic livestock farms, processing units, traceability tools, and capacity building measures, besides consumer awareness on health foods. The international trade in organic livestock products from the developing world is considered a risky business due to poor sanitary conditions, existence of diseases, traceability problems as also the self sufficiency in importing countries, which might discourage producers in India too. Organic livestock and poultry production is an emerging and evolving system, different agencies and stakeholders have to work hard to make it sustainable for the reasons of health, environment, economy, quality of life and animal welfare.

To make organic livestock production relevant to India, the following issues need urgent attention: The Indian standards for organic livestock production needs to be developed considering the local situation and requirements, which can be notified for local production, Currently, the organic livestock products like milk and meat are certified as per the other international standards or the Indian standards developed (NSOP–2002) for exports; India has to make itself free from infectious diseases like Foot and Mouth Disease (FMD), which restricts trade. The reduced opportunity for export discourages livestock producers to go organic; Small farmers find it difficult to comply with traceability requirements. The locally feasible traceability tools needs to be developed; sanitary conditions at production site and processing units need improvement; at the moment, there is little local demand for organic livestock products *per se*, though the quality consciousness was on the rise among the consumers. The domestic market for organic livestock products needs to be developed; Grazing land is shrinking due to reducing community land and also change in land use pattern. Livestock grazing systems needs to be researched to make them a sustainable option; Natural sources of essential amino acids (Methionin for instance) are not available good enough to meet the requirements of livestock particularly swine and poultry; Green fodder supply is insufficient to meet the requirement of the livestock. Animal survive on poor quality roughages; Housing conditions are often improper, increasing risk of zoonotic diseases; Research and development investment in the area of organic animal husbandry is nearly nil; The per animal health cost is almost negligible in traditional livestock keeping though the trend has been towards intensification where this cost is likely to go up. The alternative systems of animal health management may be researched, standardized so as to comply with organic standards.

Inspite of the favorable situation existing like traditional animal husbandry, Indigenous Technical Knowledge, low input and stress resistant breeds, limited or no antibiotic use, limited chemical fertilizer application, less dependence on market for inputs in many developing countries like India, the limitations too as mentioned above are seriously restricting the growth of organic animal husbandry in these countries especially the stocking density, feed and fodder scarcity, sanitation, infectious disease prevalence etc. May be the increasing interest in this underdeveloped organic sector by *inter alia* FAO, IFOAM and Government of India would help give a push to organic animal husbandry in India in long run.

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Scope and Potential of Organic Farming in Vegetable Crops

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Nowadays organic farming practices are assuming importance all over the world in order to make the harvested produce free of pesticide residues and other harmful chemicals, to minimize soil, water and environment pollution and sustain soil productivity. Organic farming is a production system which avoids or excludes the use of synthetically compounded fertilizers, pesticides, GM crops and growth regulators. It relies upon crop rotations, crop residues, animal and green manures, legumes, mechanical cultivation, biofertilizers and biological pest control to maintain soil productivity, supply nutrients and control insects, diseases and weeds. Organic food has evolved from being a fashion cult to a necessity for healthy living. Global food markets present a bright situation for the organic food suppliers, as the demand far outstrips the supply. Entrepreneurs are pumping investments in the Organic supply-chain, which in turn has made many farmers to explore the possibilities of switching over to organic agriculture. Although in common parlance, organic agriculture is chemical-free cultivation of crops, it is actually not as easy as it looks, particularly when we start realizing the predominance of certification requirements to be met while undertaking organic agriculture. Organic certification is based on Process certification i.e. it takes into account the entire process of organic farming adopted by an organic farmer on his farm. This in turn requires that the entire process of organic farming adopted by each farmer has to be extremely well documented. Most farmers are poorly equipped to undertake such an exercise and hence have to leave the option of undertaking lucrative organic farming with a heavy heart.

Vegetable farming is generally an intensive but profitable venture since per hectare yields are comparatively more and the

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income is large. In order to minimize risks involved in vegetable production, heavy fertilization as well as pesticide application is commonly practiced. To make it a sustainable and profitable system, reducing usage of these harmful chemicals and slowly changing over to non-chemical farming is the concern of the day. In this direction for change over or shift from the present heavily chemical oriented farming practices to environment friendly but profitable production systems require developing appropriate package of practices that depend on natural inputs, preferably sourced within the farm. Vegetable crops require skilled management to produce a high quality product without use of chemicals. Organic farming protocols in vegetable crops needs to be standardized more in crops which are consuming maximum chemicals and pesticides in their cultivation such as cauliflower, cabbage, okra, tomato. It is also required for vegetables that are consumed raw or in fresh form and have high export potential like rose onion, gherkins, okra, beans, peas etc.

In several countries around the world including India, consumers demand for organically produced vegetables. In this direction it is endeavor of all people concerned with organic vegetable production to develop feasible and economically viable package of practices based on the information available and technology developed which will be useful for farmers interested in organic vegetable farming. The general production practices for organic vegetable farming are discussed below.

Climate: Each vegetable crop has specific climatic requirements and the season selected for the cultivation should have best crop growth, yields and produce quality. Some disease and insect problems are especially prevalent at specific, predictable times of the year and vegetable crops can be planted at dates that protect them from these high-risk periods. The following planting schedules can be generally followed:

Kharif : Brinjal, Chilli, Okra, Drumstick
Rabi : Carrot, Cauliflower, Cabbage, Capsicums, French Beans, Onion,
Peas, Tomato, Gherkins,
Summer : Bottle gourd, Cucumber, Pumpkin, Ridge gourd, Watermelon

It is better to avoid tomato cultivation during rainy period as alternaria, phytophtora foliar and fruit rot diseases are severe. During winter okra (bhendi) growth is retarded and during high temperature period virus diseases are severe in okra, chilli, tomato and beans and in capsicum fruit set is a problem.

Soil: The ideal soils for growing vegetables are well drained, fairly deep, and relatively high in organic matter with a C:N ratio between 15–20:1. Well-drained loam soils rich in organic Carbon (about 1%) with gentle slope of 2 to 3 per cent are better for organic vegetable production. Healthy and productive soil helps crops to develop good root systems and reduce crop stress caused by drought or excess rainfall. If drainage is a problem, planting on raised beds will promote drainage and faster warming of soil. On the whole most of the vegetable crops grow well in pH range of 6.5 to 7.0.

Soil fertility management: Any definition of sustainable or organic agriculture includes a commitment to proper soil management and organic vegetable production systems are guided by an overriding philosophy of ‘feed the soil to feed the plant.’ This basic precept is implemented through a series of approved practices designed to increase soil organic matter, biological activity and nutrient availability. Over time, adding organic materials such as green manure, crop residues and composts to cultivated soils build levels of soil organic matter. As soil organic matter increases, the ability of the soil to supply nutrients to crops also increases. The ultimate goal is a healthy, fertile, biologically active soil with improved structure and enhanced nutrient reserve. Many soil amendments and fertilizers commonly approved for organic production systems have appreciable amounts of nutrients, but only a portion of these nutrients are available to the current crop. Organic soil fertility programs are designed to maintain adequate levels of nutrients in the soil nutrient pool and to augment the pool as needed. Management practices strive to optimize diverse biological processes in the soil to create a complex environment that ensures adequate nutrition to the crop.

Role of organic matter and humus: The increase of soil organic matter to optimum levels is a key aspect of any organic production system. Native organic matter levels are relatively low in Indian soils, generally less than 1 per cent. Studies have shown that it is unreasonable for a grower to expect to increase soil organic matter by more than 1 percent, but a relatively small increase can dramatically improve the soil fertility environment in a given field.

Soil organic matter improves cation-exchange capacity and serves as a reservoir of nutrients for the growing crop. Incorporation of organic matter also improves soil aeration, drainage and water-holding capacity. Green manure crops are an economical means for elevating soil organic matter and providing nitrogen for the succeeding crop. They also reduce soil erosion and may offer benefits related to pest and disease suppression. The decomposition of organic matter in soils can provide much of the nitrogen (N), phosphorus (P), and sulfur (S) needed for crop nutrition. A portion of the N from many organic amendments is converted readily into available mineral forms. Phosphorus from organic amendments reacts quickly, is bound to soil minerals and moves very little from where it is placed. Potassium (K), Calcium (Ca), and magnesium (Mg) are relatively soluble from plant residues or soil organic matter fractions and also contribute to the soil pool. Organic matter is also a valuable balanced source of many minor elements. Organic matter releases nutrients as it decomposes and provides slow and constant availability.

Management of soil biological characteristics: A complex array of soil-dwelling plants and animals decompose organic matter, mineralize organic forms of nutrients, and fix nitrogen. These beneficial biological activities enhance the soil's ability to release nutrients needed for plant growth and to break down plant residues. Tillage practices that aerate the soil enhance biological activity by providing Oxygen and mixing organic matter throughout the tilled area. On the other hand, broad-spectrum fumigants such as methyl bromide kill beneficial soil organisms along with soil pests.

Bacteria and other microorganisms: Both ammonium and nitrate are readily available sources of nitrogen to plants and soil microorganisms. A variety of soil microorganisms convert organic nitrogen to ammonium, but only specific (nitrifying) bacteria convert ammonium to nitrate (nitrification). Nitrifying bacteria are most effective in well aerated soils at soil temperatures of 80 to 90 degrees F, when the C:N ratio is low to medium and soil moisture is adequate for plant growth. High activity of these bacteria increases N availability, but the nitrates released by nitrifying bacteria are highly soluble and subject to leaching. Thus, if not absorbed by crop or covers, nitrate may be lost from the field. In addition, other soil bacteria (denitrifiers) reduce nitrates to elemental nitrogen or nitrous oxide which are lost into the atmosphere as they are volatilized. Denitrification is most likely to occur in poorly drained soils where Oxygen levels are low (anaerobic conditions).

Not only do naturally occurring microorganisms play an essential role in the nitrogen cycle, they have also been reported to decrease some populations of pathogenic bacteria and fungi. For example, the fungus *Gliocladium virens,* which tends to increase with increased levels of organic matter, controls damping-off pathogens. G. *virens* is also available commercially. *Agrobacterium,* a naturally occurring soil microorganism, reportedly restricts growth of *Fusarium,* a fungal pathogen causing a number of diseases in vegetable crops. Beneficial microorganisms in the root zone, particularly species of *Pseudomonas,* have been associated with a decrease in take-all decline of wheat.

Earthworms: Earthworms break up organic matter and enhance microbial activity. Soils with earthworm populations or soils containing earthworm castings generally have a greater ability to hold water and plant nutrients. Cation-exchange capacity, exchangeable Calcium, magnesium, Potassium, and available Phosphorus are generally higher in soils with earthworms. Mechanical soil disturbance also reduces disease severity and it is possible that the physical mixing of soil by the worms reduces pathogen severity. When earthworms are introduced to the soil, they spread rapidly from the inoculation point – up to 36 feet per year. In most soils, if organic matter increases, earthworm populations will increase rapidly. Continuous cropping without adding organic matter, copper fungicides, soil fumigation and frequent tillage usually reduces earthworm populations.

Source of nutrition in organic farming

Cover crops/green manure crops: Cover crops can be beneficial for intensive organic vegetable production in a number of ways. If leguminous cover crops are grown, soil Nitrogen can be increased through Nitrogen fixation. Grasses are particularly helpful in promoting soil structure and soil aggregate stability because of their fibrous root systems. Weed suppression for subsequent crops may be another benefit. Furthermore, cover crops can provide a favorable environment to attract and sustain beneficial arthropods. Growing a green manure crop that includes N fixing legume is the most economical way to provide Nitrogen to succeeding crop. The green manure contribute 30–60 kg N/ha /crop depending upon the crop. Sun hemp and Dhaincha (*Sesbania spp*.) could be suitable catch crop in many agro climatic situations. To realize some economic returns farmers who have irrigation facility can grow profitable vegetable crop such as French Beans or Cow pea in place of green manure crops.

Compost: Compost is a relatively cost-effective organic source of nutrients. These composts can be prepared by crop residues and farm wastes. The Carbon to Nitrogen ratio (C:N) of a compost is one indication of the maturity and N availability which should be less than 20:1.

Manure: Farm yard manure, bio gas slurry, sheep manure and other animal manures are the by-products of integrated farming system, where out put of one enterprise will become the input of the other activity and recycling is the key. However the manure used need to be certified by the certification agency.

Vermicompost: Vermi compost production is economically remunerative due to its low cost of production. The quality and nutrient content depends upon the raw material used for production.

Other fertilizers used in organic cultivation: A number of approved organic fertilizers are available for organic cultivation. Many of these nutrients are by-products of fish, meat and soybean processing industries. Other simple fertilizer materials are: rock phosphate, blood meal, rock or colloidal phosphate, Potassium sulphate (mined) and green sand (for K). Certain by-products of the meat processing industry, such as blood and bone meal have recently come under scrutiny because of food safety concerns and the potential for disease transmission.

Special purpose fertilizers: Specific approved nutrient sources of K, Ca and Mg may be useful to an organic grower when a deficiency is indicated. Materials such as gypsum, lime and Potassium magnesium sulphate have been in use.

Bio fertilizers: The contribution of rhizobium bacteria as symbiotic Nitrogen fixer is well established. *Azotobacter* and *Azospirillum* are also used as Nitrogen fixers. The use of bio fertilizers is also gaining popularity for solubulising phosphorous and VAM for absorption of nutrients from soil.

Manuring and fertility management: i) Enrichment of FYM with Trichoderma and Bio-fertilizers: Well decomposed FYM is thoroughly mixed with *Trichoderma harzianum* , *Azatobacter* or *Azospirillum* and Phosphate Solubilizing bacteria (PSB) (all @ 1 kg/tonne of FYM), moistened by sprinkling water and covered with gunny bag/leaf twings/dried coconut fronds and kept to incubate for 15 days. This enriched FYM should be mixed with remaining FYM before applying to the field; ii) About 35 to 40 tonnes of fully decomposed FYM, 1.5 tonnes of vermicompost and 250 kg/ha neem cake having 8 –10% oil content is added to the soil. Ridges for transplanting at recommended row spacing is prepared after basal manure application; iii) For enhanced supply of Nitrogen, green manuring crop can be grown and incorporated in soil at least 3 weeks before transplanting; iv) Concentrated organic cakes (4–7% N) like castor, soybean, cotton etc. can also be used depending on the availability. At 30 days after planting, vermicompost (1.5 t/ha) and neemcake (250 kg/ha) application is done followed by earthing up operation; v) As a source of P, Rock phosphate or Bone meal in combination with Phosphate Solubilizing Bacteria can be used. Both contain about 20–22% P_2O_5; vi) As a source of K, wood ash (2.5 to 3% K_2O) or Sheep manure (3–4% K_2O) can be used; vii) Spray of panchagavya can be followed 4–5 times at 10 days interval to supplement nutrients and as a plant growth promoter. Vermiwash can also be sprayed as growth promoter; viii) For legume vegetables, seeds need to be treated with *Rhizobium* cultures before sowing.

Selection of varieties: For better performance select a variety which is resistant or showing field tolerant to important diseases and insects. Also choose varieties according to the season. For example in tomato for organic cultivation during *kharif* the major problem is alternaria leaf spot. Therefore it is suggested to choose a cultivar known to have field tolerance to this disease, while for summer season, TLCV resistant hybrids need to be selected. In cabbage and cauliflower photo and thermo insensitive hybrids, while in tomato, bacterial wilt resistant varieties need to be grown. In French beans bacterial blight and rust resistant varieties need to be selected. *Tomato:* Arka Rakshak and Arka Samarat (BW,TLCV and Alternaria tolerant); NS 501 and Arka Ananya (BW,TLCV tolerant)**;** *Okra:* Arka Anamika, Arka Abhay, Parbhani Kranti (YVMV resistant); *Brinjal:* Arka Keshav, Arka Neelkant, Arka Anand (BWR); *Cowpea:* Arka Garima, Arka Suman (rust resistant); *Cluster bean:* Pusa Navbahar and Gouri; *Dolichos bean:* Arka Jay and Arka Vijay; *French Beans:* Arka Komal, Arka Suvidha and Arka Anoop (rust resistant); *Chilli:* Arka Suphal, Arka Meghana, Arka Harita (powdery mildew and CMV, CVMV tolerant); *Onion:* Arka Kalyan, Arka Niketan (purple blotch tolerant) are recommended varieties under organic management.

Organic seedling production: Seedlings can be raised either by raised bed or protray methods. However, nowadays protray method is more popular.

Raised-bed nursery raising: Beds of 10–15 cm height providing necessary drainage are prepared. During summer season following solarization of nursery beds prevent nursery diseases. FYM, vermicompost and *trichoderma* powder in the ratio of 10:1:0.1 is mixed and applied @ 0.3 kg/m^2. Neem cake @ 100 g/m^2 is also added to the nursery beds. Seeds are sown in lines with a spacing of 7.5–10.0 cm x 2.5 cm and covered by vermi compost and straw. It is good to protect nursery beds with 40 or 50 mesh nylon net cover to prevent insect vectors. The seedlings will be ready in 25 to 45 days depending on the vegetable crop.

Raising seedlings in plastic pro or flat trays: Each flat or protray having 98 cells are used for raising seedlings of tomato, capsicum/chilli, brinjal, cauliflower and cabbage. Cocopeat fully decomposed by the use of organic manure and enriched with Phosphorus is the ideal media for filling the trays. Otherwise vermicompost can be used as growing media. About 1–1.25 kg cocopeat is required to fill one tray. A small depression in the centre of the coco peat is made using finger and one seed is put per cell and covered with cocopeat just enough to cover the seeds. Such filled and sown trays are stalked and covered with black polythene mulch one over other till sprouting is observed. After sprouting, the trays are spread in nethouse and irrigated daily depending on the weather conditions. The seedlings of 20–25 days old in cabbage, cauliflower, tomato and 30–40 days in chilli, capsicum and brinjal are ideal for transplanting and better crop establishment.

Transplanting/ Direct sowing: BT (*Bacillus thuringiensis*) formulation (1g or ml/litre) is sprayed to the cabbage / cauliflower seedlings one day before transplanting. At the time of transplanting root portion of seedlings is dipped in *Trichoderma* and *Psuedomonas florescence* or seedling trays are drenched with it. Similarly biofertilizers such as *Azotobacter* or *Azospirillum* and Phosphate Solubilizing Bacterial (PSB) slurry (5%) can be used for root dipping of all vegetable seedlings. When seeds are used for direct sowing the above biofertilizers can be used @ 1% for seed coating for non leguminous vegetables while for leguminous vegetables rhizobium and PSB are recommended.

Irrigation: Irrigation schedules recommended for commercial vegetable cultivation can be followed with only caution that foliage wetting to be minimized in order to reduce foliar disease incidence. Drip irrigation with plastic mulching helps to maintain better soil moisture regimes and also reduces pest and disease incidence in addition to saving of irrigation water through reduced evaporation losses as well by preventing weed growth.

Weed management: For the production of transplants from seedbeds, select a land area that does not have a history of troublesome weeds. Vegetable crops that germinate quickly and grow rapidly in the first few weeks after planting do well because they are more competitive with weeds than crops that initially grow slowly. Hand weeding and inter cultivation are the most widely practiced method of eliminating weeds.

Organic mulches, such as dry grass, straw, bark, banana sheath, composted sawdust and similar materials, can be used for weed management. Besides, plastic mulches are now gaining popularity for weed management which may be adopted for organic vegetable production. The plastic mulch also provides a physical barrier between soil and plant surfaces and reduces the amount of disease inoculums splashed onto foliage, stems and fruits during rainy periods. Use of reflective plastic mulches will reduce the activity of vectors and there by reducing the viral disease incidence.

Organic pest and disease management practices: Organic disease management provides satisfactory protection from many vegetable diseases that commonly occur and these practices are based on non-chemical sanitation, cultural, physical and biological means, as well as application of organically approved chemicals. Used in an integrated program, these practices reduce populations of fungi, bacteria, nematodes, viruses, and other pathogenic microorganisms that cause vegetable diseases. A combination of practices is necessary, since no single practice is effective for all diseases that threaten production of a given crop. Some organic disease management practices should be carried out before the crop is planted such as soil solarization and others later in the season such as collection of debris and burning them. Some of the plant protection measures that can be followed in organic farming are: Use of resistant vegetable varieties wherever available; Clean and diseases free seeds and transplants are a must in organic vegetable production. Seeds should not be collected from the disease infected area; Use seedlings grown under protected environment. Seed treatment with *Psuedomonas fluorescens* or *Trichoderma harzianum* or *Trichoderma viride* at the rate of 10 g/kg is beneficial; Planting of healthy and vigorous seedlings early in the season is an important strategy; In crop rotation, legumes are plowed early so vegetation (green manure crop) has time to rot before main crop planting; Use mulch to keep vegetables away from soil contact and rots; Keep out weeds which harbor insects and diseases; Irrigate early in the morning; Remove and dispose of diseased plants; Turn under crop refuse as soon as harvesting is completed; Grow fodder maize or sorghum as a barrier crop all round the vegetable planted field to reduce incidence of virus carrying vector infestation on the main crop; Nursery beds are to be covered with 40 or 50 mesh nylon net cover to prevent insect vectors transmitting virus diseases; Nematodes can be managed by crop rotation with marigold. Solar heating the soil using large plastic covers reduces nematodes, soil-borne insects, some weeds and some pathogens. Summer flooding, where soil type permits, will help control nematodes and other pests. Application of *Trichoderma* and other bioagents through FYM or neem cake or seed treatment also help in management of nematodes. Application of Neem cake will also reduce the nematode population.

Bioagents for foliar and fruit diseases and soil borne organisms: *Trichoderma harzianum* (10 g/l); *Trichoderma viride; Pseudomonas fluorescens* (10 g/l); *Bacillus subtilis* (10 g/l)

Bioagents and Botanicals for management of insect pests: *Beauveria basiana* (10 g/l); *Verticillium lecani* (10 g/l); *Metarhizium anisopliae* (10 g/l); Neem soap (10 g/l); Neem oil (8 ml/l); Neen Seed Powder Extract (4%); *Pongamia* oil (8ml/l); *Pongamia* soap (10 g/l); NPV; *Bacillus thuringiensis*, on certain insects such as cabbage worms.

Protected cultivation of vegetables: Protected cultivation is an important tool to overcome many biotic and abiotic stresses in organic cultivation of vegetables. In moderate to heavy rainfall area, rain shelter is proving effective in overcoming the problems of foliar diseases of vegetable crops like tomato. In crop like brinjal, where the control of insects like shoot and fruit borer is difficult, growing these vegetables under nethouse hold a bright promise under organic farming.

Harvest and post-harvest management: Schedule harvest timings during cool hours of the day, i.e. morning or evening hours. Immediately after harvest shift the produce to sheltered place and pack them in clean ply wood boxes or plastic crates. Pick the produce at right stage to retain firmness so the transport shocks are reduced. For example, in tomato the fruits should be harvested at breaker stage or when the fruits are turning from green to light pink colour. The results of organic vegetable trials conducted at Indian Institute of Horticultural Research, Bangalore and on farm trials in farmers fields have indicated that the yield levels of 80 to 85 per cent of conventional farming can be obtained in cabbage, cauliflower, tomato, brinjal , chillies, onion, drumstick while they are on par or even more in French Beans.

Marketing: The marketing of organically produced vegetables presents growers with a number of challenges. Total supply, consumer demand, pricing, perishable nature of the product and market structure are the factors that contribute to a grower's ability to sell his/her product. Therefore, production and market risks both affect the profitability and economic viability of organically grown vegetables. In all cases, the risks associated with organic vegetable operations should be minimized. Growers must harvest, pack, and sell their products in an expedient manner to receive satisfactory returns. Therefore, from marketing perspective vegetables carry a greater risk than such storable commodities as nuts and grains. Some organic vegetable growers may reduce this risk by planting crops such as winter squash, onions, garlic and potatoes which may be stored for longer periods of time. Commodities that are produced organically can often be sold for a premium price over conventionally grown products. However, the industry is extremely competitive and returns to growers are dictated by the total supply, consumer demand and the available organic outlets. Market saturation often occurs and growers may be forced to accept lower returns and/or market their product without the organic designation at conventional prices.

Future thrust in research and development: Non availability of suitable Package of Practices on organic farming of various horticultural crops; Appropriate methods to enhance the nutrient content of the bulky organic manure; To assess the nutrient availability pattern of different organic sources during the cropping periods under different agro-climatic situations; Developing efficient biopesticides and botanicals and bio control agents for insect pests and disease management; Poor marketing access and remunerative prices when grown on large scale; Determination of quality standards for various organic inputs; Research on organic horticulture should be on farming system approach; Simplification of production protocols by the certifying agencies for the domestic markets; Organic cultivation under protected environment needs emphasis; Organic seed production and distribution system need to be encouraged.

Although information on conventional cultivation practices is available from many sources, comprehensive information on organic cultivation practices is difficult to find. Organic vegetable production differs from conventional production primarily in soil fertility, weed, insect, and disease management. While there have been varying notions of organic farming over the years, the growth of the organic farming system and the introduction of standard and certification have led to a clearer definition in recent years. The definition describes organic as a viable agriculture, based on sound farming practices that does not include synthetic chemicals. Keeping this in view, it is an endeavour of all those interested in protecting the soil sustainability by adopting eco-friendly approaches within farm operations as much as possible and generate appropriate organic vegetable production technology to supply safe vegetables for human consumption.

Maximising Yields in Organic Farming: Three Case Studies

Leena Chandran-Wadia

Man has practiced eco-friendly agriculture for approximately 10,000 years. It is only recently, in the last 100 years or so, that chemical fertilizers and pesticides have been used extensively as part of the 'Green Revolution' in many countries – to increase wheat production enormously in the 1940s in Mexico, in the 1950s in United States, and to avert famine in India in the 1960s. The Green revolution in India did not just help avert famine, it paved the way for India to take its place among the world's largest producers of food. According to statistics from the Food and Agriculture Organisation (FAO)[1] India is among the largest food producers in the world, ranking among the top 5 in several food categories – cereals such as rice and wheat, many fresh fruits and vegetables, pulses, spices and even cash crops such as coffee and cotton besides, milk, fish and livestock.

Although India's food production is high in terms of quantities, its productivity (yields per hectare) for most crops is poor relative to many countries. For example India is one of the largest producers of rice, second only to China in terms of quantities, but the top five countries in terms of yields are Egypt, Australia, Syria, Greece and USA in that order[2]! According to the Planning Commission, approximately half the people engaged in agriculture are illiterate and just five percent have completed Higher Secondary education. The farmers who have very small land holdings possess the least amount of assets, skills or education. Therefore it is imperative to look at ways to educate them, particularly about alternate farming techniques that are low in input costs (seeds, fertilisers and pesticides).

Chemicals-based farming is knowledge intensive – fertilizers and pesticides cannot be used indiscriminately else they will destroy the soil and water. Yet very little provision

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exists to educate farmers on a regular basis and to support them with soil testing facilities and related knowhow. Market forces tend to give farmers a skewed picture of the use of chemical inputs that are detrimental to their own interests and to the interests of their consumers.

It is also very well known by now that mono-cropping and the indiscriminate use of chemicals and pesticides have led to loss of biodiversity, pollution of water resources and the destruction of the primary productivity of the soil, thereby threatening the livelihoods of farmers, particularly 'small and marginal' farmers. Nearly 80 percent of farmers in India fall into the latter classification: those who own less than one hectare (Ha, approximately 2.5 acres) are called marginal farmers and those who own between one and two hectares of land are known as small farmers. With each succeeding generation the land holding is being split further and there is now a preponderance of farmers with extremely small land holdings, typically less than one acre. In terms of absolute numbers, there are nearly 10 crore farmers whose total landholding amounts to just 36 percent of the land under cultivation, all of which is rain fed and supports just one Kharif crop. More than 2 lakh farmers committed suicide in the decade between 1997 and 2007. A return to sustainable agriculture has become a human, as well as an ecological, imperative.

One of the key concerns expressed about organic farming (farming that is free of chemical fertilizers and pesticides) is whether it can provide adequate productivity and food security for densely populated countries such as India. In this paper we look at the case studies of variants of organic farming practiced by three well known farmers in India, in order to understand how they have improved yields considerably, both in large farms growing single crops as well as in small and marginal farms. The relevance of their work is the knowledge that if one farmer produces a record yield of any crop then it should be possible for others to do the same.

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[1] Crop production data by country from the Food and Agriculture organization http://faostat3.fao.org/faostat–gateway/go/to/browse/Q/QC/E

[2] Ibid. Data on Country rank by commodity (Rice, paddy) and Yields per Hectare from the Food and Agriculture Organisation (FAO) http://faostat.fao.org/site/339/default.aspx

Bhaskar Save – six decades of organic farming: Bhaskar Save, a 91 year old veteran of Organic farming, is the recipient of the One World Lifetime Achievement Award 2010[3] instituted by IFOAM (International Federation of Organic Agriculture Movements). He began his career as a teacher. For about a decade he practiced farming on his family farm alongside his teaching duties before giving up teaching completely. In the 1950s Bhaskar Save practiced chemicals based farming, became a model farmer in this space and was decorated both by the Gujarat government and the Ministry of Agriculture, Government of India, which gave him 'the best coconut farmer' award. However, he soon noticed that his input costs were spiralling because he needed to put in higher quantities of fertilizers and pesticides each year in order to sustain yields. He therefore transitioned gradually into organic farming and found that the lower input costs here helped him post profits quickly, despite lower yields initially. He was later able to improve yields in organic farming, creating a 'platform and trench system' for growing trees that produces 400 coconuts per tree per year, as against the normal 80–100 coconuts a year. Notably, this high yield of coconuts is also produced by expert farmers practicing other variants of organic farming such as Natueco farming, described elsewhere in this article.

Bhaskar Save practices the 'no-tilling' based 'Natural' farming technique pioneered by Masanobu Fukuoka of Japan[4]. Saveji speaks animatedly[5] about how farmers go wrong with the use of water, about how plants requires moisture, not water, and how flood irrigation coupled with the excessive use of fertilizers, by ignorant farmers, have contributed to the destruction of their lands. He describes how he has planted the humble croton plant at many locations in his farm so that they can be barometers of adequate moisture in the soil (their drooping leaves indicate dryness). He uses leaf litter and farm waste as mulch to prevent evaporation and keep his soil moist. He has not used

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3 See http://www.one–world–award.com/2010–one–world–award.html for details of the award and awardees

4 Fukuoka's famous book 'One Straw Revolution' helped inspire many a farmer to adopt his techniques referred to as Natural farming, which shun ploughing, weeding, pruning and fertilizers to adopt a minimalist approach

5 Observer Research Foundation Mumbai had prepared a short film to commemorate the work of Bhaskar Save on the occasion of the presentation of the One World Lifetime Achievement Award to him.

any additional water other than the annual rainfall, preserved though water harvesting, on his 14 Ha farm Kalpavruksh in Dehri, Gujarat, for many years now. Although Israel as a country is known for having pioneered and commercialised drip irrigation, India's best farmers have always known how to use water wisely.

Subhash Sharma: self-taught, nature inspired, organic farming: Subhash Sharma also began his farming career in 1975 with chemicals based farming. As with Bhaskar Save, he too found his crop yields increasing year on year in the initial years. In approximately eight years he found the yields of his crops flatten out and even decline in subsequent years, despite increasing inputs of ever more expensive chemicals. Of course all the earthworms, ants, insects, frogs and other living organisms found normally on farms were gone from his farm by then. Over the years he and many other farmers had also cut all the trees on their farms, and along with the trees went the birds too. At this time he was also using excessive amounts of water because he had access to electricity and water pumps so the water table on his 12 Ha farm had also dropped sharply. Since his soil had become hard, without any pores to drain water, he was losing 15 tonnes of fertile top soil each year.

Worried by these developments and inspired by Masanobu Fukuoka and Bhaskar Save, he started learning about 'Natural' farming and began experimenting on his own, beginning in the 1990s. He describes[6] in great detail, and in a completely quantitative fashion, how he transitioned gradually from high external inputs based chemical farming into low cost, nature inspired and sustainable, organic farming. His annual output which had fallen to 50 tonnes just before he switched to organic farming returned to 400 tonnes, the same peak level he had seen in the early years of fertilizer based farming. He touches upon how he was inspired by nature to replant hundreds of trees to maintain the temperature of the farm and bring the birds back and how he used farmyard manure such as cow dung and cow urine as agents to revive the soil, to bring earthworms and insects

[6] Talk at Roundtable on 'Problems faced by Maharashtra's Farming Community: The need to Promote Best Practices in Sustainable Agriculture' held at Observer Research Foundation Mumbai in September 2010.

back. He talks at length about his successful efforts to harvest rain water towards regenerating the water table in and around his farm and also about rotating crops and recycling plant residues in order to keep his soil healthy and his yields consistently high.

One of the key innovations of Subhash Sharma is the fact that he has made casual farm labourers into equity participants in his farm. Describing his different experiments with the use of labour during the period of high growth in his farm output (he does not use any implements or tools on his farm, just the labour of people), he outlines how he devised a win-win situation in which each casual labourer was able to multiply his / her income several times, working for fewer numbers of hours, while at the same time helping him multiply his total output many-fold.

Shripad Dabholkar and the Prayog Pariwar methodology: We focus now on the method known as 'Natueco farming' (a method of farming that is consistent with NATURE and ECOLOGY) that has been practiced in Maharashtra and elsewhere in the country for over 4 decades now. Natueco farming is a scientific farming technique pioneered by the visionary, late Prof Shripad A. Dabholkar, the architect of the famed grape revolution in Maharashtra starting in the late 1960s. Prof Dabholkar and the 'Prayog Pariwar' (his team of 'self-experimenting learners', as he called all the farmers who worked alongside him) replicated the early success with grapes with many other crops such as millets, mango, groundnut, sugarcane, maize, bamboo, and more. Not just in farms, but also in home gardens and even roof gardens, the Prayog Pariwar has produced record yields in everything from lemons and pumpkins to sandalwood and lavender.

In Prof Dabholkar's own words, 'Natueco farming is about knowing nature better and better through critical scientific inquiries and experiments'. The promise of record, assured, yields comes through the knowledge of the fertility needs of plants, their geometry and cycles of growth and their plant physiology coupled with the key principles of canopy, soil and water management with no external inputs. In the case of grapes, their yield climbed steeply from the normal 3–6 tonnes per acre to as much as 16 tonnes per acre. Prof Dabholkar's solution for food security is to grow much more food on the same land mass, using the precise techniques of Natueco farming. "There is almost a mathematical precision in the laws of Nature which, if followed, will provide Plenty for all" says Prof. Dabholkar in his book of the same title (Dabholkar, 1998). He explains in detail the concept of the Prayog Pariwar, the development of the art of Natueco farming, and its philosophy and practice. He also presents other case studies, besides grapes, describing in detail how to get maximum yields from crops such as mango, banana and sugarcane.

The prescriptive techniques provided by the Prayog Pariwar for reproducing their record yields can be shared widely and can be learnt by farmers all over the country. The medium of sharing can be the convergence programmes conceived by the Ministry of Rural Development (MoRD) of the Government of India. Since MoRD runs the National Rural Employment Guarantee Scheme (NREGS), they have envisaged cooperation with the Ministry of Agriculture so that farmers and rural workers can upgrade their skills in agriculture and allied sectors (MoRD, Guidelines for Convergence of NREGS with Programmes of the Ministry of Agriculture for enhancing productivity, 2009).

We look at some of the key principles of Natueco farming before considering knowledge management and the ways in which the knowhow and prescriptions can be disseminated. Like many other variants of organic farming, Natueco farming is also based on the principle of 'no-tilling' and also on complete recycling and management of farm-waste. However, unlike 'Natural' farming which depends on traditional practices of organic farming in an empirical way and provides no basic insights into nature's processes in programming any crop production, Natueco farming depends on a critical understanding of greening and recycling of bio-mass from within, to enrich the structure and fertility of soil in a calculated way. The three main principles of Natueco farming (Dabholkar, 1998) are based on nurturing the soil, the roots and the canopy of plants.

Harvesting the sun through proper canopy management for efficient photosynthesis: Prof Dabholkar and his team estimated that plants produce three to four grams of dry weight (glucose) per square foot of canopy (photosynthesis area) per sun-day of eight to ten hours of sunlight each day. It is therefore important to ensure that plants establish their optimum canopy spread of mature leaves, at the earliest time in their lifecycle: for example, in the fifth month for the banana plant. Since the growth of the canopy is related to the spread of the feeder roots of the plant (their extents are approximately equal in size), this can be done by a combination of maintaining appropriate planting distances, and root treatment techniques that are described in his book.

The Prayog Pariwar estimated that of the dry matter harvested by the plant each day, per square foot canopy area, approximately one to two grams is used up by the plant for its own growth and maintenance. The remaining one to two grams is stored in stems or roots or is carried to the storage organs of the fruits. Therefore it must be ensured that when optimum photosynthesis is taking place there is matching growth in the storage organ (fruit) at the same time. This is done by optimal pruning techniques as per the physiology of each plant.

Whereas elsewhere in the world the first crop of grapes is harvested in the third year, Prof Dabholkar describes how he forced the repeated branching of the grape vine through the pruning of the top part every fifteen or twenty one days, thus increasing the canopy to 31 square feet by the end of seventy five days of its new growth. In the next three to four months this canopy matures (each leaf takes 35–40 days) to produce a record yield of 400 gm per square feet of canopy developed. This translates into 16 tons of crop per acre in the very first year, which is the basis of the now famous scientific grape revolution of Maharashtra.

Soil enrichment by recycling biomass: Soil is formed by erosion of rocks and decomposition of biomass. The focus here is on the process of decomposition of biomass which ensures the maximum availability of all diverse micro nutrients. This is primarily ensured through the use of farmyard manure such as cow dung and cow urine as sources of microbes for decomposition, with jaggery as the catalyst. Subsequent recharging of the soil is done by in-situ decomposition of leaf litter and plant residue.

The Prayog Pariwar has perfected the art of making nursery soil which is extremely high in nutrients, using recycled biomass, in just 150 days. The exciting thing about this is that now, using this nursery soil as a starting point, even waste land and land whose productivity has been destroyed by conventional chemical farming can be rejuvenated successfully, giving farmers an opportunity to revive their fortunes. The quality of nursery soil, referred to as 'Amrut Mitti', produced by the techniques developed by the Prayog Parivar is extremely high, containing relatively very high proportions of organic Carbon and many minerals, as attested by tests done at many laboratories including those of the Indian Council of Agricultural Research (ICAR)[7]. Plants require well over 30 elements for their optimal growth, but soil testing (chemical, biological, microbiological and micro-nutrient) facilities do not normally check for all of them. They usually look for adequate quantities of the three primary nutrients, Nitrogen (N), Potassium (K) and Phosphorous (P), and some secondary as well as micro nutrients such as Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn). This data along with measurements of soil microbial parameters helps decide whether nursery soil needs to be used, either because the soil is low in essential nutrients or is saline due to the addition of too much chemical fertilizer in the past. Soil testing data is also important for crop selection.

Root treatment: The goal here is the development and maintenance of white feeder root zones for efficient absorption of nutrients. The presence of large quantities of micro-organisms in the soil gives essential benefits to the roots of the plants in that they convert minerals found in nature into absorbable forms. It is relatively unknown outside the farming communities that the feeder roots of plants grow essentially in the surface layer of the soil, remaining just 9 to 12 inches below ground, with their spread extending as far out as the extent of the canopy. It is mainly the roots that provide support to the plant penetrate deeper into the ground.

The Prayog Pariwar used research on different crops available in different parts of the world to get a detailed understanding of Nitrogen (N), Potassium (K), Calcium (Ca), Sulphur (S), Iron (Fe) and all the other nutrients contained in

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7 For instance the content of organic Carbon has been recently established by ICAR to be as high as 8% at the farm of Shri Deepak Suchde in Bajwada, Madhya Pradesh.

each of the different crop varieties. They took one kilogram of dry matter of each crop variety and burnt it down completely to measure the ash content that is left over. This ash is usually about six to eight percent of the dry weight of the plant and represents the nutrients that the plant absorbs from the soil. They chemically analysed the ash to find out the exact number of nutrients, and their quantities, that will have to be returned to the soil in order that the next crop of that plant can sustain itself. For example, research on mango shows that 100 grams of dry weight of the leaves contains the following nutrients (Dabholkar, 1998):

Nitrogen (N)	1.88 gm		Calcium (Ca)	2.44 gm
Phosphorus (P)	150 mg		Potassium (K)	950 mg
Magnesium (Mg)	320 mg		Zinc (Zn)	3 mg
Sulphur (S)	740 mg		Manganese (Mn)	6 mg
Boron (B)	6 mg		Copper (Cu)	1 mg
Iron (Fe)	7 mg			

Similarly 100 gm of fresh mango fruit contains N-0.12 gm, Ca-90 mg, P-6 mg, K-210 mg, and Mg-50 mg. This is the nutrition that is taken out of the soil with each fruit and must therefore be replenished by recycling. It is clear that if the dry leaves of the mango plant are returned to the soil they will more than compensate for the nutrients taken out in the previous harvest of fruits. The Prayog Pariwar then used this learning to develop various techniques of mulching (recycling of biomass) and in-situ nutrition to return appropriate nutrients to the soil and get record yields at every successive harvest. These techniques also ensure that the nutritional content of the foods remain consistent and sustainable.

Another concern often voiced about organic farming has to do with the use of indigenous seeds. Hybrid seeds that are promoted as part of modern agriculture are said to be high-yielding varieties with higher germination rates and are therefore preferred. Members of the Prayog Pariwar have used extremely innovative methods, such as in-situ nutrition, to increase the germination rates of indigenous seeds which are also well worth sharing with farmers elsewhere in the country.

An innovative social network of farmers: For the farmers themselves, Prof. Dabholkar rather far-sightedly created the Prayog Pariwar (PP) using the humble postcard, long before the days of Facebook, Twitter and other recent social media. As the name suggests, this is a social network of farmers experimenting with Natueco farming. The network was created with the aim of generating a sense of belonging and togetherness among farmers, and for providing them with a support system from within their community. He called it 'a new type of trusteeship where the motto is that amateurs must be helped and protected'. In effect, this was a means to create, preserve and propagate knowledge about sustainable farming which has been remarkably successful and needs to be studied and scaled out further.

Prof. Dabholkar created a communication system on postcards in which farmers who have common interests and who are performing similar experiments got connected to each other so that they could learn from each other. The PP created a set of standardised postcards to hold different types of communication (Information cards, Knowledge cards, Original observations cards, Contribution cards and so on) and an accompanying directory system to assist in the communication. The mandatory two-way interactions generated feedback that benefited both sides namely, the expert and the amateur. Farmers experimented independently and only communicated when there was a need to. These connections could in fact be made because there was a vehicle for group communication available, for informing new people about the support they could get. In the case of the PP, this was Prof Dabholkar's writings about success stories in a magazine called 'Kirloskar'. Given that several other broadcast technologies such as Television and group SMS are available today, this activity referred to as 'beaming' by the PP will be much easier to carry out.

The PP experiment was successful because it gave farmers easy to use methods that were flexible and served them well when they were in difficult situations. In Prof. Dabholkar's view, 'the Prayog Pariwar approach and methodology of creating self-learning and collaborative knowledge networks, of enabling spontaneous generation of learning exchanges, is too powerful a tool to be limited to solving just problems of survival and subsistence. It has the ability to uncover the hidden potential in each and every individual in any arena of life'.

Solutions for marginal and small farmers: The vision of the Prayog Pariwar, for the needs of small and marginal farmers, is to overturn the conventional paradigm of growing mono-crops to earn an income for purchasing food for the family around the year. They suggest replacing it with the paradigm of using the land for growing all the food requirements of the family (cereals, grains, fruits and vegetables) instead. Indeed it is difficult to accept that families of farmers need to go hungry at all. Multi-cropping of different food groups along with some cash crops for generating surplus income to cover other needs of the family such as clothing, education and healthcare can be ensured from even small pieces of land such as 10,000 square feet. In essence this is a return to the sustainable farming practices of the past that have been long forgotten, in the drive to serve urban consumers.

10 Guntha model: Prof Dabholkar and the Prayog Pariwar practitioners have shown that a family of 5 can live comfortably all year round on just 1000 square meters (1/4 acre or 10 Guntha). Prof. Dabholkar began work on the '10 Guntha' project at the suggestion of Shri Annasaheb Sahasrabudhe, a co-worker of Gandhiji at Wardha, who asked him to find a solution that would benefit small and marginal farmers. For this reason the project was always very close to his heart and when Shri Deepak Suchde joined him, he asked him to focus exclusively on this model and work out all of the details by experimenting in as much detail as possible. Shri Deepak Suchde has since spent almost 20 years perfecting this model and he provides a detailed calculation of the surplus income from his own farm in Bajwada, Madhya Pradesh. While incomes will differ for different choices of crops they will remain largely predictable barring slight fluctuations.

Many other 'case studies' are now available for the allocation of land to various crops and other uses under the 10 Guntha model. One such model allocation is shown in Figure 1. Of the 10 Gunthas, typically only about five or five and a half Gunthas are available for cultivation. The home, shed or godown, some recreational space, a pond and a live fence typically consume four and a half to five Gunthas. The live fence has a very special role to play: not only does it provide a secure perimeter and growing space for a cash crop (that acts as 'Any Time Money' to the farmer) but it also helps to regulate temperature and wind velocity, prevent soil erosion and keep pests away when herbal medicinal plants are made part of the live fence. The cultivation area can be allocated to crops as per the farmers' choice. The different groups of crops that can be selected are broadly indicated in the figure. The farmer makes a selection based on his own needs, on the requirements of the market, and on the local climatic conditions (agri-zone). Selecting and planting the correct set of crops is a key aspect of the design.

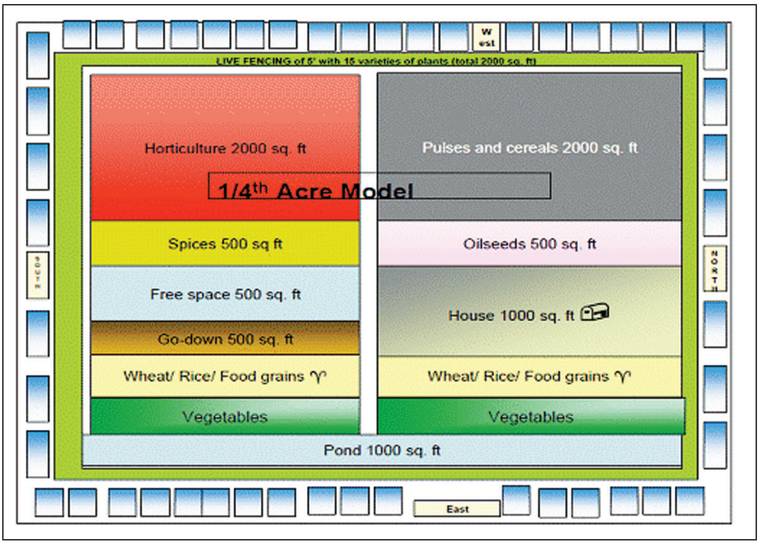

Figure 1: Sample layout of 10 Guntha model showing live fence, home, shed, recreational area, pond and crops for selection.

In order to maintain the 10 Guntha farm a farmer will require about 1000 litres of water each day. The government's commitment would therefore be to meet the family's daily minimum requirement of 1000 litres of water. For the rest, in Prof Dabholkar's words, 'the waste water generated by the family will suffice for farming if one knows the rules of nature and listens to them constantly'. Since plant growth requires only moisture and not water, Natueco farming creates optimally moist conditions by using mulching to reduce evaporation of ground water, and canopy management to ensure that as little sunlight as possible falls on the soil, so that it does not dry in the first place. If in addition, water harvesting can be done during the monsoon periods in either a pond or a channel around the land, and recycling techniques are put in place, the farmer is relieved to a very great extent from dependence on government water supply.

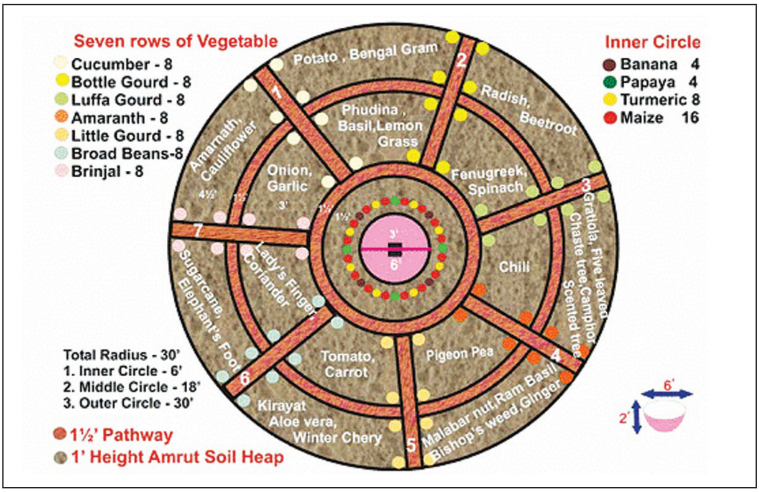

Figure 2: **Layout and sample crop allocation for Gangama Mandal. It provides year round nutrition for a family of five.**

Gangama Mandal: This model was originally proposed by a poor farmer woman in South India, by the name Gangama, at a workshop conducted by renowned agriculturist Bill Mollison of Australia. The challenge that Bill put to the participants was to come up with a cropping model using minimum land, water, and energy to create the maximum output. Gangama created a model for a landholding of just 750 square feet. The original design of Gangama has been modified and improved slightly by Shri Suchde and the land usage has now gone up to 1000 square feet. The Gangama Mandal is essentially a nutritional garden best suited for eliminating hunger and is not really for creating supplies of food. One suggested pattern of cultivation is shown in Figure 2. There are currently hundreds of such nutrition gardens in existence today, at many locations around the country, created through the work of the Rural Transformation Unit of the Reliance Foundation. They report an output of between 3.5

Kg to 6 Kg of vegetables and fruits each day[8], which is certainly sufficient to cover the daily food requirements for a family of five.

Given the potential for increasing yields many-fold, and the potential to revive the vast tracts of degraded and waste lands by using nursery soil, we have an opportunity to use the prescriptions of Natueco farming to bring food security to the people of India, and indeed the world, in a sustainable fashion. As discussed in this article, any efficient practice of other variations of organic farming can also produce the same record yields that have been established by the expert practitioners of Natueco and Natural farming. Therefore poor yields within organic agriculture need not be a worry anymore.

However, there is a serious challenge ahead to trying to reproduce these kinds of yields in farms all across the country. It will require sharing of knowhow on an unprecedented scale, a sharing that is not easy to incentivise and scale out. The Krishi Vigyan Kendras (KVKs) under the ICAR and the Ministry of Agriculture will be involved in imparting training to the stakeholders under the convergence programmes of the MoRD. An initial list of 50 districts has been chosen for the pilot programme and details of locations as well as the technology available with the associated KVKs are listed on the website (MoRD, 2008). We suggest that details regarding Natueco farming are incorporated into appropriate programmes.

Meanwhile the practitioners of the Prayog Pariwar, particularly people like Shri Deepak Suchde, are working both privately, with NGOs, with some State governments (Gujarat, Madhya Pradesh) and with NABARD (National Bank for Agriculture and Rural Development) to conduct training sessions ranging in time from just one day to 5-day, 15-day, one-month and three-month long courses for interested farmers. It remains to be seen whether the laudable goals of these educational efforts will bear fruit.

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8 Private conversation. See also http://www.reliancefoundation.orf/rural_transformation.html

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Bhaskar Save, the Gandhi of Natural Farming

Bharat Mansata

On 27th January, 2014, Bhaskar Save, *aka* Save-guruji – the acclaimed 'Gandhi of Natural Farming' – completed 92 years. He has inspired and mentored three generations of organic farmers. Masanobu Fukuoka, the legendary Japanese natural farmer, visited his farm in 1997, and described it as 'the best in the world, even better than my own farm!' It is a veritable food forest and a net supplier of water, energy and fertility to the local eco-system, rather than a net consumer. Save's way of farming and teachings are rooted in his deep understanding of the symbiotic relationships in nature, knowledge of which he is ever happy to share freely (and still very enthusiastically!) with anyone interested. In 2010, the International Federation of Organic Agriculture Movements (IFOAM) – the world-wide umbrella body of organic farmers and movements – honoured Save with the 'One World Award for Lifetime Achievement.' Its jury declared, 'He is one of the most outstanding personalities in the organic world.'

Bhaskar Save's 14 acre orchard-farm – Kalpavruksha – is located on the coastal highway near village Dehri, district Valsad, in southernmost coastal Gujarat, a few km north of the Maharashtra-Gujarat border. The nearest railway station is Umergam on the Mumbai-Ahmedabad route. About 10 acres of the farm are under a mixed natural orchard of mainly coconut and chikoo (sapota) with fewer numbers of other species. About two acres are under seasonal field crops cultivated organically in traditional rotation. Another two acres are for a nursery for raising coconut saplings that are in great demand. The farm yield – in all aspects of total quantity, nutritional quality, taste, biological diversity, ecological sustainability, water conservation, energy efficiency, and economic profitability – is superior to any farm using chemicals, while costs (mainly labour for harvesting) are minimal, and external inputs almost zero.

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Natural farming and its fruits: Natural farming is holistic and bio-diverse organic farming in harmony with nature. It is low-intervention, ecological, sustainable and economically rewarding. In its purest advanced form, it is a 'do-nothing' way of farming, where nature does everything, or almost everything, and little needs to be done by the farmer. This can best be achieved in a progressive manner with tree crops. As Bhaskar Save explains, 'When a tree sapling planted by a farmer is still young and tender, it needs some attention. But as it matures, it can look after itself, and then it looks after the farmer.' With annual or seasonal field crops, more continuing attention and work by the farmer are needed, but even here, the work and input needed progressively diminishes as the soil regains its health and symbiotic biodiversity is re-integrated.

'Who planted the great, ancient forests? Who tilled the land? Who provided seed, manure, irrigation, or protection from pests?' asks Bhaskar Save. 'In our forests, untended by man, the (human) food trees – like *ber* (jujube), *jambul* (jambolan), *amba* (mango), *umbar* (wild fig), *mahua* (butter tree), *imli* (tamarind), *raini* ('jungle sapota') – yield so abundantly in their season, that the branches sag with the weight of the fruit. The annual fruit yield per tree is commonly over a tonne, year after year, carried away by forest dwellers, including man. But the earth around each tree remains whole and undiminished. There is no gaping hole in the ground! If anything, the soil is richer. From where do the trees – including those on rocky mountains – get their water, their nitrogen, phosphorous, potash? Though stationary, Nature provides their needs right where they stand. But arrogant modern technology, with its blinkered, meddling itch, is blind to this.

'Our ancient sages understood Nature's ways far better than most modern day technologists. The Upanishads say:

'Om Purnamadaha
Purnamidam Purnat Purnamudachyate
Purnasya Purnamadaya Purnamewa Vashishyate'
This creation is whole and complete.
From the whole emerge creations, each whole and complete.
Take the whole from the whole
(Respectfully, as many times as you need)
the whole yet remains,
undiminished, complete!'

'Not so long ago,' adds Bhaskar Save, 'the poet and writer, Bankim Chandra, paid lyrical tribute to our *sujalam*, *sufalam* land.' Ours indeed was a remarkably fertile and prosperous country – with rich soils, abundant sunshine and water, thick forests, wondrous bio-diversity; and gentle, peace-loving people with a vast store of farming know-how and wisdom. For generations beyond count, this land sustained one of the highest densities of population on earth – without chemical 'fertilizers', pesticides, exotic dwarf varieties of grain, or any of the new, expensive 'bio-tech' inputs now being promoted. 'Gandhi believed in gram swaraj (or village self-governance),' says Save. 'Central to his vision was complete self-reliance at the village level in all the basics needed for a healthy life.' He had confidence in the strength of organic farming in this country... but we have strayed far from this path. Vinoba Bhave too pointed out that industries merely transform "raw materials" sourced from Nature. They cannot create anew. Only Nature is truly creative and self-regenerating – through synergy with the fresh daily inflow of the sun's energy. 'There is on earth, a constant inter-play of the six *paribals* (key factors) of Nature, interacting with sunlight. Three are: air, water and soil. Working in tandem with these, are the three orders of life: *vanaspati srushti*, the world of plants; *jeev srushti*, the realm of insects and micro-organisms; and *prani srushti*, the animal kingdom. These six *paribals* maintain a dynamic balance.' Together, they harmonise Nature's grand symphony – mystic grace! Man has no right to disrupt any of the *paribals* of Nature. But modern technology, wedded to commerce – rather than compassion – has proved disastrous at all levels. We have despoiled and polluted the soil, water and air. We have wiped out most of our forests and killed its creatures. And relentlessly, modern farmers spray deadly poisons on their fields, massacring Nature's *jeev srushti*, or micro-organisms and insects – the unpretentious, but tireless little fertility workers that maintain the vital, ventilated quality of the soil, recycling all life-ebbed biomass into nourishment for plants. The noxious chemicals also inevitably poison the water, and Nature's *prani srushti* or animal kingdom, including humans.

Gandhi declared, "Where there is *soshan,* or oppression, there can be no *poshan,* or nurture!" Vinoba Bhave added, 'Science wedded to compassion can bring about a paradise on earth. But divorced from *ahimsa,* or non-violence, it can only cause a massive conflagration that swallows us in its flames.' Trying to increase Nature's 'productivity,' is the fundamental blunder that highlights the arrogant ignorance of agricultural scientists. Nature, unspoiled by man, is already most abundant in her yield. When a grain of rice can reproduce a thousand-fold within months, where is the need to increase its productivity! What is required at most is to help ensure the necessary natural conditions for optimal, wholesome yield. 'In all the years a student spends for a M.Sc., or PhD., in agriculture, the only goal is short-term – and narrowly perceived – economic (rather than nutritional) 'productivity'. For this, the farmer is urged to *buy* and *do* a hundred things, greatly increasing his costs. But not a thought is spared to what a farmer must *never* do so that the land remains unharmed for future generations and other creatures.

A quarter century ago, 'Poison in your Food' – a well-researched, lead feature in 'India Today,' 15th June, 1989 – starkly exposed that 'Indians are daily eating food laced with some of the highest amounts of toxic pesticide residues found in the world. In the process, they are exposed to the risk of heart diseases; brain, kidney and liver damage; and cancer.' Last year, even the Food Safety and Standards Authority of India, Union Ministry of Agriculture, reported that the toxic pesticides and chemicals contained in the foods we commonly buy are hugely in excess of permissible limits, exposing consumers to unacceptable risk of myriad diseases. Such poisons are even more dangerous for pregnant women, the babies they bear, and young children, as well as the ill and diseased.

The differences between chemical farming and organic farming: Bhaskar Save lists 17 major points of difference between chemical farming and organic farming in harmony with nature: 1) Chemical farming fragments the web of life; organic farming nurtures its wholeness; 2) Chemical farming depends on fossil oil; organic farming on living soil; 3) Chemical farmers see their land as a dead medium; organic farmers know theirs is teeming with life; 4) Chemical farming pollutes the air, water and soil; organic farming purifies and renews them; 5) Chemical farming uses large quantities of water and depletes aquifers; organic farming requires much less irrigation, and recharges groundwater; 6) Chemical farming is mono-cultural and destroys diversity; organic farming is poly-cultural and nurtures diversity; 7) Chemical farming produces poisoned food; organic farming yields nourishing, poison-free food; 8) Chemical farming has a short history and threatens a dim future; organic farming has a long history and promises a bright future; 9) Chemical farming is an alien, imported technology; organic farming has evolved indigenously; 10) Chemical farming is propagated through schooled, institutional misinformation; organic farming learns from Nature and farmers' experience; 11) Chemical farming benefits traders and industrialists; organic farming benefits the farmer, the environment and society as a whole; 12) Chemical farming robs the self-reliance (and self-respect) of farmers and villages; organic farming restores and strengthens it; 13) Chemical farming progressively leads to bankruptcy and misery; organic farming liberates from debt and woe; 14) Chemical farming is violent and entropic; organic farming is non-violent and synergistic; Chemical farming is a hollow 'green revolution'; organic farming is the true green revolution; 15) Chemical farming is crudely materialistic, with no ideological mooring; organic farming is rooted in spirituality and abiding truth; 16) Chemical farming is suicidal, moving from life to death; organic farming is the road to regeneration; 17) Chemical farming is the vehicle of commerce and oppression; organic farming is the path of culture and co-evolution.

Bhaskar Save's plea for India's agro-ecological resurgence: On 29th July, 2006, Bhaskar Save addressed a detailed 8 page Open Letter (along with six annexures) to M.S. Swaminathan, then chairman of the National Commission on Farmers. This was at a time of an unrelenting wave of farmer suicides in various parts of India, particularly Vidarbha and Andhra Pradesh, but also Punjab, the frontline state of India's 'green revolution', now turned black. Bhaskar Save's Open Letter – widely circulated and translated all over the world (just google and check) – presented a devastating critique of the government's agricultural policies favouring chemical farming, while making an eloquent plea for urgent and fundamental reorientation. Save states, 'I say with conviction that only by mixed organic farming in harmony with Nature, can India sustainably provide abundant wholesome food and meet every basic need of all – to live in health, dignity and peace.' Swaminathan wrote back to Save, 'I have long admired your work and am grateful to you for the detailed suggestions… valuable comments and recommendations. We shall take them into consideration in our final report.'

A further independent Open Letter from Bhaskar Save, dated 1st November, 2006, was sent to the Prime Minister. Save asks in his letter, 'In this vast nation, does any government agricultural department or university have a single farm run on modern methods, which is a net supplier of water, energy and fertility to the local eco-system, rather than a net consumer? But where there is undisturbed synergy of Nature, this is a reality! By all criteria of ecological audit, my farm has only a positive contribution to the health of the environment. Economically too, I get a manifold higher income than 'modern' farmers." The success demonstrated by Bhaskar Save – decreasing and eliminating external fertility inputs while achieving high productivity – is thus a model for promoting food security; and his method of tree-cropping – integrating short life-span, medium life-span and long life-span species – has been hailed as potentially revolutionary for wasteland regeneration, while also offering sustainable and rewarding livelihoods to large numbers of people.

Natural abundance at Kalpavruksha: About twenty steps inside the gate of Bhaskar Save's farm is a sign that says: 'Co-operation is the fundamental Law of Nature' – A simple and concise introduction to the philosophy and practice of natural farming! Further inside the farm are numerous other signs that attract attention with brief, thought-provoking *sutras* or aphorisms. These pithy sayings contain all the distilled wisdom on nature, farming, health, culture and spirituality that Bhaskarbhai has gathered over the years, apart from his extraordinary harvest of food! If you ask this farmer where he learnt his way of natural farming, he might tell you – quite humbly – 'My university is my farm.' His farm has now become a sacred university for many, as every Saturday (Visitors' Day) brings numerous people. These have included farmers from all over India, as also agricultural scientists, students, senior government officials, city folk, and occasional travellers from distant lands, who have read or heard of Bhaskar Save's work. Kalpavruksha compels attention for its high yield and it easily out-performs any modern farm using chemicals. This is readily visible at all times. The number of coconuts per tree is perhaps the highest in the country. A few of the palms yield over 400 coconuts each year, while the average is closer to 350. The crop of *chikoo* (sapota) – largely planted more than forty-five years ago – is similarly abundant, providing about 300 kg of delicious fruit per tree each year.

Also growing in the orchard are numerous bananas, papayas, areca-nuts, and a few trees of date-palm, drumstick, mango, jackfruit, toddy palm, custard apple, *jambul*, guava, pomegranate, lime, pomelo, *mahua*, tamarind, neem, *audumber;* apart from some bamboo and various under-storey shrubs like *kadipatta* (curry leaves), crotons, tulsi; and vines like pepper, betel leaf, passion-fruit, etc. *Nawabi Kolam*, a tall, delicious and high-yielding native variety of rice, several kinds of pulses, winter wheat and some vegetables and tubers too are grown in seasonal rotation on about two acres of land. These provide enough for this self-sustained farmer's immediate family and occasional guests. In most years, there is some surplus of rice, which is gifted to relatives or friends, who appreciate its superior flavour and quality. The diverse plants in Bhaskar Save's farm co-exist as a mixed, harmonious community of dense vegetation. Rarely can one spot even a small patch of bare soil exposed to the direct impact of the sun, wind or rain. The deeply shaded areas under the *chikoo* trees have a spongy carpet of leaf litter covering the soil, while various weeds spring up wherever some sunlight penetrates.

The thick ground cover is an excellent moderator of the soil's micro-climate, which – Bhaskar Save emphasizes – is of utmost importance in agriculture. 'On a hot summer day, the shade from the plants or the mulch (leaf litter) keeps the surface of the soil cool and slightly damp. During cold winter nights, the ground cover is like a blanket conserving the warmth gained during the day. Humidity too is higher under the canopy of dense vegetation, and evaporation is greatly reduced. Consequently, irrigation needs are very low. The many little insect friends and micro-organisms of the soil thrive under these conditions.'

Excluding the two acres under coconut nursery, and another two acres of paddy field, the remaining ten acres of orchard have consistently yielded an average food yield of over 15,000 kg per acre per annum! (This has declined in the past 15-20 years following pollution from progressive industrialization of the area.) In nutritional value, this is many times superior to an equivalent weight of food grown with the intensive use of toxic chemicals, whether in Punjab, Haryana and many other parts of India.

Nature's tillers and fertility builders: It is not without reason that Charles Darwin declared a century ago: it may be doubted whether there are many other creatures that have played so important a part in world history as have the earthworms. Bhaskar Save confirms, 'A farmer who aids the natural regeneration of the earthworms and soil-dwelling organisms on his farm, is firmly back on the road to prosperity.' Earthworms flourish in a dark, moist, aerated soil-habitat, protected from extremes of heat and cold, and having an abundance of biomass. These tireless workers digest organic matter like crumbling leaf litter along with the soil, while churning out in every cycle of 24 hours, one and a half times their weight of rich compost, rich in all plant nutrients.

Vermi-compost is a treasure of fertility. In relation to the surrounding 'parent soil' of the area, the intricately sculpted worm castings may contain twice as much magnesium, five times as much nitrogen, seven times as much phosphorous, and eleven times as much potash. Moreover, the bacterial population in such castings is nearly a hundred times more than in the surrounding soil. The earthworm's burrowing action efficiently tills the land, imparting a porous structure to the soil. This increases its capacity to hold air and moisture, the most important requirements of plant roots. The worm castings too are well aerated and absorbent, while allowing excess water to drain away. They form stable aggregates, whose soil particles hold firmly together, resisting erosion. Various other soil-dwelling creatures – ants, termites, many species of micro-organisms – similarly aid in the physical conditioning of the soil and in the recycling of plant nutrients; and there are innumerable such helpful creatures in every square foot of a natural farm like Kalpavruksha.

In stark contrast, modern agricultural practices have proved disastrous to the organic life of the soil. Many of the burrowing creatures are killed by the toxic effect of the chemicals used, or crushed under the weight of heavy tractors. The consequent soil compaction, resulting from their death, has reduced soil aeration and the earth's capacity to absorb moisture. Often, this is further aggravated by soil-surface salinisation, caused by excessive irrigation and poor drainage.

By ruining the natural fertility of the soil, we actually create artificial 'needs' for more and more external inputs and unnecessary labour for ourselves, while the results are inferior and more expensive in every way. 'The living soil,' stresses Bhaskar Save, 'is an organic unity, and it is this entire web of life that must be protected and nurtured. Natural Farming is the Way.'

Weeds as friends: 'In nature, every humble creature and plant plays its role in the functioning of the eco-system. Each is an inseparable part of the food chain. The excrement of one species is nutrition for another. In death too, every organism, withered leaf, or dry blade of grass leaves behind its contribution of fertility for bringing forth new life.' Consequently, pleads Bhaskar Save – if we truly seek to regain ecological harmony, the very first principle we must learn to follow is, 'Live and let live'. In a country like India, a variety of weeds rapidly cover bare ground with the first showers of the rainy season. When torrential downpours follow as the monsoon progresses, the weeds buffer the hammering force of the raindrops, while their roots bind the soil against erosion. Such soil erosion could otherwise be severe in our tropical conditions, particularly on sloping terrain. Bhaskarbhai thus observes – it is our foolish ignorance that we fail to understand how great a blessing the weeds are!

The roots of the weeds also improve aeration in the passages they make in the soil. Moisture absorption and retention are higher. By shading the ground, the weeds moderate the temperature of the earth, reducing evaporation and maintaining suitable conditions for soil organisms. And when the weeds die, the earthworms, ants and decomposer-bacteria that feed on their dead leaves and roots, return their mineral nutrients to the soil to help the next generation of plants, and the long life-span trees. Weeds may additionally perform a variety of specialised functions. As soil conditions change, there is a natural progression of different kinds of weeds that inhabit the earth. Some are excellent pioneers that steadily work to improve the soil where little else yet grows. Some are leguminous, and provide nitrogen. Yet others may function as reproduction inhibitors of the little insects that sit on them, thereby checking the plant damage that some of these creatures might cause. 'The variety of plants in nature is amazing, and there is no end to learning in the university of the natural farm or forest,' says Bhaskar Save. 'I have seen at Kalpavruksha hundreds of different kinds of species appear on their own in different years and seasons. Among these are plants with known medicinal value. For example, a large number of *punarnava* (or *satodi*) plants appeared in 1992.' These are believed to be excellent for health, and '*punarnava*' literally means 'rejuvenation'.

Bhaskar*bhai* points out that the irrational and violent prejudice against weeds in modern tree cropping can be traced back to our colonial past. In colder, temperate conditions, the bacteria in the soil are fewer and less active. Consequently, the decomposition of residual plant matter in it is much slower. For this reason, most Englishmen were not conscious of the vital importance of weeds and leaf litter in periodically replenishing the fibrous cushion of organic matter in the soil – and also checking erosion – in warm, high rainfall conditions, like ours.

When weed control is needed and how: While weeds, in general, are friends of a farmer, in certain unnatural conditions, some species may become stubbornly rampant. Such weeds may then be a nuisance if they rapidly overgrow the crops planted by the farmer, blocking off sunlight. However, here too, the weeds help check and heal a more fundamental problem – that of soil erosion or impoverishment. They persistently signal to the farmer that s/he is planting a wrong crop in the given circumstances, or growing it in a wrong way, hurting the earth and her creatures. The only sensible and lasting 'root-cure' to situations of weed rampancy among field crops is to adopt mixed planting and crop rotation, while discontinuing chemicals and deep tillage. Since the problematic weeds will only phase out gradually as the soil regains its health, they may still tend to over-shade the food crops in the interim period of recovery. The way to manage this is to periodically cut the weeds (before they flower), and mulch them at least 3-4 inches thick on the soil under the crops. Without any sunlight falling on the weed seeds buried in the soil, their fresh germination is effectively checked.

There may thus be some competition between crops and weeds for sunlight, though not for soil nutrients. If the crops emerge taller, says Bhaskar Save, their shade will suppress the weeds, which will then be unable to cause any problem. This happens naturally in healthy, living, non-acidic soils. Our ancestors have been farming for many generations. But because their soil was healthy, they never faced any serious problem from weeds, even as recently as a few decades ago. There is thus a thumb-rule for seed spacing while planting your crops. If your soil is poor/weak, increase the quantum of seeds you plant. In other words, plant closer. By this stratagem, the crops cast shade on the ground more rapidly, retarding the weeds. If, however, your soil is fairly healthy, plant fewer seeds, that is, keep a larger gap between them. When farmers shift back to organic farming, their soil steadily improves in health each year. Correspondingly, crop growth gets better, while weed growth declines. In just 2-3 years, there should be no need for any weeding at all. Until then, the farmer is better advised to cut and mulch the weeds. The cutting of weed growth above the land surface – without disturbing the roots – and laying it on the earth as 'mulch,' benefits the soil in numerous ways. With mulching, there is less erosion of soil by wind or rain, less compaction, less evaporation, and less need for irrigation. Soil aeration is higher. So is moisture absorption, and insulation from heat and cold. The mulch also supplies food for the earthworms and micro-organisms to provide nutrient-rich compost for the crops. Moreover, since the roots of the weeds are left in the earth, these continue to bind the soil, and aid its organic life in a similar manner as the mulch on the surface. For when the dead roots get weathered, they too serve as food for the soil-dwelling creatures.

The correct mulching method for weed control: Mulching is effective in checking the rapid re-emergence of the cut weeds, only if the mulch layer is thick enough to block off sunlight. For example, the weeds cut from a plot of 100 sq. feet will never provide a thick enough layer to fully cover the entire 100 sq. feet. It may be adequate for 25 sq. ft., or perhaps just 10 sq. ft., depending on the density of weed growth. If sunlight penetrates through a layer of mulch that is too thin (less than 3 inches), the weeds may grow back vigorously again. Moreover, with light mulching, the cut weeds will not come in close, direct contact with the soil, to enable the soil organisms to do their work of decomposition. In such condition, the weeds will just dry up in the air, without getting integrated in the soil as humus. Thus, if 25 (or 10) sq. ft. is the area that can be adequately mulched, at least 3 to 4 inches thick, with the weeds cut from 100 sq. ft., that is what the farmer should stick to, unless additional biomass can be obtained from an external source. The fresh weed growth from the balance unmulched land would again need to be cut and mulched in the selected area. In this manner, the mulch method of shading out weeds can be successful in 4 or 5 stages. The decomposition of the weeds may take several months, but the compost formed will be very helpful for the crop. What was viewed as an enemy, will now serve as friend! It is also important that the cutting and mulching operations should be done before the weeds have flowered and pollinated. If the farmer is too late, and the mulch contains pollinated weed seeds, a new generation of the same weeds will re-emerge strongly in the mulched areas.

Weed control through over-shading plants: The *Dabhro* weed is considered a menace by most farmers. To control it, one needs to plant crops that thickly shade the ground, says Bhaskar Save. No matter how often you remove it, the *dabhro* comes up again from its deep reaching roots. You cannot destroy it this way. Rather, you should plant an over-shading crop like banana at 4 ft by 4 ft, or 5 ft by 5 ft. When these have grown a little, provide them a good quantity of dung manure. The leaves that emerge will span out such that the canopies of adjacent plants will touch, thickly shading the ground and thereby suppressing the *dabhdo*, and gradually destroying it.

Multi-storey, multi-function: Above the ground cover of weeds that constitute the lowest storey of vegetation in the orchard area (where any sunlight penetrates to the ground), there are numerous shrubs like the '*kadipatta*' (or curry leaf, *Murraya koenigii*) and the homely croton that line the pathways through the orchard. The latter plant, of various spotted and striped varieties, is relatively shallow rooted. It serves as a 'water meter', indicating by the drooping of its leaves that the moisture level of the soil is falling! The shrubs of curry leaf contribute to moderating the population of several species of crop-feeding insects, while also providing an important edible herb widely used in Indian cooking. From this minor crop alone, Bhaskar Save earns an income of at least Rs 2,500 each month, grown at zero cost. (Even the harvesting and bundling is done by the purchaser.) Here and there, one might see climbers like the pepper vine or betel leaf in a spiral garland around a *supari* (arecanut) palm, or perhaps a passion fruit vine arching across a clearing. These provide additional bonus yield.

The principles of farming in harmony with nature: 'The four fundamental principles of natural farming are quite simple!' declares Bhaskar Save. 'The first is, "all living creatures have an equal right to live." To respect such right, farming must be non-violent. The second principle recognizes that "everything in Nature is useful and serves a purpose in the web of life." The third principle is: "farming is a *dharma*, a sacred path of serving Nature and fellow creatures; it must not degenerate into a pure *dhandha* or money-oriented business." Short-sighted greed to earn more – ignoring Nature's laws – is the root of the ever-mounting problems we face. "Fourth is the principle of perennial fertility regeneration. It observes that we humans have a right to only the fruits and seeds of the crops we grow."

Plant needs – What? How much?: Dispelling a common misunderstanding, Bhaskarbhai clarifies that the organic matter we add to the soil is not the 'food' of a plant, at least in any direct sense. Rather, it is food for the innumerable soil-dwelling creatures and micro-organisms, which function ceaselessly to maintain the fertility of the land. And there are more micro-organisms in half a cup of good soil than there are humans on earth! Through the digestive processes of the soil dwelling creatures, including earthworms, the organic matter added to the soil gets decomposed into a progressively more inorganic or mineral form. The mineral rich excreta of these creatures must then dissolve in moisture, before being absorbed by the roots of plants.

More serious yet is the misconception about *how much* of the minerals or water is needed. Bhaskar Save never tires to emphasize that plants are actually *mitahari*, or very small consumers of the nutrients in the soil. Sunlight and air are what they need in abundance, while the moisture requirement of most plants – barring aquatic and semi-aquatic species like mangroves and rice – is best met when the soil is just damp rather than soaked. Since India has no lack of sunlight, it is the porous, humus-covered soils that absorb and hold more air and moisture, which are the most productive in giving a sustained, high yield of biomass. This is ancient knowledge, though less understood these days.

Scientific analysis confirms that approximately 88% of the weight of a plant – or any organic matter – consists of just carbon and oxygen, with roughly equal contributions of about 44% each. Much of these two elements is drawn by the plant from atmospheric carbon dioxide, absorbed through minute pores or stomata in the underside of leaves. Hydrogen, drawn from moisture, is third in the list and contributes about 6% of the plant's weight. The moisture also provides some of the oxygen, as does the air contained in the pores of the soil. These three main elements – carbon, oxygen & hydrogen – obtained from air and moisture, together form about 94% of the entire weight of a plant! They are combined together into living matter in the presence of sunlight by a process called photosynthesis.

It is important to understand that though the principal needs of plants are originally derived from air and moisture, a considerable part of these may be drawn via the soil and the root system. Hence, the physical condition and absorptive quality of the soil is far more vital than its chemical or mineral composition typically over-emphasized by modern agriculture. Where the porosity, or internal pore space of the soil is high – as in all good, living soils characterized by a granular, 'crumb structure' – this enables it to hold enormous reserves of both air and moisture. Such a condition – known to local farmers as *waafsa* – where dampness and air (also warmth) are simultaneously present in the soil, is ideal for plant growth.

This was recognized by outstanding agricultural scientists like Sir Albert Howard. His book, *An Agricultural Testament* (1940), is hailed as a classic, but its contents were too inconvenient for the agribusiness interests of his time to acknowledge. While today, many in western countries look upon Howard as a 'pioneer' in sustainable, organic farming, he himself confessed that he learnt it all from the simple, peasant farmers in India.

Continuing with the list of the 'building-blocks' required by a plant, nitrogen comes a distant fourth, contributing between 1 to 2 per cent of its weight. This element, abundant in the air, is made available in the soil through the action of billions of rhizobia – the micro-organisms that dwell in the root nodules of leguminous plants. Nitrogen is also supplied when dead organic matter is broken down in the soil, under the action of even larger numbers of decomposer bacteria. Less than 5 per cent of the weight of a plant originates in the various other mineral nutrients provided by the soil itself. These are elements like phosphorous, potassium, calcium, silicon, magnesium; and a number of trace elements or micronutrients required in very minute quantities, such as iron, copper, zinc, boron, cobalt, manganese, etc.

The earthworm castings in a mixed natural farm or forest provide an abundant supply of these minerals and trace elements. Myriad other animals, birds, insects and micro-organisms (bacteria, fungi, molds etc.) add their contribution in recycling nutrients to the soil. In fact, every creature – in excretion and in death – is an integral part of the continuous fertility cycle of nature.

Additionally, deep-rooted trees draw up fresh supplies of minerals dissolved over time from the underlying parent rock or sub-soil. Thus a farmer, who is mindful of the natural, biological processes of fertility regeneration, scarcely needs to bother about the chemical analysis of his soil. The important thing is to religiously return all crop residues and bio-wastes to the earth. Any pronounced 'nutrient deficiency' in the topsoil – often caused by cash-cropping monocultures – then becomes largely corrected in a few years by reverting to mixed cropping. Of course, checking soil erosion and shunning agro-chemicals is also essential.

Unfortunately, in present times, much of our bio-wastes are literally wasted, instead of being returned to the farmlands. And all the plants grown in monocultures – year after year, in the same plot – draw the same mineral nutrients from the same level of the soil, depleting these. Most problems of 'nutrient or micro-nutrient deficiency' in the soil today, unimaginable in most parts of the world just a hundred years ago, are a direct result of these two factors. And we must remember that farmers in India, China, Japan and Korea have been growing their crops for well over forty centuries. India, according to some, has a 10,000 year old history of sustainable agriculture!

In tropical and sub-tropical regions, the rate of decomposition of organic matter is much faster than in the temperate climates of Europe or most of USA. In particular, the hot, humid conditions in the wet tropics cause high bacterial activity in breaking down the bio-residues that come in contact with the soil. Thus an abundance of mineral nutrients is recurrently available for the plants.

However, during tropical monsoons, the newly recycled nutrients near the surface of the topsoil are also prone to rapid erosion and leaching under strong rain or wind. This makes it all the more imperative to have a protective ground cover of vegetation, and to constantly replenish the organic matter (leaf litter, crop residues, etc.) on the surface to bind the soil under a carpet of humus.

In contrast, the problems caused by agro-chemicals are less severe and show up more slowly in the temperate conditions of Europe or USA. Not only are there fewer decomposer bacteria in the soil, the snowfall in winter conserves organic material underneath, further retarding its break-down into inorganic minerals. This is why the organic matter status of soils in temperate countries is much higher. Because of this extra cushion of carbonaceous material, the soils have a larger capacity to absorb artificial nitrogen. While chemical inputs hasten the decomposition process in temperate lands as well, they do not deplete the soil of its organic content as rapidly as they do in the tropics and sub-tropics, where the natural rate of decomposition is already high. Nor are there torrential monsoon downpours, as in many parts of India. Consequently, both the eroding and polluting effects of chemical fertilizers are much slower and less visible in temperate climates. Caution was recommended even in temperate countries through the combined use of considerable quantities of organic manure along with the chemicals. The farmers were moreover taught to exercise precision in the dosages and ratios of their inputs. Nonetheless, the West seems to be witnessing a significant turn-around from chemical methods. The movement towards organic farming is picking up faster than one would have imagined a few decades ago.

Do nothing?: While the physical work on a natural farm is much less than on a modern farm, regular mindful attention is a must. Hence the saying: ‘The footsteps of a farmer are the best fertilizer to his plants!’ In the case of trees, this is especially important in the first few years. Gradually, as they become self-reliant, the work of the farmer is reduced – till ultimately, nothing needs to be done, except harvesting. In the case of coconuts, Bhaskarbhai has even dispensed with harvesting. He waits for the coconuts to ripen and fall on their own, and merely collects those fallen on the ground! For growing field crops like rice, wheat, pulses, vegetables, etc., some seasonal attention, year after year, is unavoidable. This is why Bhaskarbhai terms his method of growing field crops – organic farming, while a fairly pure form of ‘do-nothing natural farming’ is only attained in a mature, tree crop system. However, even with field crops, any intervention by the farmer should be kept to the bare minimum, respecting the superior wisdom of nature, and minimizing violence.

The five concerns of farming: Bhaskar Save summarizes the key practical aspects of his approach to natural farming with reference to the five major areas of activity that are commonly a preoccupation of farmers all over the world. These are tillage, fertility inputs, weeding, irrigation, and crop protection.

Tillage: Tillage in the case of tree-crops is only permissible as a one-time intervention to loosen the soil before planting the saplings or seeds. Post planting, the work of maintaining the porosity and aeration of the soil should be left entirely to the organisms, soil-dwelling creatures and plant roots in the earth.

Fertility inputs: The recycling of all crop residues and biomass on the farm is an imperative for ensuring its continued fertility. Where farm-derived biomass is scarce, initial external provision of organic inputs is helpful. However, no chemical fertilizer whatsoever should be used.

Weeding: Weeding too should be avoided. It is only if the weeds tend to overgrow the crops, blocking off sunlight, that they may be controlled by cutting and mulching, rather than by uprooting for ‘clean cultivation’. Herbicides, of course, should never be used.

Irrigation: Irrigation should be conservative, no more than what is required for maintaining the dampness of the soil. Complete vegetative cover – preferably multi-storied – and mulching greatly reduce water needs.

Crop protection: Crop protection may be left entirely to the natural processes of biological control by naturally occurring predators. Poly-cultures of healthy, organically grown crops in healthy soil have a high resistance to pest attack. Any damage is usually minimal, and self-limiting. At most, some non-chemical measures like the use of neem, diluted *desi* cow urine, etc., may be resorted to. But this too is ultimately unnecessary. By thus returning to Nature many of the tasks that were originally hers, a weighty burden slips off the back of the half-broken, modern day farmer. And the land begins to regenerate once more.

Why the agro-chemical path is suicidal: As mentioned earlier, organic matter decomposes much faster into inorganic minerals in our tropical conditions, compared to temperate lands. The artificial supply of chemical nutrients is thus not only quite unnecessary; it is particularly harmful. Adding a nitrogenous fertilizer like urea further hastens the process of decomposition, depleting the soil's fibrous cushion of organic matter. The loss of this protective buffer then heightens the susceptibility of the soil to erosion and the leaching of nutrients, which assume alarming proportions during torrential downpours of the tropical monsoon. In any case, the inorganic compounds in synthetic fertilizers contain just a few of the chemical elements required by plants. These few are supplied in a concentrated form. Since the plants cannot immediately absorb all that is provided, the nutrients are subject to high losses. But far more significantly, the toxic chemicals harm the organic life of the soil. Pesticides, in particular, are murderous to the soil micro-fauna, earthworms, etc. As an inevitable consequence of the loss of the soil conditioning (tillage) action of these creatures, the porous granular structure of the soil collapses, expelling all the air from it.

Numerous other problems follow. Artificial tillage and irrigation needs are increased; 'pests' multiply. With spraying, they soon develop resistance to the pesticides, leading to the use of stronger poisons. But the natural predators of the pests get wiped out. Helpful pollinating agents like the bees are similarly exterminated. Micronutrient deficiencies and plant 'diseases' increase in incidence; while toxic residues in the food harvested reach dangerous levels. Where before, everything worked smoothly in Nature, man's 'cleverness' now brings upon him a lot more work and worry. After the British quit India, and the partition trauma eased somewhat, Indian farming had a 15 year respite. From the mid sixties, India slipped relentlessly into the path of monocultural chemical farming.

M.S. Randhawa – retired vice president of ICAR, who himself promoted this method – adds, 'As (this) crop production technology is mainly dependent on *progressively larger* use of fertilizers, the gap between the availability and demand is going to widen.' In his first Open Letter to Swaminathan, Bhaskar Save drew attention to the engineered erosion of crop diversity, the consequent scarcity of organic matter, and the progressive degradation of our soils. He states, 'Our numerous tall, indigenous varieties of grain – adapted over millennia to local conditions and needs – provided more biomass, shaded the soil from the sun, and protected against its erosion under heavy monsoon rains. But in the guise of increasing crop production, exotic dwarf varieties were introduced and promoted.' Wendell Berry, a perceptive thinker, organic farmer and writer states: 'When we change the way we grow our food, we change our food, our values, our society. Natural farming is about healing our relationships.' Bhaskar Save adds: 'Non-violence, the essential mark of cultural and spiritual evolution, is only possible through natural farming.'

The mind-boggling cost of soil erosion: Presently in India, when rivers are in spate as the monsoon intensifies, many of them turn murky brown or red. This is the colour imparted by the huge amounts of topsoil bled from higher catchments of the river valley. Most of such eroded soil is flushed down to the sea and is irretrievably lost. Only a small fraction of it gets deposited in deltas. And what gets deposited on the riverbed reduces its water holding capacity, increasing the possibility of the river over-spilling its embankments and aggravating floods during heavy rains. Already a couple of decades ago, India's Sixth Plan document observed that 150 million hectares of land are seriously affected by soil erosion caused by rain and wind. The current figure is perhaps closer to 200 million hectares. 'The Gaia Atlas of Planet Management' estimated in 1984 that Asia as a whole is losing 25 billion tonnes of topsoil each year! Closer home, the Indian Council of Agricultural Research reported that in the state of Maharashtra, more than 70% of the cultivated land has been affected by erosion in varying degrees, and 32% of the land is so highly eroded that it is no longer cultivable.

On sloping land, unprotected by vegetation, more than one hundred tonnes of soil per hectare can be eroded in a single monsoon, especially in high rainfall zones like the Konkan belt! With acceleration under gravity, there is a rapid build-up of momentum as eroded soil moves down-slope. A mere doubling of velocity can then multiply sixty-four times the size of the soil particles that can be dislodged and transported by the floodwaters. Dr. Murthy and Dr. Hirekerur, directors at the National Bureau of Soil Survey, ICAR (now retired), lament that 'if erosion is permitted to continue at this rate, it is possible that all future work will be the reclamation of soil, rather than the conservation and management of soil and water!'

According to B.B. Vohra, former Indian Minister of Water Resources, this nation's loss of topsoil, eroded by water run-off alone, was around 12,000 million tonnes per annum in 1985. The current figure probably exceeds 15,000 million tonnes. At a notional token value of just ten paise (or one-fifth of a cent!) per kg of topsoil – though even lifeless sand used for construction costs much more – the consequent loss works out to Rs 150,000 crore *every year*, making a total mockery of this country's balance sheets presented at annual national budgets and Five Year Plans! Since topsoil loss represents a permanent depletion of a vital natural resource, a slightly more sensible valuation at Re 1 (or barely two cents) per kg would indicate that we are losing soil capital worth a staggering Rs 15 lakh crore or over 350 billion dollars – every year! According to Drs. Murthy and Hirekerur, the available data on run-off and soil loss under different soil, climatic and slope conditions clearly indicate that if the land is left undisturbed under a natural cover, the run-off and soil loss are the least. But once the vegetation is removed and the land is ploughed (especially for chemical mono-cropping), the soil loss may increase a hundred fold (10,000%) under conditions like sloping terrain receiving heavy rainfall.

'Children,' reminds Save, 'have a birth-right to suckle the sweet, wholesome milk from their mother's bosom! But tragically, our modern, rapacious way of farming, rampant industrialism and consumerist culture draw on Mother Earth's life-blood and flesh. How then can we hope to receive her continuing nourishment?' More urgently than ever before, we need to heed the exhortation of K.M. Munshi, the first Agriculture Minister of free India. Five decades ago, he repeatedly emphasized that restoring the soil nutrient cycle and hydrological cycle in every village and bio-region is the paramount challenge we face for safeguarding the well-being of this land and her inhabitants. By far the most efficient in conserving and regenerating both our soils and our groundwater – while also mitigating climate change – are our natural forests, and the mixed organic tree-cropping systems, like those raised by Bhaskar Save and his family.

In conclusion, says Save, 'Natural farming is blessed by Annapurna, the mother goddess of abundant food for all that lives.' A residential learning centre on natural farming will start in a few months at Bhaskar Save's farm.

Organic Farming and Food Security: A Model for India

C P S Yadav and Harimohan Gupta

Agriculture is life and blood of our country's economy. It was highly gratifying that India achieved self-reliance in food production in the shortest span of time in the world, but despite everything, our traditional agro system suffered a great setback, especially owing to the indiscriminate use of fertilizers, insecticides, fungicides and herbicides. This has also created the problem of decline in the soil fertility, pollution of water resources, and chemical contamination of food grain. There is an urgent need to take a holistic view of this problem to curb its negative impact. Organic Agriculture is a major pillar for sustainable Agriculture and an answer to our problem of environment degradation, unsafe food, polluted water, degraded land and wide range of illness due to unsustainable Agriculture practiced in the recent past.

The organic agriculture is not only the need of the hour but also a timely answer to the problems of environment-degradation, unsafe food, polluted water, degraded land and a plethora of agro-maladies emanating from unsustainable agro-system. It hardly needs reiteration that organic agriculture can ensure maintenance of soil health, protection of the environment and sustaining of crop productivity. Furthermore, organic agriculture in keeping with the traditional Indian agro-system not only maintains ecological balance but also ensures sustainability in terms of food production and safeguarding the human health. From the very beginning, the agriculture in India was based on natural farming, meaning thereby that whatever nutrients were drawn from the soil in the form of agricultural produce were returned to the soil in some form or other, as a result all nutrients required for production of crops were always available in the soil in plenty. Thus, the productivity of the soil was maintained and there was no need to add any inorganic nutrient into the soil from outside.

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There may be people who feel that by switching over to organic farming the production will decrease. Yes, this may happen in the initial 3–5 years. The reason for this is that during past 50 years, we have drawn out most of the nutrients from the soil by practicing intensive agriculture. Today when we shift to organic farming, it will not be possible to maintain the nutritional balance in the very first year but in subsequent year, the soil fertility status will improve and by 5 years the production will reach to pre-organic level and may increase above it in the years to come. Once this situation is reached, it will remain sustainable year after year. The pest and disease problems will also be minimized, the number of irrigation will also come down and most of the living forms like earthworms will return to the soil to add to the fertility and to improve its health. This way, the organic farming will cut down the cost on fertilizers, micronutrients, pesticides and irrigation. As a result the overall cost of production will be reduced and farmer will get more economic return with less investment. Besides this, the organic products do not cause any harm to human health and the health of domesticated animals like cattle, goat and sheep. If health improves the expenditure on medicine will be reduced. Analyzing the economic aspects of organic agriculture, it can be mentioned that marketing of healthy produce from agriculture will earn additional revenue to the farmer and will cut down the cost of inputs needed for such production. Further, there will be gradual improvement in the fertility status of the soil, which will yield more produce per unit area. In sum total, there will be considerable economic benefit on long-term basis and farmer will get rid of maladies associated with the market purchased inputs.

On the cost of soil health if we continue to practice intensive agriculture without making proper nutritional management through organic process the soil will soon become infertile and dead. The produce from chemical treated soil and crop will adversely affect the human health and diseases of different types will appear. In support of this let us take the example of Punjab state. In this state plenty of water is available for irrigation. In greed for taking more yield and benefit, the farmers have made excessive use of chemical fertilizers. There is no doubt it increased the production of wheat and paddy but now 25 per cent of Punjab population is suffering from diabetes. The probe into such happening indicated considerable zinc deficiency in the diet of Punjab people which may have been one of the factors responsible for this. The zinc deficiency is mainly attributed to continuous drain of zinc from soil following excessive use of fertilizers. Likewise, excessive use of pesticides has been responsible for diseases like cancer. Forty year ago in the state only few shops of chemist were there. Today in every village there is one or more shop. It is a testimony of the fact that because of excessive use of chemicals in agriculture, the food, water, soil and air have been polluted to the extent that it has adversely affected the human health in spite of the fact that food availability per capita has increased as compared to past 40 years.

In brief it can be concluded that if one shifts from chemical agriculture to organic agriculture, in the first year there may be 30–40 per cent loss in production which will come down to 15–20 per cent in the second year and 5–10 per cent in the third year. This loss will be compensated by additional income the farmer will get by marketing good quality organic produce. In subsequent years the production will reach the pre-organic level and may increase further over the years. Some loss will also be compensated by lower cost of input in organic agriculture. It first happened in Brazil. And even the internationally acclaimed agricultural scientist, Novel Laureate Dr. Norman Borlaug, could not first believe it. To grow a bumper crop of soybean and that too without chemical fertilizers, it was beyond the imagination of Dr Borlaug. Prof. Johanna Dobereiner of the Third World Academy of Sciences persuaded Dr. Borlaug to visit Brazil and see the miracle in crop cultivation without Nitrogen fertilizer. Almost the entire soybean crop in Brazil today is grown without the application of Nitrogen fertilizers. And unlike the soybean growing tracts of India, which suffer from excessive usage of fertilizers, the entire soybean growing belt in Brazil is healthy, shows no sign of degradation and fatigue. In other words, absence of Nitrogen fertilizers has encouraged sustainable cultivation of soybean.

Necessity is the mother of invention. With Nitrogen fertilizers not subsidized in Brazil, and obviously priced beyond the reach of farmers, soybean growers were left with no choice but to depend upon organic sources. Agriculture scientists too were forced to undertake research on increasing the efficiency of organic manures. As result of not applying synthetic Nitrogen, Brazil is incurring an annual saving of US $3.2 billion. Soybean is not the only crop that grows without any application of artificial Nitrogen. Sugarcane too has emerged as a key to high energy balance with the elimination of Nitrogen fertilizers for the production of bio-energy. Brazil has transformed its rural economy by producing ethanol from sugarcane as an alternate fuel for motor vehicles. The vehicles running on alcohol are far less damaging to the environment, emitting 57 per cent less Carbon monoxide, 64 per cent less hydroCarbons and 13 per cent reduced Nitrogen peroxide than cars running on gasoline. The ethanol fuel now runs four million cars, saving equivalent of 2,60,000 liters of petrol per day.

Scientists meanwhile succeeded in isolating a soil bacterium that helped in the increased uptake of plant nutrients from organic manure. With the result that sugarcane varieties under cultivation are receiving the highest bacterial Nitrogen fixation, directly from the atmosphere, among all non-legume crops. When grown with ample doses of Phosphorus fertilizer and with foliar application of Molybdenum, the crop takes about 150 kg of Nitrogen directly from the atmosphere. Selecting the favourable genotypes resulted in some of the best sugarcane varieties that can produce enough without the intake of Nitrogen fertilizers. And still, the crop yields in semi-organically farmed sugarcane in Brazil are much higher than that of the chemically fertilized crop in India. From 4.2 million hectare, Brazil harvests on an average 64 tones of sugarcane per hectare. Between 1971 and 1981, the initial years of the Green Revolution, excessive intake of chemical fertilizers had led to an increase in the nitrate content of ground water by two and a half times. The seriousness of the problem lies in the fact that once nitrates get into aquifer, it will be decades before the nitrate level in the water falls below the acceptable limit for drinking. High levels of nitrates in drinking water are not only unsafe and cause birth defects but may also lead to nervous breakdown and cancer. Contamination of soils by heavy metals like cadmium through phosphatic fertilizers is yet another hidden threat. And more recently, fertilizers have been found to be playing a significant role in extending the Ozone hole.

Let us now examine the emerging barriers to crop sustainability. Punjab has often been hailed as the country's granary. The land which once produced a rich golden harvest is now beginning to collapse under its own artificial burden of intensive cultivation. The warning bells have been sounding for quite some time and have gone unheeded – intensive cultivation of wheat and rice has already exhausted the nutrient reservoir of the soil. The indiscriminate marketing of chemical fertilizers, without the accompanying doses of organic manures, has drastically reduced the soil fertility. With the organic content of soil hovering around a pathetically low of >0.2 per cent, Punjab soils are getting increasingly dependent on chemical fertilizers. A Government task force in 1979, comprising scientist and economists, concluded that 'some farmers actually experienced no reduction at all when they gave up the use of chemicals. And those who did, lose some production still made more money because they didn't have to pay for expensive chemicals.' In another study conducted by the Centre for the Study of Biological Systems, University of Washington at St. Louis, two groups of farms with similar soil and environmental conditions, with one using chemical and the other without it, were evaluated for five years. The study concluded: 'A five year average shows that the organic farms yielded, in dollars per acre, exactly the same returns. In terms of yield, the organic farms although yielded 10 per cent less but gave similar profits due to savings on cost of chemical inputs'. Now, before any opinion is made, don't forget that the comparison was between a no chemical farm and an energy efficient farm the likes of which do not exist in India. In Indian context, such study would have been clearly in favour of an organic farm. In any case, it is better to harvest 10 per cent less from a farm than be faced with a near collapse of the farming system.

The answer, therefore, lies in following a non-chemical integrated plant nutrient management system which reinforces the role of organic matter in soil. Since much of the damage to the soil structure and fertility, and the contamination of ground water, is the result of excessive fertilizer usage, the industry need to be made responsible for the damages and also accountable for any further destruction of the soil system. Besides above, for revolutionary change to organic agriculture establishment of Gobar Gas Plants will be a sustainable option in India's context. A model for optimum utilization of available organic material dove tailing with Livestock development and conservation is given hereunder. In other words in this script we have advocated for organic farming, through Livestock Production. For a cluster of 100 Hectares of land, it would need 400 animals especially indigenous milking cows and 200 cubic meter capacity Gobar Gas Plant on community basis. These Gobar Gas plants can even be run and maintained by the panchayats. The Gobar slurry from the plant so obtained will have twice the value of nutrients and simultaneously make available Gobar Gas for cooking or even for lighting. Where there is difficulty in establishing community Gobar Gas Plants, small individual Gas Plants of 5 to 10 Cubic meter may be established which will also give same benefits.

In this sustainable model subsidy on all the components would be a better option than the Nutrient based subsidy. In nutrient based subsidy the money instead of benefiting the farmers will go in the coffers of the fertilizer companies. To get the Micro nutrient analysis of the soil done for every farmer's field it would need around 1,00,000 soil testing laboratories which is not possible in distant future. In proposed cluster low cost input alternative in first year simultaneously sow three different types of legumes in strips, first of 60 days (like moong) second of 90–120 days (cow pea or soyabean) and third of more than 120 days (red gram) in strips. Nutrient management is done by using NADAP compost, Vermi compost, PROM compost, enriched with Azotobacter, PSB, and Rhizobium. Frequent use of Beejamrut and Panchgavya and soil enrichment formulations such as Sanjivak, Jivamrut, Amrit-Pani has also been found to be useful. Pest management is ensured through cultural, mechnical and Biological alternatives. Use of Biopesticide, Botanical Pespicide like Neem and its preparations, cow urine, Fermented curd water, Dasparni extract, Chilli-garlic extract etc can be used as prophylactics.

Model of food security for India: Government of India is making all efforts to ensure food security to its people. In doing so it has provided sizeable state support for keeping fertilizers affordable to farmers. Quantum of fertilizer subsidy during last few years is given in Table 1. The pattern of Government support on every 50 kg fertilizer bag is given in Table 2 (as mentioned by the then Minister of Fertilizers and Chemicals during 2008–09).

Table 1. Yearly Quantum of fertilizer subsidy between 2000 and 2012

Year	Amount Rs. (in crores)
2000–2001	13,800
2001–2002	14,170
2002–2003	14,858
2003–2004	15,252
2004–2005	15,779
2005–2006	18,299
2006–2007	25,952
2007–2008	40,338
2008–2009	98,450
2009–2010	52,000
2010–2011	70,012
2011–2012	65, 974

Source: Union Budget 2013–14, Govt. of India

Table 2. Pattern of Government support provided for each bag of fertilizer

Fertilizer	Govt. support (per mt in Rs.)	Each 50Kg bag of Fertilizer (in Rs.)
DAP	49234.00	2468.00 (domestic and imported both)
UREA	28336.00	1460.00 (imported urea)
MOP	31108.00	1550.00 (not produced)
NPK	36722.00	1837.00 (domestic)
SSP	8134.00	407.00 (domestic)

Source: Union Budget 2013–14, Government of India

If this support is reduced, the cost of food commodities will go up. On this ground the state support is being justified and continued and on this logic no one would like to speak against it as this is likely to put the food security in danger. This has also been made amply clear by the scientists not only in India but world over that excessive and continued use of fertilizers may make soil unproductive and barren if corrective measures are not taken in time. Under such scenario and no alternative solution in sight, the food security may again be threatened in coming 40 to 50 years and how the continued availability of food grains to feed the 1.50 billion people of the country will be ensured is not clear.

The Government of India's stand to keep the state support going on the fertilizer is justified on the ground that the entire 14 crore ha cultivable land can not be brought under organic farming over night and organic matter in the form of dung urine and crop residues etc. can not be generated to meet the need of entire cultivable land. Also there is possibility of 30–40% reduction in yield in the 1st year of shifting to organic farming. As per Govt. of India estimates of Rs. 2 lakh per ha conversion cost to organic farming, if we convert India's 1% cultivable land (1% of 14 crore ha) i.e. 14 lakh ha. crop area, then Rs 28,000 crore additional state support will be needed. If 50% of this state support i.e. Rs. 14,000 crores is spent on live stock development and Rs. 25,000 per milch animals is provided to individual farmer then 14 lakh small and marginal farmers will get 56 lakh milch animals @ of 4 animal per ha. In other words milk, dung and urine of four animal per ha will become available continuously. These farmers on being converted to organic even if face 30–40% reduction in grain yield will get the following additional produce to compensate the loss.

Milk at the rate of 7.5 liter per day/ animal, will yield 30 liter milk per day for 8 months. Annually 7200 liter milk @ Rs. 20 will give an additional income of Rs.1,44,000 per year. On the other hand expenditure on feed, fodder and labour per day/ animal will be (Rs.80 per animal per day, for 4 animals Rs. 320 per day, 9600 per month) Rs. 1,15,200 per year. The income from milk per year (Rs 1,44,000) minus the expenditure of Rs.1,15,200 per year will give a net profit of Rs. 28,800 with milk alone. Gobar per animal per day will be 10 kg. From four animals it will be 40 kg per day and 14,400 kg/ year. With this gobar, desi khad worth Rs.15, 000 can be produced without any extra cost. From above khad following nutrients will become available to the farmer for use in his farm (Table 3).

Table 3. Nutrient availability from desi khad made from the dung of 4 animals

Nutrients	Percentage	Total nutrients
Nitrogen	1.5%	216 kg.
Phosphorus	1%	144kg.
Potash	1%	144kg.
Total		504 kg. + micronutrients

At the present rate of recommendations per ha/year in Rabi, (Wheat) and Kharif (Paddy) the state support on fertilizer is worth Rs. 20,000 per year. In lieu of this the farmer gets 80 quintal (wheat+paddy), the market value of this produce is Rs. 96,000/– (@ Rs.1200/Qtls approx). If Government stops this support of Rs. 20,000 on fertilizers to farmers then on the basis of 40% yield reduction under organic farming, the farmer will get only Rs. 76,000 per year. This reduction in income due to yield loss will be compensated by additional income the farmer will get from milk and cow dung etc. which will amount to Rs. 43,800 (28,800 from milk and 15,000 from cow dung etc.), therefore farmer will earn additional net income of Rs. 7400 over wheat and paddy if he would have adopted organic in the first year. Five years fertilizer subsidy @ 20,000 per year equals Rs. 1 lac. If Govt assistance is provided to the farmer to purchase 4 milch animals in the very first year then the related impact will be as shown in Table 4.

Table 4. Yield reduction and return in organic farming over 10 years period

Year of organic	Yield (%)	Value of reduction/ increase in yield (in Rs.)	Additional income from milk and cow dung (in Rs.)	Gain (in Rs.)
1	– 40	–38400.00	43800.00	5400.00
2	–30	–28800.00	43800.00	15000.00
3	–20	–19200.00	43800.00	24600.00
4	–10	–9600.00	43800.00	34200.00
5	Nil	–	43800.00	43800.00
6	+5	+4800.00	43800.00	49600.00
7	+10	+9600.00	43800.00	53400.00
8	+15	+14400.00	43800.00	58200.00
9	+25	+24000.00	43800.00	67800.00
10	+25	+24000.00	43800.00	67800.00

As is proposed in the Table 4, if the total subsidy to be provided on chemical fertilizer over a period of five years is provided to all the farmers for purchase of good Indian breeds of cows @ of Rs. 25,000 per milch animal amounting to Rs. 1.00 lakh then by 5th year by making use of the gober (dropping) of these milk animals, he will prepare compost, NADEP compost, vermicompost and other bio inputs and the production per ha will level up in 5 years and in 6th years there will be additional income of Rs. 48,600/– from milk and dung where as by providing a subsidy of Rs. 20,000/– on fertilizers no additional profit will accrue, instead the amount of subsidy on fertilizer will increase over time with concomitant adverse impacts.

In the proposed model the food security is built because the milk and gobar obtained from the milch animals will compensate for the yield losses or it may even be more than that. Milk in itself is a complete food and gobar and urine are very useful sustainable bio inputs for crops. This model can be considered as 100% sustainable agriculture model. It has no risk involved for food security. Simultaneously it is eco-friendly as well as health friendly. The specialty of this model will be that Govt. of India will get a permanent relief from fertilizer subsidy over a period of time. Also the farmer adopting this model will earn additional income of Rs 66,800/year/ha in 10th year and the fertility of the field will increase thereby the yield will increase by 25% hence food security will increase and by 10th years the number of animal will increase to reach a number of 13 animals. The increase in animal population has been indicated in Table 5.

Table 5. Increase in number of animals from 5 to 10 years

Year	No. Milk animal	Milk animal raised	Additional income in Rs.	Area brought under organic farming in ha.
1st year	4	–	–	1.00
2nd year	4	–	–	1.00
3rd year	4	–	–	1.00
4th year	6	2	50000	1.50
5th year	6	–	–	1.50
6th year	6	–	–	1.50
7th year	9	3	75000	2.00
8th year	9	–	–	2.00
9th year	9	–	–	2.00
10th year	13	4	100000	3.00
Total :–	13	9	225000	3.00

As is evident from Table 5, a farmer who receives a subsidy of Rs. 1.00 lakh in the 1st year will be owner of 13 milch animals by the 10th year. With these additional 9 milch animals 2 ha additional land will be brought under organic farming from non organic chemical intensive farming. If this continues then in coming 40–50 years the entire country can be brought under organic farming with residue free food, healthy soil and clean environment.

In an alternative model (Table 6) it is proposed that if a farmer is provided interest free loan of Rs. 1.00 lakh for purchase of 4 milch animals then as per proposed model from 5th year to 8th year at a rate of Rs. 25,000 per year he will repay the entire loan amount to the Bank. After that he will continue to get additional income.

Table 6. Alternative model for animal procurement through interest free loan

Year of organic	Yield (%)	Value of reduced yield (in Rs.)	Additional income from milk and cow dung (in Rs.)	Gain (in Rs.)	Repayment Of interest free loan (In Rs.)
1	– 40	–38400.00	43800.00	5400.00	Nil
2	–30	–28800.00	43800.00	15000.00	Nil
3	–20	–19200.00	43800.00	24600.00	Nil
4	–10	–9600.00	43800.00	34200.00	Nil
5	Nil	–	43800.00	43800.00	25000.00
6	+5	+4800.00	43800.00	49600.00	25000.00
7	+10	+9600.00	43800.00	53400.00	25000.00
8	+15	+14400.00	43800.00	58200.00	25000.00
9	+25	+24000.00	43800.00	67800.00	Nil
10	+25	+24000.00	43800.00	67800.00	Nil
Total					100000.00

Now the question will arise that, for 1% cropped area (14 lakh ha) out of 14 crore cropped area of the country, if four milch animals/ha are to be provided then from where such a large number of animals i.e. 56 lakh will be managed to implement the proposed model. Not only this, many other question will be raised such as, whether the Govt. of India will be able to earmark a budget of Rs. 14000 crores or farmers will accept the model or what will be the scenario if milk supply is increased. Here for this sustainable agriculture model, we only would like to mention that during past 10 years Govt. of India had spent Rs. 4,18,220 crore on fertilizer subsidy (Table 1) and additional

70,000 crores on waving of the loan amount taken by the farmers but in spite of all this, there has been an increase of only 311 kg/ha (Table 7) in food grain yield over this period. If the calculation of this increase in yield is worked out further then it will come to barely 31 kg per ha/year which itself rings the danger bell for food security.

As per proposed model of sustainable agriculture for 14 lakh ha land support of Rs. 14,000 crores for 56 lakh improved breed of milch cattle to the farmers can eliminate the need for fertilizer subsidy forever for that land and can ensure food security and environmental safely.

Table 7. Status of cereal production in some countries

Countries	Population (x100000)	YEAR 1994–96			YEAR 2006			Yield increased/ decreased Kg/ha	Availability/ capita/day (In gm)
		A	P	Y	A	P	Y		
Bangladesh	16,22.2	10770	27883	2588	11799	44790	3796	(+)1208	756
Brazil	19,24.02	19099	46818	2451	18424	59159	3210	(+)753	1027
China	1,33,55.3	90106	422930	4693	83725	444055	5303	(+)610	890
India	1,17,63.6	99978	213568	2136	99006	242887	2453	(+)311	564
Japan	12,75.30	2340	14526	6208	2006	11742	5853	(–)345	252
Pakistan	16,85.94	12269	24256	1977	12897	32864	2548	(+)571	534
Russia	14,19.27	51065	69380	1359	40574	76866	1894	(+)535	1482
South Africa	49,32.05	5652	12388	2191	3011	9454	3140	(+)943	5626
America	30,85.74	62862	323073	5440	52875	338513	6402	(+)962	2989

Area(A) –1000 ha Production (P) –1000 MT Yield (Y)–Kg/hac.

Source: 1. Statistics Division FAO 2009 (Area harvested, production and yield),
2. List of countries by population–Wikipedia–The Free Encyclopedia

If the Government decides to test the validity of this sustainable model, then such models can be run in each state in a cluster of 100 ha for 5 years (the mark of yield to level-up).

After this for implementation of this sustainable model subsidy provision as indicated in the model be made. This model can also be tested over a small unit of 100 ha in an area where farmers are using 1 tonne of chemical fertilizer per ha per year and claim subsidy of more than Rs. 50,000 on fertilizer.

The Full Value of Organic

K C Raghu

"A man who knows the price of everything and the value of nothing"

–Oscar Wilde.

This is how he defined who a cynic is. This would aptly describe the very spirit of our age. Measurement tools, metrics, parameters count all the discountable and discredit all that is really countable. When such an 'expert' system collapses we look askance. We seem to have great answers for all wrong questions. False dichotomy; mismatch of cause and effect; right remedy wrong malady; remedy being worse than malady, play their script and narrative to subdue and captivate us. We are enthralled. Yet paradoxes, contrasts and contradictions stare us nakedly. Eating and mating are brass tacks of life. We seem to have gone wrong on both the count.

Food is so closely connected to everything, be it economics, health, ecology, sociology but more so with pleasure, art, community, culture, tradition, rites, rituals, religion and spiritualism. *Taitiriyya upanishad* talks of transcending from material being to a state of eternal bliss and their interconnectedness. In its own words, it is from *Annamaya* to *Anandamaya*. The origin of culture as many Anthropologists avert began with cooking. Cooking in a way disconnected us from nature initiating culture. All the ecological concerns: sustainability, biodiversity, biological mass extinction, global warming, ecological foot print, dead zones in the ocean have strong link with the way we produce, process and consume food.

Sustainability: The way we produce food today is highly unsustainable. We are spending ten calories to produce one calorie. This is like burning the house to get rid of a mouse. Sustainability is defined by Gro Brundtland committee of the United Nation as meeting our needs without compromising

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the ability of the future generation to meet their needs. We are often warned not to be a borrower from future generation. Food production system today is a energy guzzler. The inputs for agriculture like fertilizers and pesticides are extremely energy intensive. The three nutrient mantra of N, P and K (Nitrogen, Phosphorous and Potassium) and the way they are extracted and synthesized is proving to be a pyrrhic victory. The world today uses about 200 million tons of synthetically produced urea to grow about 2000 million tons of grains. German scientists Carl Bosch and Fritz Haber mastered the art of making urea by drawing Nitrogen (N_2) and splitting it to combine with hydrogen from natural gas to make ammonia and then urea from it. They also made explosive Nitrogenous chemicals for warfare and for Hitler's gas chambers to exterminate the Jews. They both won Nobel Prize. The Haber-Bosch process of producing urea is an energy guzzler. It requires 200–400 Pascal of atmospheric pressure and about 600 degree centigrade temperature to split the strongly bound dinitrogen (N_2) and to combine with hydrogen. Energy being energy irrespective of the form, what is consumed to produce one tonne of urea, if converted to food calories, can feed 35 lakh people a day! As of phosphorous, Nature magazine warns us that at the current rate of extraction and usage the phosphorous would be mined out completely in less than 100 years. There won't be any more phosphorous left in the mines. We can do so if the fate of humanity is restricted to 100 years.

Biodiversity: The more diverse the food system, the stronger and healthier it is. It is said that all ancient civilization like Incas, Mayas, Aztec, Harappa was known for diverse dietary habits. Every year they would consume a minimum of 3000 varieties of base food materials apart from myriad cuisines evolved according to culture and season. Dr. Richharia renowned geneticist of India mentions that the rice itself had more than 30,000 varieties within the country. This can be termed as a Vavilovian museum. Today the food varieties we eat can be counted on our finger tips. This is not just with rice. We have lost precious breeds, seeds and species. We can list number of cattle breeds, poultry, sheep and goat that have gone into oblivion. Our food system is driving more towards homogenization, monoculture and standardization of menu. Death of diversity is everywhere. We can see it in languages, culture and cuisine.

Global warming: Even though agriculture is said to contribute about 20% of global greenhouse gases, it is estimated by Barbara Harris–White that taking the transport and the food movement and geography it could be around 50%. It can be simply attributed to intensive input dependant and energy guzzling agricultural system. Further meatification of our diet with food to meat conversion ratio being about 5:1 on an average is also responsible for greenhouse gases and consequent global warming. Intensive CAFOs (Concentrated Animal Feeding Operations) have contributed to release of methane which is 72 times more potential in global warming than Carbon dioxide, a common culprit.

Food security: Whenever organic agriculture is talked about, the common question one would confront is that we can't feed the world. In a recent book 'Feeding Frenzy', Paul McMahon deconstructs this fallacy. It is now known that the food grain comprising of cereals, pulses and oil seeds being produced annually can feed 13 Billion people! About half of it being fed to animals for annual 100 pound meat consumption in the developed world per person and nearly 20% either wasted or lost. Nature magazine published during 2012 presents a thorough analysis of productivity comparisons between organic and intensive farming. The broad consensus was that there is not much difference in yield as far as fruits and vegetables are concerned, but in cereals, organic yields are 15% lower. With a healthy eating habit of increased consumption of fruits and vegetables and decreasing meat, sugar and fat, organic farming can feed even 10 Billion people that the population expert talk about the plateau of population. Food security is considered to be a narrow concept devoid of nutrition security and density. Organic does weigh over the intensive in this regard.

Nutrition comparison: There are contradicting studies as of now when it comes to nutrition comparison between organic and non-organic. Some meta-analysis studies say that there is no difference. But some show clear difference. All said and done, comparison itself is confined to 19^{th} century standardize nutrition table of foods. It doesn't cover large number of phytochemicals which are otherwise known as antioxidants, flavonoids, anthocyanins, indoles etc., there could be substantial difference in the farm and function of the nutrients present. If you take vitamin E as an example, the difference can be found depending on the form it is present in. Matt Ridley, renowned biologist in his book 'Rational Optimist' mentions that in high yielding, short duration varieties carbohydrate will be more sugary with higher content of amylopectin. Carbohydrate provides more than 60% of human energy. Among poor people it could be as high as 90%. For example, South Indian food is often described as 'Mountain of rice and rivers of sambar'. A sugary starch can flood your blood with glucose very quickly confusing the hormone system eventually leading to diabetes– a metabolic disorder. It goes without saying that organic is devoid of pesticide residues, hormonal traces and pharmaceutical inputs at the farm level and plethora of additives, colours, preservatives, fumigants and flavors at the processing level. Philosopher Seneca aptly said 'People don't die, they kill themselves with fork and spoon'.

Philosophy of science: The current techno fixes and scientific solutions being offered as panacea to all the ills of agriculture appears to be misplaced and falsely dichotomized. It's often a convenient construct of cause and effect relationship so as to fit a profitable solution at hand. A deft definition on genetic engineering goes like this – DNA makes RNA, RNA makes Protein, Protein makes Money. If you take pest as a problem, pesticide falls in as a solution. But pest could be an emergence of a problem due to water logging, monoculture, and abuse of pesticide. Then pesticide as a remedy for pest becomes an epistemic error. Sleeping tablet may be a right solution for sleep disorders in medical parlance. It is said that we need more science and technology. But it should think of an intensive technology that accommodates all threads of complexity. For example, Nitrogen is a major nutrient of plants. But urea itself may not be the solution, because Nitrogen is abundant in the atmosphere to the extent of 80%. It can be fixed easily by soil microbes and complementary fungi free of cost. All that is required is polyculture, complementarity between cereals and pulses. With the advent of genetic engineering, the relevance of technology and its associated risk or cost benefit analysis must be more broad based covering tangible and intangible aspects. Precautionary principle and post normal science as adopted by European Union appears to be in the right direction. This principle holds good when there are unknown aspects, uncertainties galore in the very knowledge of genes and genetics. We seem to be building a new science at the funeral of the old science almost every month!

Health care cost: The average income of an American is about 48000 Dollar and they spend about 4000 dollar for food and 8000 dollar for healthcare! Healthcare cost in India today is about 10 lakh crore compared to 15 lakh crore of food economy. We seem to be catching up with a wrong model. Gandhi famously said that speed is irrelevant if you are going in the wrong direction. Ashish Bose, renowned demographer calls modern hospitals as paradise of sickness and heavens of diseases. The need of the hour is to focus on disease prevention rather than incurable 'manageable' lifestyle diseases.

In conclusion it can be said that organic agriculture reckons nature's myriad functions and features. Health being an ecosystem function cannot be alienated from its organic link. The need of the hour is to reduce inputs of fertilizers, pesticides and hormones to bring about food safety. There is research happening in this direction but without much emphasis from the state and policy makers. Perennial crop system, conservation of diversity, ecological economics deserves much more attention.

'To see the world in a grain of sand,
and to see heaven in a wild flower,
hold infinity in the palm of your hands, and
eternity in an hour'.

\- William Blake

Organic Farming in an Era of Climate Change

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Global warming: It is an increase in the earth's temperature due to burning of fossil fuels, industry emissions, and other gas emissions from agricultural processes caused by human, and natural processes. This is due to 1) An increased emission of greenhouse gases, 2) Short-wave solar radiation sinks into the Earth's atmosphere and warms its surface and 3) While long wave infrared radiation emitted by earth's surface is absorbed, and then re-emitted by trace gases. This increased carbon component withhold more and more heat units causing atmosphere to become warmer and warmer. The IPCC (2007) projects that the planet will become warmer by an additional 2.2 to 10°F in the next 100 years. GHGs attributed to agriculture by the IPCC include emissions from soils, enteric fermentation (GHG emissions from the digestion process of ruminant animals), rice production, biomass burning and manure management. Other indirect sources of GHG emissions are from land-use changes, use of fossil fuels for mechanization, transport and agro-chemical and fertilizer production. The most significant indirect emissions are changes in natural vegetation and traditional land use, including deforestation and soil degradation.

Climatic change: Climate Change leads to extreme meteorological events, such as spells of high temperature, heavy storms, droughts etc which disrupt crop production. Frequent droughts not only reduce water supplies but also increase the amount of water needed for plant. This modifies rainfall, evaporation, and runoff and soil moisture storage.

Effect of increased temperature on soil: Increase in temperatures lead to 1) Reductions in soil organic C; 2) Increased CO_2 release from soils to the atmosphere; 3) Increase in the Soil compactness (bulk density); 4) Declining Water Holding Capacity; 5) Quick loss of stored water due to increased

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evaporation; 6) Higher Runoff due to restricted deep drainage and soil compactness; 7) Decline in Nutrient holding capacity; 8) Increased erosion and biodiversity loss; 9) Reduction in quantity and quality of soil micro flora and fauna and; 10) Increase in weed population

Impact of altered rainfall distribution on crop production: Altered rainfall pattern affect crop production by way of 1) Erratic distribution (un-seasonal, early and delayed); 2) Decreased number of rainy days reducing the length of growing period; 3) Increase in number of draughts and prolonged dry spells; 4) Flash floods devastates whole crop; 5) Decreased quantum of rainfall during cropping season reduces the sowing window and growing period of the crop**;** 6) Leading to selection for short duration and medium duration crop with less production potential.

Impact of climate change on farming systems: It is widely known that Climate change is causing radical changes in the agroecosystems in the world. Global warming not only increases global mean temperatures, but also increases the frequency of extreme weather events and the variability of weather in general. It also causes changes on land vegetation, ocean circulation, sea surface temperature and global atmosphere composition and impacts rainfall patterns. These changes will bring new challenges to farmers. Climate change may reduce the yields of thermal sensitive crops in the tropics due to enhanced temperature. Many agricultural systems provide necessary environmental services that are also vulnerable to the effects of global climate change. Climate change is likely to affect farmers more in the developing countries and poorest of the poor becomes more vulnerable to climate change. The IPCC indicated that rainfall variability and extreme events are the single most determining factor endangering agricultural production in developing countries'.

Impact of current practice of farming: Before chemical fertilizers were invented, farming was mainly dependent on farm yard manure through which organic Carbon used to be added to the soil. Though crop yields were low, soil health was maintained. In view of enhancing the food production to meet the increasing population, higher quantum of Carbon components in the form of in-organic compounds were added to the soil. This gradually increased the bulk density of the soil, decreased the porosity, increased the runoff and declined the water holding capacity leading to reduction in the length of crop growing period and holding greater quantum of heat causing increase in soil temperature, reduction in cation exchange and so on. Increased temperature is likely to have a negative effect on C allocation to the soil, leading to reduction in soil organic C. A study by Link *et al* (2006) in a semi-arid steppe, observed that soil warming and drying led to 32% reduction in soil C over a five year period, a much more rapid reduction in soil C than reductions that have been observed due to increased tillage. Experiments conducted at Dryland project (Anonymous, 2012) Bangalore have indicated that the crop yield was not uniform in all the 35 years when crop was grown using in-organic fertilizers. IPCC has indicated decline in grain production under the changed climate scenario and likely trend are indicated in Table 1.

Table 1. IPCC estimated the percentage grain production changes from climate change.

Scenario	World	Developed Countries	Developing Countries
No offsetting effects considered	–11 to –20	–4 to –24	–14 to –16
Including CO_2 fertilization effect	–1 to –8	–4 to +11	–9 to –11
Including CO_2 fertilization and modest farmer adaptation	0 to –5	+2 to +11	–9 to –13
Including CO_2 fertilization and more ambitious farmer adaption	–2 to +1	+4 to +14	–6 to –7

Rajegowda *et al* (2008) have indicated that inspite of marginal increase in annual rainfall in Karnataka, India, the quantum of monsoon rains are decreasing and pre-monsoon and North East monsoon rains are increasing. Length of growing period is decreasing in many parts of the State. The temperature is likely to be enhanced by 2.0 Degree Celsius by 2035 causing increase in marginal droughts. The water requirement may also increases in such climate change scenario (Table 2). The simulation crop weather models have revealed decline in productivity in many crops under the changed climate scenario (Rajegowda *et al*, 2013). In view of minimising the loss due to the climate change and for sustainable food security, gradual changes in cultivation from the vulnerable crops to the potential crops is required.

Table 2. Water requirement for the crops to be grown in present and climate change scenario (2035)

	Crops	Water required at present (mm)	Water required during 2035 (mm)
1	Finger millet	300 mm	375 mm
2.	Red gram	450 mm	550 mm
3.	Groundnut	375 mm	450 mm
4.	Wheat	325 mm	400 mm
5.	Millets	300 mm	375 mm
6.	Mango	832 mm	1050 mm
7.	Rice	1370 mm	1500 mm
8.	Sugarcane	1450 mm	1950 mm

Assessment of crop yields under mean climate change in different regions: Rajegowda *et al* (2013) studied the productivity of major crops in Karnataka, using the simulation Infocrop model (Anonymous, 2010) to predict the productivity of Rice, Maize, Sorghum, Redgram, and Stocheometric Crop weather model (Muralidhara and Rajegowda, 2002) in the changed climatic scenario (RCP 4.5) for the year 2035. The current and estimated productivity and percentage of deviation from the baseline yield have been listed in Table 3. The simulation analysis indicates that the productivity of kharif crops such as irrigated rice in the State is likely to change by –14.4 to 9.5% from its base yield. Majority of the irrigated rice growing area is projected to lose the yields up to about 8.2% and smaller non-rice growing districts projected to gain up to 6.2% indicating the net decline in the irrigated rice. In case of rainfed rice, the projected change in yield is in the range of –13.8 to 7.2% with large portion of the region likely to lose the rice yields up to 9.6%. Since irrigated rice, in general, is supplied with better amount of fertilizers than the rainfed rice, it has better opportunity to benefit from CO_2 fertilization effects for production and accumulation of dry matter and hence grain yield. Both Irrigated and Aerobic rice in smaller area of south-western Karnataka is also likely to gain. In these areas, current seasonal minimum and maximum temperatures are relatively lower (20–22°C Tmin; 27–28°C Tmax) and projected increase in maximum temperature is also relatively less in these areas (1–1.5°C) as also increase in minimum temperature, which is projected to be about 1.3°C.

In Western ghats region, climate change is likely to change yields of maize from 27.6% to –19.3% and sorghum by 17.2% to –18.4 in different districts with respect to baseline yield. These crops have C4 photosynthetic system and hence do not have relative advantage at higher CO_2 concentrations. Increase in rainfall in already high rainfall zones is detrimental to the crop production due to low sunshine. Further, increase in temperature causes reduction in the crop duration due to increased growth rates. Reduced crop duration means less opportunity for crop canopy to accumulate the photosynthates and thus dry matter. These conditions can cause the reduction in grain yield. Further, any coincidence of high rainfall with pollination period will affect the production due to spikelet sterility, especially in cross pollinated crops such as maize and sorghum.

The estimated 2.1°C rise in mean temperature and a 4.5% increase in mean precipitation would reduce net agricultural productivity in the state by 1.2%. Agriculture in the Coastal and Ghat regions is found to be most negatively affected. Small losses are also indicated for the major food-grain producing regions of few districts. On the other hand, interior North and South Karnataka districts have shown benefit in rainfed crops to a small extent from warming. Although total productivity is likely to be decreased by about 1.2% in the State, due to the benefit of the raise in temperature and CO_2 level, few districts have indicated gain in productivity up to 35% (in some crops). By changing over to such crops in those vulnerable districts, the loss in the productivity can be compensated and the advantages of the climate change effects can be absorbed positively. Likely impacts of climate change on the productivity of four important crops by 2035 vis-a-vis current levels are presented in Table 3A and Table 3B.

Need for adaptation in the farming system: In view of counter acting the negative impacts of climate change on agriculture, farming systems should be well equipped to absorb the impacts of affecting parameters and provide the sustainable soil and atmospheric systems for favourable agricultural productions. Farmers in developing countries need tools to help them adapt to these new conditions. Adaptation in agriculture is certainly not new. Changing weather has always concerned farmers and they have developed methodologies to adjust

Table 3A. Yield projection under the climate change scenario (2035 of RCP 4.5 scenario)

Districts	Productivity in Rice			Productivity in Maize		
	Present	2035	Deviation %	Present	2035	Deviation %
Bagalakote	3606	3560	–1.3	2890	2990	3.5
Bangalore rural	3520	3580	1.7	4327	5543	28.1
Bangalore urban	3951	4552	15.2	3204	4180	30.5
Belgaum	2760	2678	–3	2530	2754	8.9
Bellary	4918	4628	–5.9	2914	2812	–3.5
Bidar	3458	2853	–18	1890	2050	8.5
Bijapur	3978	3768	–5.3	2261	2459	8.8
Chamarajanagar	4012	3799	–5.3	2274	2509	10.3
Chikmagalure	3441	3169	–7.9	2540	2108	–17
Chitradurga	3262	3435	5.3	1995	2154	8.0
Dakshina Kannada	3487	3051	–13	2901	2350	–19
Davanagere	4689	4975	6.1	2800	3056	9.1
Dharwar	3209	3273	2	2208	2375	7.6
Gadag	3279	3381	3.1	3293	3587	8.9
Gulbarga	3032	2659	–12	2769	2990	8.0
Hassan	3312	3478	5	2887	2750	–4.8
Haveri	3012	3181	5.6	2167	2340	8
Kodagu	3394	3986	17.4	4385	3602	–17.9
Kolar	2821	3018	7	2561	2720	6.2
Koppal	3282	3653	11.3	2638	2690	2
Mandya	4525	4398	–1.9	4301	4550	5.8
Mysore	4303	4421	2.7	3374	3590	6.4
Raichur	3624	4052	11.8	3032	3090	1.9
Shimoga	3982	3597	–9.7	2755	2375	–13.8
Tumkur	3721	3933	5.7	4012	3873	–3.5
Udupi	3802	3346	–12	3112	2590	–16.8
Uttara Kannada	3940	3507	–11	2333	1975	–15.3
State	3608	3627	–0.2	2902	2943	2.2

Table 3B. Yield projection under the climate change scenario (2035 of RCP 4.5 scenario)

Districts	Productivity in Jowar			Productivity in Redgram		
	Present	2035	Deviation %	Present	2035	Deviation %
Bagalakote	2130	2280	7.0	690	615	–10.9
Bangalore rural	1059	1150	8.6	687	767	11.6
Bangalore urban	1059	1190	12.4	471	543	15.3
Belgaum	774	830	7.2	288	280	–2.8
Bellary	1293	1486	14.9	460	415	–9.8
Bidar	1054	1212	15.0	580	590	1.7
Bijapur	2534	2650	4.6	346	315	–9.0
Chamarajanagar	2031	2250	10.8	463	501	8.2
Chikmagalure	1509	1410	–6.6	433	501	15.7
Chitradurga	2018	2345	16.2	505	664	31.5
Dakshina Kannada	1021	928	–9.1	678	540	–20.4
Davanagere	2304	2075	–9.9	992	1116	12.5
Dharwar	1982	1802	–9.1	553	623	12.7
Gadag	1892	2087	10.3	303	373	23.1
Gulbarga	1302	1502	15.4	475	469	–1.3
Hassan	1820	1650	–9.3	307	341	11.1
Haveri	2340	2468	5.5	560	632	12.9
Kodagu	986	905	–8.2	540	373	–30.9
Kolar	1720	1510	–12.2	595	698	17.3
Koppal	1892	2109	11.5	302	250	–17.2
Mandya	2093	2268	8.4	502	575	14.5
Mysore	2130	2203	3.4	608	681	12.0
Raichur	1502	1480	–1.5	346	298	–13.9
Shimoga	1618	1386	–14.3	502	602	19.9
Tumkur	1520	1423	–6.4	581	469	–19.3
Udupi	1420	1266	–10.8	745	509	–31.7
Uttara Kannada	1270	1105	–13.0	880	545	–38.1
State	1640	1666	1.5	533	529	0.6

the climate change. Due to non- attainment of higher order of forecast, farmers must be able to increase their farms' resilience to change. Resilience has been described as a system's ability to maintain normal functions in the face of unexpected conditions. Applied to agriculture, the concept also includes the farm's dependence on its own resources instead of external inputs and the farmer's ability to experiment with different practices and learn what works best. As farmers observe conditions and develop responses to current challenges, they develop necessary skills to adapt to climate change as well (Ziesemer, 2007 & Borron, 2006). Farmers in developed countries may include in their response to climate change increased inputs such as synthetic fertilizers and pesticides and capital investments in irrigation and greenhouses to help their crops survive. Farmers in developing countries and small holders in general have a much smaller set of options and must rely to the greatest extent possible on resources available on their farms and within their communities.

Organic agriculture: Carbon and Nitrogen are major components of soil organic matter. Organic matter is important for many soil properties, including structure formation and maintenance. The benefits of the Organic Farming are: 1) Incorporation of organic matter in to the soil reduces bulk density, increases water holding capacity, reduces the runoff, increases the porosity and increases the cation activity; 2) Increases the growing period due to more water holding capacity and slow release of water molecule to the crop roots; 3) Regulates the soil heat flux due to high cation exchange; 4) Affordably captures Carbon from the air and effectively stores it in the soil in high levels for long-periods; 5) Integrates trees, hedgerows and pastures into farming systems to increase Carbon capture and biodiversity; 6) Reduces greenhouse gas emissions and fossil fuel use through an appropriate combination of organic fertilizers, cover crops and less intensive tillage; 7) Puts people at the center of the farming system to increase resilience, income and food security.

Organic farming to mitigate climate change: With the right type of agriculture, emissions leading to climate change can be minimized and the capacity of nature to mitigate climate change can be harnessed to sequestrate significant quantities of atmospheric Carbon dioxide – especially in the soil. Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It utilizes ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. It combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. Farmers in developing countries need tools to help them adapt to these new conditions. Adaptation in agriculture is certainly not new. Changing weather has always concerned farmers, and they have developed ways to respond. The phenomenon of global climate change makes the ability to adapt even more important, as adaptation will need to occur at a much faster pace. IPCC (2001) defines adaptation to climate change specifically as 'adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.'

Organic agriculture's potential to mitigate climate change: Organic Agriculture has a role to play in climate change adaptation and mitigation, including avoided damage and many farming practices contribute to both processes. Agriculture also has the potential to avoid climate change through emission reductions and mitigate climate change through Carbon sequestration. While individual practices could be implemented on almost any farm, organic agriculture is unique in creating a whole system of agriculture based on ecological principles from production to consumption by privileging closed energy and nutrient cycles at the farm and by promoting short supply chains. While agriculture's mitigating potential is not nearly enough to prevent climate change from happening, its potential to reduce climate change is quite significant. Organic Agriculture is often ignored in discussions of climate change mitigation, but is worth considering.

Long term studies on response of crops to Organic and In-organic fertilizers and their integration: A long term (34 years) experiment conducted in UAS, Bangalore (Anonymous, 2012) on fertilizer effect on yields indicated that continuous use of only inorganic fertilizers has increased the crop productivity in the initial stages. However, it has declined over the years as a result of deterioration of soil health. Addition of organic manure helps in maintenance of crop productivity and soil quality. The fingermillet grain yield data from 1978 to 2011 indicates that the yield ranged from 54 kg/ha in control (2006) to 4552 kg/ha in FYM 10 t/ha + 100 per cent NPK (1984). Application of FYM @ 10 t/ha + 100 per cent NPK gave 3,573 kg/ha in the first 10 years and maintained its yield around 3,022 kg/ha in last 10 years with a mean of 3,227 kg/ha indicating stability in productivity due to integration of Organic and In-organic fertilizers. Similarly, the fingermillet grain yield data from 1993 to 2011 under crop rotation with groundnut showed yield ranging from 4314 kg/ha in FYM + 100 per cent NPK in the year 2011. The mean grain yield of fingermillet in the first 5 years and last 5 years recorded higher grain yield in all the treatments except NPK alone. The higher mean grain yield of 3884 kg/ha was observed in FYM + 100 per cent NPK which is higher by 20 per cent when compared to mono-cropping of only fingermillet (Table 4). When fingermillet crop was rotated with groundnut, the yield of fingermillet has increased by 145 per cent in FYM @ 10 t/ha + 100 per cent NPK than the control. This clearly indicates that by adopting crop rotation along with integrated organic and in-organic fertilizers yield stability is possible in fingermillet under rainfed situation.

Table 4: Mean grain yield of fingermillet (kg/ha) as influenced by farmyard manure, fertilizers and their integration under fingermillet monocropping and rotation with groundnut.

Treatments	Fingermillet - Monocropping				Fingermillet-Groundnut Rotation		
	Grain yield of fingermillet (kg/ha)				Grain yield of fingermillet (kg/ha)		
	First 10 years 1978–87	Mid 10 years 1988–97	Last 10 years 2002–11	Mean 1978–11	First 5 years 1993–01	Last 5 years 2003–11	Mean 1993–11
T_1- Control	1544	644	254	729	766	745	756
T_2- FYM @ 10 t/ha	2528	2507	2324	2426	3162	2973	3068
T_3-FYM @ 10 t/ha + 50% NPK	2903	2857	2881	2879	3699	3598	3649
T_4-FYM @ 10 t/ha + 100% NPK	3573	3271	3022	3227	3971	3797	3884
T_5-Only NPK	2942	1894	1734	2077	2496	2538	2517

The five years moving average data on fingermillet grain yield (Figure 1) clearly indicates the effect of continuous use of only organic, inorganic and their integration on yield of fingermillet. The grain yield of Fingermillet has decreased both in control as well as use of only chemical fertilizers (NPK), where as in case of combination yield levels were stabilised around 3200 kg/ha. The yield stability and sustainability yield index (SYI) data for 34 years as shown in table 5 indicated that SYI was highly sustainable with a SYI value 0.70 in FYM + 100 per cent NPK followed by FYM + 50 per cent NPK (0.57), only NPK (0.45) and INM has shown high productivity (3–5 t/ha) and maintained productivity level for longer duration when compared to only NPK, indicating the importance of both organic manures and inorganic fertilizers for achieving yield stability. The SYI computed for the targeted yield of 3000, 3500 and 4000 kg/ha indicates that, FYM +100 per cent NPK is highly sustainable for all the targeted yields recording higher SYI of 0.75, 0.65 and 0.57 respectively. Very low SYI values were recorded in control and only NPK (Table 5)

Table 5. Yield stability and sustainability yield index of fingermillet as influenced by farmyard manure, fertilizers and their integration (1978–2011).

Treatments	Sustainability			
	SYI	SYI at fixed yield level (kg/ha)		
		3000	3500	4000
T_1- Control	–0.07	–0.08	–0.07	–0.06
T_2- FYM @ 10 t/ha	0.45	0.49	0.42	0.37
T_3-FYM @ 10 t/ha + 50% NPK	0.59	0.64	0.55	0.48
T_4-FYM @ 10 t/ha + 100% NPK	0.70	0.75	0.65	0.57
T_5-Only NPK	**0.34**	**0.37**	**0.32**	**0.28**

Regarding soil chemical and Physical properties (Table 6), in mono-cropping system, soil pH and EC decreased significantly with control and NPK alone treatments. The organic Carbon content was observed to be higher with FYM/INM treatments as compared to control and NPK alone. The decrease in bulk density was higher with FYM alone along with crop rotation. The porosity was higher

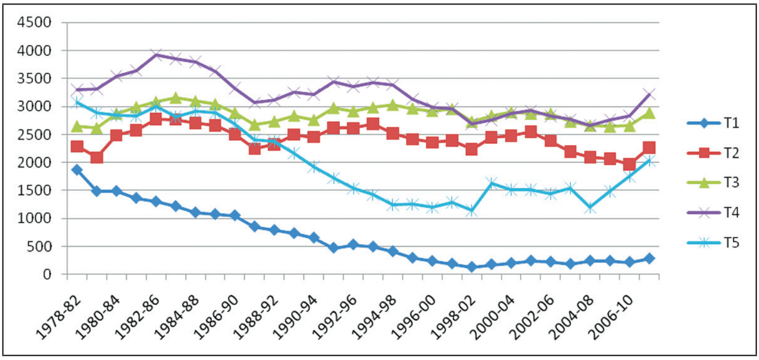

Figure 1: Five years moving average yield of fingermillet (kg/ha) as influenced by farmyard manure, chemical fertilizers and their integration (1978–2011).

with Farm Yard Manure (FYM) application and decreased with addition of fertilizers mainly due to loss of organic matter.

Table 6: Soil Chemical and Physical properties under fingermillet mono cropping and fingermillet–groundnut rotation (2010–11).

Treatment	pH	EC (dS/m)	OC (%)	BD (g/cc)	Porosity (%)	pH	EC (dS/m)	OC (%)	BD (g/cc)	Porosity (%)
	Finger millet mono cropping					Groundnut- Finger millet rotation				
Initial (1978)	5.0	0.20	0.70							
T1	5.00	0.09	0.26	1.5	43.4	5.30	0.07	0.30	1.49	43.9
T2	5.41	0.13	0.41	1.4	47.9	5.61	0.13	0.51	1.36	48.7
T3	5.38	0.14	0.43	1.4	45.7	5.50	0.11	0.49	1.42	46.4
T4	5.73	0.15	0.60	1.4	44.1	5.82	0.06	0.53	1.45	45.3
T5	5.12	0.09	0.34	1.5	42.6	5.12	0.15	0.33	1.50	43.4
S. Em.+	0.14	0.005	0.012			0.22	0.02	0.17		
CD @5%	0.55	0.021	0.04	0.08	2.46	0.89	0.89	0.89	NS	2.1

Freyera and Birechb (2009) have reported that crop yields in comparison of organic and farmer practice (non–organic), the organic farming has yielded more than the non-organic in the Kenyan Rift Valley between 2003 and 2006 (Table 7). They opined that the combination of pre-cropping and intercropping provides more secure yields even in times of limited rainfall, because when the investment in soil fertility during the fallows is low because of limited rainfall, the intercropping Nitrogen fixing plant integrated in the long rain will add nitrogen.

Table 7: Crop yields in comparison of organic and farmer practice in the Kenyan Rift Valley between 2003 and 2006

Cropping system/ management	Organic trials with legume green manure (kg/ha)	Farmer Practice (FP) (non–organic) (kg/ha)	Difference in yields between organic and FP (kg/ha)	Relation between organic and FP (%)
Maize sole	3934	1900	2034	207.1
Maize/ legumes intercrop	3197/261	2360	836	135.5
Potatos sole	16885	11240	5645	150.2
Wheat sole	3700	2500	1200	148.0

Increasing water use efficiency: Boki Luske (2009) indicated that due to climate change and technical interventions like river dams, water availability in many dryland regions in Africa is becoming more and more problematic. At the same time and in the same areas, land degradation takes place at an alarming rate. Farmers in these regions need to adapt to the changing circumstances to halt and reverse the loss of soil fertility and to improve water use efficiency. This case study demonstrates that the application of compost on degraded soils is an effective measure to adapt to this changing environment.

Performance during extreme events: Lotter *et al* (2003) have indicated that, the Organic fields have performed better during extreme rainfall, absorbing more water and experiencing less runoff and erosion. Water absorption is necessary for groundwater recharge, an environmental service that protects the whole ecosystem. Another study of Central American smallholder farms after Hurricane Mitch found that those who used sustainable soil management practices, including intercropping, composting, and terracing, recovered much more quickly from the devastation (Tengo and Belfrage, 2004). Both of these studies indicate that organic management can help protecting soil and water during extreme weather.

Benefits of organic agriculture in relation to climate change adaptation. Organic farming practices preserve and restore soil organic matter, soil structure and water holding capacity, and are therefore able to maintain productivity in the event of drought, irregular rainfall events, with floods and rising temperatures. This adaptive quality of organic agriculture is very important for the agricultural sector. In a study conducted by Kees van Veluwa (2009) in the Netherlands reported that Organic dairy farming emits 40% less green house gasses (GHG) per hectare of land than conventional agriculture. He also pointed out that it can be further improved by using the Pure Graze system in which farms are adapted to align with natural animal and plant cycles. Dairy farming contributes significantly to greenhouse gasses. They found organic dairy farms emit 40% less greenhouse gas per hectare of land and 10% less per kilogram milk, compared to conventional dairy farming (Table 8).

Table 8: Emission of greenhouse gasses on organic and conventional dairy farms in the Netherlands

Gases	Emissions in kilograms per hectare		Emissions in kilograms per 1,000 kilograms milk	
	Conventional	Organic	Conventional	Organic
CO_2	4,250–11,630	2,650–4,950	420–550	320–410
N_2O	15.3–37.1	12.4–18.8	1.5–1.9	1.5–2.0
CH_4	250–520	180–300	25–26	22–26
CO_2–equivalents	14,470–34,160	10,990–17,010	1,450–1,650	1,310–1,460

Organic agricultural practices increase the nutrient and water retention capacity of soils through high organic matter content and soil cover. As a result, nutrients and water are used more effectively for agricultural production and less water is needed. Soil fertility and soil structure improve when utilizing organic agricultural practices. Organic agriculture increases biodiversity by using trees and diverse crops, intercropping and crop rotations. Enhanced biodiversity reduces pest outbreaks, the severity of plant and animal diseases, thereby increasing the production of high quality agricultural produce. Organic agriculture decreases soil erosion caused by wind and water as well as by overgrazing. Organic agriculture is well adapted to local circumstances as it encourages the use of local and indigenous farmer knowledge and adaptive learning techniques. Organic agriculture reduces the financial risk of farm operations, since farmers are less dependent on external inputs like synthetic fertilizers, seeds, irrigation equipment etc. They do not have to borrow money to buy these inputs and are therefore financially less affected in case of crop failure. In sum, all these positive contributions of organic agriculture result in higher yields and thereby have increased food security and better options for development. Organic Agriculture promotes agroecological resilience, biodiversity, healthy landscape management and strong community knowledge processes. Improved soil quality and efficient water use strengthen agroecosystems. Farmers must closely observe their agroecosystems and often work with other farmers to share information and learn. As a whole, Organic Agriculture thus builds adaptive capacity on farms.

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Biofertiliser Use in Organic Farming: A Practical and Challenging Approach

P Bhattacharyya

India is mainly an agriculture based country as agriculture plays most important role in Indian economy. Nearly sixty percent population being involved in agriculture is accounting for approximately 18–20 percent of the nation's Gross Domestic Product (GDP). But unfortunately the present scenario of Indian agriculture is not encouraging as the population is increasing at an alarming rate but the cultivable area is not (Bhattacharya and Tandon, 2012). The net cropped area as stagnated at around 141 m ha is showing a declining trend. There is sharp fall of the land man ratio from 0.48 ha in 1950–51 to 0.14 ha at present. Moreover, fifty seven percent of total land area in India has been degraded by many ways for which the per capita arable land has decreased tremendously. The population of India is expected to reach 1.4 billion by 2025 for which the country needs more than 300 million tonnes (mt) food grain which is a gigantic task.

Importance of soil fertility: Crop productivity and soil fertility – both are complementary to each other. Soil fertility is a condition of soil having enrichment of most of the micro as well as macro element which have capacity to give steady flow of nutrient for the optimum growth of plants. The management of soil fertility means the total management of physical, chemical and biological quality of soil which contributes a lot to maintain soil health and sustain crop productivity. As soil is considered as a medium for intense crop production, it is very essential to maintain soil health for ensuring sustainable food production especially when there is a continuous decline in soil fertility as soils are being mined of necessary nutrient reserves due to continuous cropping. Estimated annual depletion of Nitrogen, Phosphorus and Potassium from Indian soils due to intensive cropping is 36 mt which is a matter of grave concern. So, Soil needs either outsourcing of nutrients from external inputs

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(e.g. fertilizer) or there needs to be an alternative strategy for improving soil health by exploiting natural and sustainable resource.

Beginning of chemical fertiliser era: Plant needs nutrient for its growth and production. Out of 16 essential plant nutrients, 13 are taken up from soil and these are required to be supplied from external sources which are commonly known as fertilizer. Apart from Nitrogen, Phosphorous and Potash (NPK), fertilisers form a wide group of materials including secondary elements and micronutrients and are being promoted with an aim to enhance soil fertility and crop productivity. Historically, the use of chemical fertiliser in agriculture was initiated in 1830–1840 by the utilization of chilian nitrate deposits. India first produced fertilizer in 1906 at Tamilnadu. Initially, use of fertilizer was restricted to plantation crops and growth of fertilizer was slow. Now, in India total fertilizer consumption – nitrogen, phosphorus and potassium (NPK) has gone up from 0.07 mt in1951–52 to 28.12 mt in 2010–11 (401 times higher). On the other hand, per ha fertilizer consumption has increased from 0.5 Kg in 1951–52 to 141 Kg in 2010–11 which is 282 times higher (FAI, 2012). The global use of Chemical fertilizer is around 200 mt with main focus on Nitrogen fertilizer (roughly 100 mt). India is the second largest user of fertilizers, next only to China.

Lesson from chemical fertiliser use: not encouraging: No doubt, during Green Revolution (1967–78) and after Green Revolution, Chemical fertilizer played a crucial role in enhancing crop productivity and production of food grains increased five fold from 50.82 mt in 1950–51 to 255.36 mt in 2012–13 transforming the country from food deficient to food surplus. But post – green revolution era has witnessed several ill effects of chemical fertilizer use in agriculture. These are:

- Imbalance in nutrient dynamics due to imbalance use of fertilizers (mainly Nitrogen)
- Reduction in organic Carbon levels, leading to loss of narural nutrient mobilization potential due to declining microbial load.
- Increasing salinity and alkalinity due to high fertilizer and irrigation water usage.
- Emerging secondary and micronutrient deficiencies and
- Contamination of surface water bodies and ground water aquifers.

Besides above distortions other direct and indirect effects include natural ecological imbalance, loss of Biodiversity, declining population of soil improving invertebrates, loss of native strains of agriculturally beneficial microbes in soil and contamination of soils with heavy metals through fertilizers. The excessive use of Nitrogen fertilizer also contributed to climate change through emission of nitrous oxide and green house gases (Pathak, 2013).

Emergence of organic farming: a crisis saving effort: Organic farming has emerged as one of the better options to address the sustainability of agriculture and effective utilization of natural resources. The concept of Organic Farming is based on 4Ps like Principle of health, principle of ecology, principle of fairness and principle of care. It is holistic production management which promotes and enhances agro-eco system health including biodiversity, biological cycles and soil biological activity.

Currently 162 countries are engaged in organic cultivation involving 37.2 million ha (Yadav, 2013). Asia covers thirty four percent of the world's organic producers where India ranks 33rd in terms of total land under organic cultivation. In fact, in India, organic agriculture has its roots in traditional agricultural practices that evolved in countless villages and farming communities over the millennium. Up to 1950, Indian agriculture was fully organic and the intensive agriculture is of recent origin. Looking ill effects of chemical farming, it is farmers who have taken lead role in promoting organic farming in India. In 2003–04, certified organic areas in the country were mere 45,000 ha which has now grown to more than –1.08 million ha. Besides this cultivated area, India also has 4.48 million ha under wild harvest collection (Table 1).

Table 1. Status of Certified Organic Area

Year	India (mha)			World (mha)
	Cultivated	Wild Harvest	Total	
2003–04	0.42	NA	0.42	30.0
2006– 07	0.53	2.43	2.96	35.0
2011–12	1.08	4.48	5.56	37.0

Besides, several areas including dry land and hill zones are by default organic where chemical farming is not followed. Now, it is known that certified organic farming is market driven approach. India exported 86 organic items (Basmati rice, pulses, oilseeds, tea, coffee, spices, horticultural crops, herbal products etc) and its value is more than Rs. 5000 crore. The hilly State Sikkim has under taken organic farming in 40% of its farmland and its entire agriculture set to go organic by 2015. Chattishgarh Government has launched 'Organic Farming Mission' in districts of Bastar, Bilashpur and Ambikapur. The State of Karnataka, Madhya Pradesh, Uttarakhand have formulated specific program for promoting organic farming. Other states have also undertaken various programs in respect of organic agriculture.

It has already been mentioned that organic farming approach is basically farmers' choice based on their long experience in farming system under intensive agriculture depending on chemicals. Now, several Research Institutes, internationally and nationally, have taken up R and D works on feasibility of organic farming and results are encouraging. These Institutes include The Research Institute of Organic Agriculture (FiBL), Switzerland, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad, Central Research Institute for Dry Land Agriculture (CRIDA), Hyderabad, Central Research Institute of Cotton Research (CRICR), Nagpur, Network Project on Organic Farming (NPOF–ICAR), PDSFR, Modipuram etc who have contributed valuable information in favour of feasibility of organic farming in the country. Some results indicate that Organic farming is good for soil health. Based on 22 year study, the Rodale Institute Farming System Trial (RIFST) report suggests that soil carbon levels in the organic system are significantly higher than in the conventional system. By restoring the organic matter content, organic farming may counteract climate change. Organic farming also helps in preserving biodiversity, soil improving invertebrates, various species of birds and producing abundant biomass (Pratap, 2012). As regard crop yield, there may be recession during initial years, but yield may start increasing under organic after 5–6 years (Bhattacharyya, 2009).

But still many scientists and policy makers are not convinced with Organic Farming. They are of the view that India cannot rely on organic food to feed the nation as there is just not enough organic material available to meet crop plant nutrient requirements. There is strong view of chemical lobby that farming in India without use of chemical fertilizers will prove disastrous for food security in the country. Obviously, there are challenges of meeting nutrient needs in organic farming (Tiwari *et al*, 2005).

Nutrient sources of organic farming: Organic Farming System, as per Standard, excludes use of synthetic or manufactured chemical inputs and relies on natural sources like organic manures, organic recycling, composts, vermicomposts, crop rotation, inputs of microbial origin etc. The conventional farming system is based on the concept of 'Fertilising the crop', while organic farming aims on 'Fertilizing the soil'. India has vast resources of organic input, but it is very difficult to assess its actual estimate as production of dung, residues etc fluctuate every year and their availability is in declining trend. Burning of crop residues, inadequate green manure, lack of quality compost etc are the limiting factors in getting sufficient organic inputs (Bhattacharyya, 2007). Farmers are using some indigenous organic inputs which have not been validated scientifically. Against this backdrop, there needs searching of alternative viable resources of organic inputs which are abundant in nature, cost effective and pollution free.

Relevance of biofertiliser and its concept: The National Standard of Organic Production (NSOP, APEDA) allows fertilizer of microbial origin i.e. Biofertiliser which is the product containing carrier based (Solid or Liquid) living microorganisms which are agriculturally useful in terms of Nitrogen fixation, Phosphorus solubilisation, or nutrient mobilization, to increase the productivity of the soil and/or crop.'Bio' means living and 'Fertiliser' means a product which provides nutrients in usable form. Biofertilisers are also known as microbial inoculants or bio-inoculants (Bhattacharyya, 2013).

The concept of Biofertiliser was initiated in 1834 when J B Boussingault, a French agricultural chemist, contributed classical concept of Biological Nitrogen Fixation by legumes. In 1888, Beijerinck, a Dutch Scientist, confirmed that a bacterium (Now named Rhizobium) is responsible for nitrogen fixation in legumes. The commercial history of Biofertiliser began with the launch of Rhizobium (Trade name 'Nitragin') by F Nobbe and L Hiltner in 1896. First Commercial Production of Biofertiliser (Rhizobium) in India began in 1956 (Bhattacharya and Tandon, 2012).

Type of biofertilisers: Biofertilisers are of two types which are,

Nitrogen Biofertiliser (N-BF):

i) **Rhizobium:** A symbiotic, aerobic soil bacterium which fixes atmospheric Nitrogen in symbiotic association with legumes. Nitrogen fixed by Rhizobium can vary from 25 Kg N to 200 Kg N/ha depending on crop and growth condition. Nodule is the site of N-fixation.

ii) **Azotobacter:** The most common free living rod shaped pleomorphic Nitrogen fixing bacterium, fixes N @ 10–20 mg/g of carbohydrate. It can fix 20–40Kg N per ha. Apart from Nitrogen fixation, it produces vitamins, growth promoters etc which assures seed germination. It can also suppress pathogens.

iii) **Azospirillum:** A spiral shaped associative N-fixing bacteria which are widely distributed in soils and grass roots. It can fix 20–40 Kg N/ha in association with roots (equivalent to 20–40 mg N/g malate in laboratory). It also produces growth promoting substances.

iv) **Gluconacetobacter:** Gluconacetobacter diazotrophicus is an endophytic N-fixing bacteria found in the roots, stems and leaves of Sugarcane, potential to fix 200 Kg N/ha.

v) **Azolla:** A floating water fern, acts as a host for cyanobacterium (BGA) Anabaena azollae which fixes atmospheric N in a symbiotic association with azolla. It is an ideal biofertilizer for rice.

vi) **Blue Green Algae (BGA):** A prokaryotic, unicellular, photosynthetic Nitrogen fixing, aerobic organism, fix 20–30 Kg N/ha and is an ideal biofertilizer for flooded paddy.

BGA and Azolla can be produced by farmers in their field and application is simple.

Phosphorous Biofertiliser (P-BF)

i) **Phosphorus Solubilising Biofertiliser (PSB)**: A group of heterotrophic microbes, mainly bacteria, which are known to have the ability to solubilise inorganic P from insoluble sources by release of a variety of organic acids. Microbes are – Bacillus sp., Pseudomonas sp. etc and these are biofertilisers for all crops.

ii) **Phosphorus Mobilizing Biofertiliser (PMB)**: A group of endomycorrhiza (Glomus, Gigaspora etc.) are able to take up, accumulate and transfer large amount of Phosphorus to the plant by releasing the nutrients in root cells

Other Biofertilisers

Recently few other biofertilisers are getting demand. These are:

i) **Potash Biofertiliser (K-BF):** Faturia aurantia, Bacillus mucilaginosus etc are capable of mobilizing potash.

ii) **Zinc solubilisers (Z-BF)**: Few Bacillus sp. are capable of Zinc Solubilisation. These are important biofertilisers in Zinc deficient soils.

iii) **Compost Developing Biofertilisers (C-BF):** Some cellulose decomposers (Trichoderma sp) are used as compost accelerating biofertilisers.

iv) **Microbial Consortium Biofertiliser (MC-BF)**: Mixture of N-fixing BF, P–solubilising BF, Compost accelerating BF etc, used as Consortium, are found effective

v) **PGPR Biofertiliser (PGPR-BF)**: The group of beneficial, root associative bacteria that stimulates the growth of plant is termed as Plant Growth Promoting Rhizobacteria (PGPR), may be used for multipurpose. These are part of MC-BF.

Generally, biofertilisers are available in a solid (Using peat, lignite, charcoal as carrier), or in liquid base. Biofertilisers may be prepared from either single or multiple strains.

Biofertiliser technology in brief: The microorganisms present in biofertiliser are available in nature. Initially, these organisms are isolated from sources (Root nodule for Rhizobium and soil /plant parts for other BF microbes) and multiplied/developed in specific media (e.g., Yeast Extract Mannitol media for Rhizobium, Nitrogen free Jensen Media for *Azotobacter*, Nitrogen free malate media for *Azospirillum*, triCalcium phosphate containing Pikovaskia media for PSB). After needful growth these organisms are multiplied in liquid broth either in rotary shaker or in fermentor; when organisms attain maximum population ($10^8/10^9$ per ml), the broth containing specific microbe (eg *Rhizobium* or *Azotobacte*r or PSB) are mixed with carrier (Peat, lignite etc) or produced in liquid form maintaining all precautionary measures. For liquid product of *Rhizobium* and *Azospirillum*, different cell protectants like Trehalose, poly vinyl pyrrolidone, Glycerol, Arabinose etc are being used to increase shelf life for more than a year (Chandra and Greep, n.d.). Contamination level is also minimum in liquid form. For liquid biofertiliser of *Azotobacter*, encystation process is followed while for liquid PSB, sporulation process is applied. Generally, there are 4 methods of biofertiliser application which includes: i) Seed treatment, ii) Seedling treatment, iii) Sett/Cutting treatment and, iv) Soil application. Doses vary from crop to crop depending on soil. Application of liquid biofertiliser follows methodology like seed treatment, seedling dip, furrow application and foliar spray. Methodologies are generally mentioned on packet/container/ pouch itself.

Impact of biofertiliser use on different crops: Several Research Projects are ongoing to assess impact of different biofertilisers on different crops. From the results of 'Front Line Demonstration' under 'All India Network Project on Biofertiliser' conducted (2004–2007) in the state of Tamilnadu, Maharashtra and Madhya Pradesh, it was observed that inoculation gave additional groundnut pod yields of 5–27% in Tamilnadu, and 15–27% in Maharashtra; additional soybean seed yields of 5–10% in Madhya Pradesh and 30% in Maharashtra (Rao, 2007). Under the umbrella of All India Coordinated Research Projects on pulses, groundnut, soybean and dry farming, in multi location trials benefit due to innoculation ranged from 9–70%, depending on the crop,location and the season (Venkateswarlu, 2008). Where success was not achieved, several biotic and abiotic factors were responsible as they influence the performance of different biofertilisers. Under National Project on Development and use of Biofertilisers, 1050 field demonstration were conducted on 53 crops in 25 States/Union Territories. The results of these trials show that biofertiliser application resulted in an increase of 11.4% in crop yield on an average.

Current status of biofertiliser production and marketing channels: Biofertiliser use in Indian agriculture is getting momentum. In 1990, the country produced only 1000 metric tonne of biofertiliser. During 2009–10, the total biofertiliser production was 20,040 metric tonne. Out of this production, the production of different biofertilisers were: PSB=12,836 metric tonne (64% of total), Azotobacter =3,197 metric tonne (16% of total), *Rhizobium*=2,339 metric tonne (12% of total) and *Azospirillum*=1,668 metric tonne (8% of total). In 2010–11, the total production was 38,000 metric tonne (Bhattacharyya and Tandon, 2012) and current production is more than 40,000 metric tonne. At present, there are more than 150 biofertiliser production units in India. Biofertiliser production is basically demand driven. The product needs more PUSH due to lack of demand PULL. The marketing/distribution channels include Govt. Institutions, Agricultural Universities, Agro Industries, Cooperatives, Private manufactures, Private Dealers, Fertiliser Companies etc. The price of Carrier based biofertilisers generally range from Rs 40 to Rs 100/Kg and for liquid biofertiliser price is from Rs 150 to Rs 400/liter.

Quality protocol and regulatory mechanism: Under Fertilizers Control Order (FCO), the Ministry of Agriculture, Government of India has notified the specification of 3 Nitrogen biofertilisers (*Rhizobium,Azotobacter and Azospirillum*), 2 Phosphorus Biofertilisers (PSB and Mycorrhizae), 1 potash Biofertiliser and 1 Zinc Biofertiliser. The notified specifications of different biofertilisers are given in Table 2. The centres under National Centre of Organic Farming or any other notified laboratory by State Agricultural Departments are permitted to test the quality of biofertilisers.The Joint Secretary (INM); Krishi Bhawan is the appellate authority.

Table 2. Quality specification of biofertilisers as per FCO

	Parameters	Rhizo	Azoto	Azsp	PSB	KMB	ZSB	Myco-rrhiza
1	Base	Powder/ Liquid	Powder/ Liquid	Powder/ Liquid	Powder/ Liquid	Powder/ Liquid	Powder/ Liquid	Powder
2	Viable cell count (a)for solid carrier/g (b)for liquid carrier/ml	5×10^7 1×10^8	5×10^7 1×10^8	5×10^7 1×10^8	5×10^7 1×10^8	5×10^7 1×10^8	5×10^7 1×10^8	— —
3	Viable (Propagule/g)	—	—	—	—	—	—	100
4	Contamination (at 10^5)	nil	nil	nil	nil	nil	nil	—
5	pH	6.5–7.5	6.5–7.5	6.5–7.5	6.5–7.5	6.5–7.5	6.5–7.5	6.5–7.5
6	Moisture Cont. (%)	30–40	30–40	30–40	30–40	30–40	30–40	8–12
7	Passable Particle size (mm)	0.15–0.212	0.15–0.212	0.15–0.212	0.15–0.212	0.15–0.212	0.15–0.212	250 µ
8	Efficiency test	+nod-ulation	10mg N–fix	White pellicle In NFB	>5mm sol zone	>10mm sol zone	>10mm sol zone	80 infection pt.

Note: Rhiz=*Rhizobium*, Azoto=*Azotobacte*r, Azsp=*Azospirillum*, PSB=Phosphorus solubilising biofertiliser, KMB=Potash mobilizing, ZSB =Zinc Solubilising Biofertiliser. Tolerance Limit = 1×10^7 cfu/g or 5×10^7 cfu/ml, or viable propagule 80/g(Mycorrhiza)

Biofertiliser use in organic farming: a practical approach

As per guideline provided by National Standard of Organic Production (NSOP Standard), biofertilisers as input of microbial origin may be used in organic farming. It is practical approach. The reason may be understood from following SWOT analysis:

Strength: a) Production of Chemical fertilizer Nitrogen is oil dependent and excessive energy budgeted process. The energy requirement of 1 Kg fertilizer is 80 MJ or 11.2 KWH for Nitrogen, 12 MJ or 1.1 KWH for Phosphorus and 8 MJ or 1 KWH for potash. On the other hand, the annual biological Nitrogen fixation (BNF) on land is estimated 140 Teragrams (T_g =Million Metric Tonnes) and for this, the total energy cost is around 2,744 MJ of glucose which is equal to 2.5% of primary photosynthesis on land and for which the energy bill is paid by nature; b) One of the major disadvantages of organic nutrient resource is that they have very low nutrient concentration that make them uneconomical and transport from their sources. A tonne of FYM can be equated to 3.6 Kg of N + P_2O_5 +K_2O in fertilizer nutrient value when used to grow rice. Transport cost for FYM (Unless subsidy is given) in this case is a matter of concern. The availability of green manure is inadequate and use of crop residues has numerous limitations. Further, indigenous nutrient approach (On which organic farmers depend more) still needs scientific validation. On the otherhand, biofertiliser is the preparation of microorganisms which are natural resources (e.g., soil). Biofertiliser is required in very low quantity as compared to other organic inputs. When the recommendation of compost/vermicomposts is 5–10 tonne costing Rs 20,000–Rs 40,000/–from outsources, the cost of biofertiliser on the other hand is restricted to Rs 40/– to Rs 100/ha with the requirement of 1–2 Kg/ha.This can be managed easily. Moreover, BGA and Azolla can be produced by farmers in their own farm which is additional advantage, So, application of Biofertiliser in Organic Farming is a practical approach.

Weakness: But there are some challenges in respect of biofertiliser use. These are: a) Biofertiliser is microbe oriented product and it has shelf-life. Unfortunately, the shelf life of biofertiliser is not adequate (not more than 6 months). After the expiry of the product, it cannot be used; b) If proper storage facility is not maintained, the viable cell number of the organisms present in the product may decline and in turn, may be ineffective; c) Many farmers do not know its importance as it cannot always exhibit visible difference over control; d) Quality of the product is occasionally referred as substandard which has eroded the confidence of farmers on its use; e) The application methodology is time consuming; f) No single nutrient resource can produce better result. Many times, biofertilisers are used alone without support of any organic matter; g) Maximum R and D data on biofertiliser have been obtained from experiments conducted in intensive farming.

Opportunity: a) Organic farming areas mainly cover dry land and hill zones. Using biofertilisers in dry land, about 35 million ha under coarse cereals, 23 mha under pulses, 8 mha under groundnut and 4 mha under soybean can be benefitted by using one or other type of biofertilisers (Venkateswarlu, 2008). Similarly, North Eastern Hill Zones offer wide potential of high quantity of biofertilisers; b) Development of liquid biofertilisers has improved the shelf life of the product; c) Biofertilisers play an important role in improving soil health (e.g. Inoculation with BGA in submerged soils is shown to improve soil health by building up of organic activities, poly saccharide production and soil aggregation which in turn improves soil fertility); d) Through various Central Sector Schemes like National Project on Organic Farming, Rashtriya Krishi Vikash Yojana, National Horticultural Mission etc, financial and technical assistance are being provided to promote biofertiliser.

Threat: a) The main threat of biofertiliser is high expectation on enhancing crop productivity which is not always possible due to various constraints including biotic and abiotic factors; b) There is no scope of checking whether genetically modified organisms are used as source of strains during preparation of the product; c) Emergence of some Bio-Organic mafia groups who are selling substandard product.

Microbes are very much powerful and Soil is the main source of microbes responsible for preparing biofertilisers.The total bacterial biomass could reach 3599 Kg/ha (Bhattacharyya, 2012) of surface soil. Besides, other organisms like fungi, actinomycetes etc also contribute in nutrient transformation in soil, their performance in Nitrogen fixation, Phosphorus solubilisation, and potash mobilsation, zinc solubilisation etc make nutrients available to plants. They are also involved in transformation of sulphur, Calcium, iron. If farmers get high quality biofertilisers, they may get adequate benefits on the way to their prosperity (Bhattacharyya, 2013).

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Integrated Pest Management Strategies in Organic Farming

C T Ashok Kumar and Sanjay Topagi

Pests-arthropods and pathogens had been, are and will continue to be major constraints to agricultural production throughout the world. Synthetic chemical pesticides were introduced in the 1940's and used widely on agricultural crops in the hope that they would control agricultural pests. It is now clear that, their use has some unfortunate consequences. In some cases, undesirable environmental impacts of synthetic pesticides have caused agriculturists to oppose the use of these materials in agriculture and caused governments to regulate or outlaw their use. Pests develop resistance to synthetic chemical pesticides. In the recent years, population of many pests has developed resistance to many commercially available pesticides (Ramakrishnan *et al*, 1984 & Rame Gowda, 1999). In fact, pest resistance currently limits the efficacy of many insecticides, fungicides and herbicides and there are some pests for which no effective pesticides are available. Many synthetic chemical pesticides are broad spectrum, killing not only arthropod pests but also beneficial organisms that serve as natural pest-control systems. Without benefit of the natural control that keep pest populations in check, growers become increasingly dependent on chemical pesticides to which pests may eventually develop resistance. Thus, there is an urgent need for an alternative approach to pest management that can complement and partially replace current chemical based pest management practices.

Organic farming and sustainable farming systems are the best alternative approach to conventional agriculture. It is an interdisciplinary system, which aims at co-operating rather than confronting with the nature, has been hailed as the only answer to bring sustainability to agriculture. Though 'Green revolution' helped us to overcome domestic food deficits and ushered in an era of food security, sole reliance on an array of chemicals has

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led to several problems *viz.*, insecticide resistance, resurgence, residual hazards, lack of bio-diversity and replacement of natural enemies created imbalance in nature and resulted in outbreak of pests and diseases. To overcome all these problems, organic agriculture has emerged as a dynamic 'Alternate Farming System'. In organic farming system, pest control strategies are largely preventive rather than reactive. It is not a single approach but rather variety of techniques which are aimed at reducing cost, preserving the environment and protecting human health by eliminating the use of toxic farm chemicals. Historically, organic wastes of animal origin were most commonly used for nutrition and plant protection. In addition, herbs processed in liquid excreta of animals were used for plant protection. Cow dung manure and liquid manure called Kunapajala were used universally. In this direction, scientific evaluation of biodynamic pesticides, botanicals and biorationals including indigenous technologies are considered very much essential to combat noxious pests of groundnut in the transitional belt of Karnataka during rainy season. Use of botanical pesticides for protecting crops from insect pests has assumed greater importance in recent years all over the world (Hiremath, 1994).

According to the organic standard, insect pest problems may be controlled through cultural, mechanical or physical methods; augmentation or introduction of predators or parasites of the pest species; development of habitat for natural enemies of pests; and non-synthetic controls, such as lures, traps, and repellents. When these practices are insufficient to prevent or control crop pests, biological and botanical applications come handy. However, the conditions for using the material must be documented in the organic system plan. Pest management plans are site-specific. Farmers should develop their own strategies based on their knowledge, available time, and capital–the resources they can devote to pest management.

Organic pest management: Integrated Pest Management (IPM) practices are more crucial in organic farming systems as opposed to other farming systems because producers cannot use conventional insecticides for a quick fix: i) IPM practices in other farming systems (not organic), allow the use of IPM compatible pesticides which are not necessarily 'organic'. In organic farming systems one must ensure that the product is OMRI listed; ii) IPM compatible insecticides refer to those which are compatible with other IPM tactics employed; iii) These insecticides are usually effective but have the least toxic effects on the environment and non-target organisms.

Overview of IPM practices in organic farming systems: 1) Choose crops that have relatively few pests**;** 2) Select planting time that allows crops to avoid the insect all together or at least avoid peak populations (e.g. plant early or late); 3) As much as possible, select crop varieties that are resistant to key pests; 4) Practice crop rotation; 5) Avoid staggered planting of the same crop with successive planting near earlier ones; 6) Think about position of crops in relation to other crops; 7) Sanitation – destroy old crop residue soon after final harvest; 8) Know when to give up on a crop; 9) Eliminate weeds before planting and control while crops are in the field; this helps to keep a number of insect pests under control including: cutworms; false chinch bugs; vegetable weevils; spider mites; slugs and crickets.

Mechanical weed control (tilling) has other advantages: i) Thorough tilling helps control insects that overwinter in the soil or under crop debris; ii) Tilling also reduces the number of in-field fire ant mounds.

The term 'biopesticides' usually refers to all biological materials and organisms that can be formulated and used as pesticide to manage obnoxious pests and diseases threatening the productivity of crops and animals. These include microscopic organisms like virus, bacteria, fungi, protozoa, nematodes, antagonistic fungi, bacteria and macroscopic animals like insects (parasitoids and predators), mites, plants (botanicals) and semiochemical that alter behavior of insects. The modes of action of biopesticides involve competition, antagonism/inhibition, toxication, infection, infestation parasitization and predation.

The major advantages of biopesticides over chemical pesticides in organic farming are: i) Economical once method is developed; ii) Selective in action and hence no side effects; iii) Self propagating and self perpetuating as they are biological entities; iv) No development of resistance; v) Safe to non-target organisms; vi) Virtually permanent unless ecosystem is disturbed; vii) Effective against pests that are not accessible through chemical approaches and vii) Compatible with other pest management tools except with broad spectrum toxicants.

During the past 100 years of bio-control, parasitoids and predators have played a key role world wide. Till 1990, more than 5500 natural enemies had been identified and introduced. In 1200 of such cases, the natural enemies became established and led to successful control of insect pests in 420 instances. Of these successful natural enemies, 340 were species of parasitoids, 74 were predators and 6 were pathogens. It is clear that during the first era of biological control, parasitoids and predators made up 99 per cent of the successful cases. The rapid evaluation and introduction of a number of natural enemies in situations where chemical control was either insufficient or impossible, has taught crop protection specialists that biological control within IPM programmes is a powerful, economical and profitable option. During the last decade (1994–95 to 2001–2002) the government of India spent nearly Rs. 14,926 million for biocontrol of pests on different crops, covering an area of 38.5 lakh hectares.

Cultural practices: a) The place to start: Insect pest problems are influenced by three components of a farming system. Farmers can manipulate all of these components to suppress pest species. i) The crop species and cultivar present a set of resources, growth habits, and structure. ii) Production practices, such as rotation, timeliness of planting and harvesting, spacing of plants, fertility and water management, tillage, mulching, sanitation, and companion planting. iii) Agro-ecosystem structure includes field borders, natural vegetation, and other crop production areas that resupply fields with pest insects and beneficial species when crops are replanted. b) Protecting the crop: Sanitary measures; healthy planting material, clean seeds, clean tools *etc*. Use of Resistant Varieties: Exploiting host resistance. Some of the varieties of different crops are found to be resistant or tolerant to particular disease or insect pest. Growing of such variations will help in getting good yields even if there is a pest attack e.g. DVS-3 sorghum varieties resistant to earhead midge; DSV-4 sorghum varieties resistant to charcoal rot. Monsanto Boll guard–resistant to boll worms due to incorporation of Bt gene in that variety

Cultural measures: a) Higher seed rate: Increased seed rate will help to retain required plant population even after uprooting and destroying the interested plants by pests like shoot borer and stem borer. b) Planting distances: High plant density reduces necrosis of groundnut; low plant density reduces damping off in nursery and sorghum charcoal rot. Wider row sparing in rice reduces BPH in rice. Higher seed rate will help to retain required plant population even after uprooting and destroying the infested plants by pests like, shoot borer, shoot fly. c) Use of trap crops: Bhendy/Okra can be used as trap crop in cotton (10:1), which will help to trap the boll worms and stem weevils of cotton; similarly, Castor as trap crop against *Spodoptera* in groundnut and tobacco; Marigold as trap crop in tomato (16:1) against *Helicoverpa* will reduce the incidence. d) Use of fertilizers: Excessive use of fertilizer will result in succulent and vulnerable conditions for the attack of insect pests and diseases. Hence excessive use of N fertilizer in most of the crops will aggravate the pest problem; while use of organic manures will induce tolerance to pest and diseases.

Mechanical methods

Collection and destruction of insect pests: Root grubs in adult stage can be collected during summer on the day of first rain at 7.30 to 9.00 pm with the help of petromax or fire and destroyed. The grown up caterpillars of *Helicoverpa*, *Spodoptera etc* can be collected by hand picking and subsequently destroyed.

Destruction of stubbles and crop residues: Stubbles of *Sorghum* and Maize known to give shelter to stem borer larva which continue their next generation after summer. Hence, destruction of such stubless either by burning or by burying in the soil will kill the stem borer larvae or pupae. The egg masses and the early larval stages of *Spodoptera*, Bihar laity caterpillar soon after hatching can be collected easily on tobacco, soybean, groundnut and other crops and destroyed to avoid the further spread of the pest. Similarly, the egg masses of stem borer of paddy and early shoot borer of sugar cane *etc*. can be removed by clipping the tips of the leaf and destroyed. Passing a rope across the paddy field will help to eliminate the leaf cases along with case worm larvae which will fall in water and die. Intercropping, crop rotation (rotation of crops with non host plants) will help to reduce the incidence of many key pests in different ecosystems.

Pheromones and other attractants: Insects are very small creatures in a very large world. They evolved many different ways of finding each other to mate. Many insects find each other over long distances by emitting chemical signals or *pheromones* to attract individuals of the same species into an area so they can find each other to mate. Once the individuals get close together, visual cues–such as color, shape, and behavior become more important. Entomologists have determined the chemical structure of pheromones for many pest species and duplicated them synthetically. Insects also use other chemical messages. Chemical cues to the location of food can draw insects into a particular area where, once they get close enough, visual and tactile cues lead them to food sources. Pheromones and other chemical attractants can be used in several different ways: to monitor pests, disrupt mating, capture a large number of adults (called *mass trapping*), distribute an insect pathogen or lure pests to consume poisoned bait. Any trap baited with an attractant must be used carefully. Some research has demonstrated that a trap can bring more pests into an agro ecosystem than it kills. Overall, by three ways we can use pheromones; To Monitor Insect Populations, to Disrupt Mating and for Mass Trapping

Biological control using insect pathogens: Insects have many types of natural enemies. As with other organisms, insects can become infected with disease-causing organisms called *pathogens*. Soil serves as a natural home and reservoir for many kinds of insect pathogens, including viruses, bacteria, protozoa, fungi, and nematodes. When micro organisms or their products (toxins) are employed by man for the management of insects, animals and weed plants in a particular area it is referred to as microbial control. The microbes involved in insect control are referred to as the insect pathogens. So far over 3000 micro-organisms are known to cause diseases in insects. Some of them can be easily mass produced and are reported to be utilized in the management of insects as microbial insecticides. In all 281 biopesticides involving insect pheromones (38.17%), bacteria (37%), nematodes (15.7%), fungi (4.7%), viruses (2.85%) and protozoa (2.14%) are available in the market.

Insect-parasitic nematodes and protozoa: Insect-parasitic nematodes show promise as biological control agents for soil pests. Nematodes are microscopic, whitish to transparent, unsegmented round worms. Nematodes in the families Steinernematidae and Heterorhabditdae have been studied

Table 1: Classical biological control agents used in India

Sl. No	Biocontrol agents	Imported from	Against
1	*Cryptolaemus montrouzieri*	Australia	Mealy bugs
2	*Rodolia cardinolis*	USA	*Icerya purchasi* in citrus, Casurina
3	*Telenomus remus*	New guinea	*Spodoptera litura* on tobacco
4	*Eriborus trochanteratus*	Srilanka	*Opisina arenosella*
5	*Lepatomastix dactylopii*	West Indies	Mealy bugs in citrus, coffee, guava
6	*Curinus coerulus*	Thailand	Subabul psyllid
7	*Cephalonomia stephanoderis*		Coffee berry borer
8	*Cyrtobagous salvinae*	Argentina	Gaint Water fern *Eichhornia crassiper*
9	*Neochaetina bruchi* *N. eichhorniae* *Orthogalumna terebrantis*	Brazil	Water hycinth
10	*Zygogramma biocolorata*	Mexico	Parthenium
11	*Dactylopus tomentosus*	Srilanka	Pricklypear

extensively as biological control agents for soil-dwelling insects. The most promising nematode involved in insect control belongs to the family Steinernematidae. These nematodes are characterized by their association with bacteria of the *Xenorhabdus* genus. The infective juveniles of the nematode carry their symbiotic bacteria in their intestines. These nematodes occur naturally in soil and possess a durable and motile infective stage that can actively seek out and infect a broad range of insects. When they enter their insect host through natural openings, they release the bacterial cells that propagate and kill the insect within 48 hours. These nematodes are virulent, kill hosts quickly and are easily mass produced *in vivo* and *in vitro.* The most commonly and commercially used nematode is *Steinernema feltiae*. They do not infect birds or mammals. Because of these attributes, as well as their ease of mass production and exemption from EPA registration, a number of commercial enterprises produce insect-parasitic nematodes as biological 'insecticides.'

Application: Some nematodes that are commercially available are *Steinernema carpocapsae, S. feltiae, S. riobrave, Heterorhabditis bacteriophora,* and *H. megidis*. Treatment with these nematodes can be expensive, and they are most commonly used for managing soil insect pests in high-value crops, such as turf, nurseries, citrus, cranberries, and mushrooms, as well as in home lawns and gardens. As production technologies improve, the cost of using nematodes is falling, and it may be economical to use them in lower value crops in days to come.

Protozoa: Protozoa are also employed in pest management programme. *Nosema locustae* is a moderately virulent protozoan that infects a wide range of grasshoppers and locusts. The organism has been registered in USA for use as a microbial insecticide against grasshoppers and is currently produced and sold commercially.

Insect-parasitic fungi: Some fungi are used successfully to protect crops from a variety of insect pests. More than 900 species of entomopathogenic fungi belonging to 100 genera are recorded and only 10 species have been commercially exploited of which *Beauveria bassiana, Metarhizium anisopliae, Nomuraea rileyi, Lecanicillium lacanii, Hirsutella thompsoni,* and *Paecilomycis* sp. are popular in India. Most fungi can cause natural outbreaks when environmental conditions are favorable. Fungi and nematodes are the only insect pathogens that are capable of invading insect by penetrating the cuticle. This is the most useful means of infection. Therefore, those insects that feed by sucking such as aphids, scales *etc*. attacked only by fungal pathogens. This mode of infection means that fungi are very dependent on environmental conditions, in particular high humidity in order to achieve infection. Most successes with fungi have been with Deuteromycetes group which cause epizootic on foliage feeding insect only in tropical environments. *M. anisopliae* (Metschnikoff) can infect more than 300 insect hosts. The potential is proved beyond doubt in the management of different species of grasshoppers, termites, root grub, pyrilla of sugarcane, BPH in paddy, rhinocerous beetle, *etc, L. laccanii* has been reported to be highly potent against aphids, thrips, scales, mealy bugs, hoppers, whiteflies, mites *etc*. This fungus could reduce the green bug infestation considerably in coffee plantation in South India. *B. bassiana* has been exploited to control many pests like root grubs, caterpillars, BPH, coffee berry borers, *Helicoverpa etc.* Several species have been developed as commercial products because of their ability to be mass produced. Specific fungal strains in commercial products target thrips, whiteflies, aphids, caterpillars, weevils, grasshoppers, ants, Colorado potato beetles, and mealybugs. *N. rileyi* is an important fungal pathogen, which causes natural mortality of few lepidopteran hosts like *Spodoptera, Helicoverpa,* semiloopers, cutworms, hairy caterpillars *etc*., in crop ecosystem under transitional and high humid climates. These entomopathogens being facultative can be easily and cheaply mass multiplied on any Carbon rich substrate especially on broken rice.

Application*:* The best time to apply fungi is before pest populations reach their peak, so early application can increase their effectiveness. Apply fungal inoculum carefully to get effective coverage; cover all plants thoroughly and also try to reduce spillover into refuge areas where natural enemies may be present; do not apply fungal products during the heat of the day because this will diminish the potency of the spores.

Insect-parasitic viruses: Insect viruses are obligate disease-causing organisms that can only reproduce within a host insect. They can provide safe, effective, and sustainable control of a variety of insect pests, although they are most effective as part of a diverse IPM program. Some viruses are produced as commercial products, most notably for fruit pests, but many others are naturally occurring and can initiate outbreaks without additional inputs. Most virus-infected insects die attached to the plant on which they feed. Virus-killed insects break open and spill virus particles into the environment. These particles can infect new insect hosts. Because their internal tissues are destroyed, dead insects often look ‘melted’. The contents of a dead insect can range from milky-white to dark-brown or black. The best documented example of the classical approach using a virus is the introduction of a baculovirus to control the rhinocerous beetle (*Oryctes rhinoceros* L*)* in coconut. There are viruses that have been produced commercially or developed for large scale inundative use. NPV (Nuclear Polyheadrosis Viruses) against *H. armigera, S litura*, RHHC, DBM, PTM and armyworm have been found effective. The Department of Biotechnology, (DBT) GOI, has provided financial support to establish units for mass production of NPV at SAU's and ICAR institutes. Many government institutions and private organizations are engaged in large scale production and supply *Ha* NPV and *Sl* NPV.

Application: Apply viruses in the morning or evening or on cloudy days when degradation from sunlight is reduced. Avoid applying on rainy days, as rain will wash virus particles off the leaf surfaces. Use formulations with ultraviolet (UV) light blockers and sticking agents to increase longevity. Check carefully to make sure these formulations comply with organic standards.

Insect-pathogenic bacteria: Many insect diseases are caused by bacteria. The most commonly used bacterial product available to 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. Because *Bt* products are applied like insecticides, it will be discussed in the section on insecticides in this publication. Not all formulations of *Bt* are allowed in organic production, so it is important to check with your certifier before purchasing or using Bt. In most cases bacteria affect their hosts after they have been ingested along with food and often by producing toxic metabolites that damage the gut wall and brings the death. *Bt* Products represent about 1% of the total agrochemical market (fungicides, herbicides and insecticides) across the world. The commercial *Bt* products are powders containing a mixture of dried spores and toxin crystals.

Biological control using insect natural enemies: One of the important components of the biological environment is natural enemies viz., predators and parasitoids that dampen pest insect populations. Organic farmers often assume that withholding conventional pesticides will have a beneficial effect on population levels of species that weaken and kill pest insects. The absence of conventional pesticides are likely to encourage the natural enemies of pest insects. But that encouragement may not be enough to provide substantive control of chronic pests without additional changes in the agro-ecosystem, which provide habitat for the pests and their natural enemies.

Parasitoids and predators: India is blessed with a rich natural beneficial insect fauna. India is considered one among the 12 mega hot spots of bio-diversities in the world. It accounts for 6.2% of global hymenopteran fauna that includes major parasitoid groups. It is significant to note that at least 27 natural enemies are worth billions of rupees; out of 18 species of parasitoids imported into USA for biological suppression of *Helicoverpa*, 11species were from India. This rich biodiversity gives us ample scope to be potential exporter of natural enemies. From the review of the world scenario it is evident that at least 120 species of major insects pests and 27 species of weeds have been controlled by introducing parasitoids/predators/weed killers from different regions, including control of cottony cushion scale by Australian lady beetle, the coconut moth in Fiji by the Tachinid fly from Java, the coffee mealy bug in Kenya by the Encyrtid parasitoid from India and prickly pear weed in Australia. In India, aqutic weeds, viz., water hyacinth, *Parthenium* and *Salvinia molesta* have been successfully controlled by introduced weed killers. The nymphal and adult parasite of sugarcane pyrilla, *Epiricania melanoleuca* has been successfully established in the states of Karnataka, Rajasthan, West Bengal, Maharashtra and Gujarat. The parasitoid has adaptability to a wide range of ecological conditions. A chacid parasitoid, *Aphelinus mali* which was first introduced in the Kulu valley and later in Kodainakanal and Coonoor of the Nilgiri, has become established and caused 70–80% mortality in woolly aphids of apple. Very recently a trivelian pest, sugarcane woolly aphid (SWA) which has caused turbulence in the sugarcane production in peninsular India could be controlled by predators like *Micromus igorotus, Dipha aphidivora* and syrphids. Massive financial support has been extended from Government of Karnataka for distribution of predators for the biological control of this pest.

Similarly, an egg parasitoid, *Trichogramma* spp., which has been extensively used world over to suppress lepidopterous pests in number of cropping systems viz., cotton, vegetables, fruit tree etc. Effectiveness has been established against sugarcane borers, stemborers and *Helicoverpa armigera* in tomato, brinjal, potato, Lucerne, maize, jowar, paddy (Yadav *et al.,* 1985 and Sithanatham, 1980). Several countries have taken lead in establishing insectaries which are managed by private entrepreneurs, growers, Cooperatives, government agencies, from pilot scale production in developing countries to highly mechanized way in Russia. India's first commercial insectary was established at Bangalore in 1981 by Pest Control India Pvt. Ltd. (PCIL), The parasitoids and predators of sugarcane borers, coconut black headed caterpillar, coffee/citrus/grape/mealy bugs and cotton bolloworms are available. *Bracon kirkpatrie, Chelomus blackburni, Apanteles angleti, Rogos aligerensis, Campoleties cholridaea, etc*., are some of the larval parasitoids which have greater potentiality in biocontrol programmes on various crops. Chrysopid predator, *Chrysopa* spp. also offers great scope in suppression of sucking pests in cotton. A mass production technology has been developed for various predators by NBAII Bangalore, SAU's and other ICAR institutes.

Amongst the lady bird beetles, *Chilomenus sexmaculata, Coccinella* spp. *Scymnus* spp. were found effective against aphids in crops like groundnut, cotton, cowpea, tobacco *etc*. Several species of spiders, bugs, and mirid bugs were also found to regulate the pest population in many crop ecosystems. In India, 409 bio-control production units are functioning under both public and private sectors of which 17 biocontrol production and supply units are working in Karnataka.

Table 2: Release dosage of parasitoids in different crops

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Sugarcane					
Borers	*Trichogramma chilonis*	5000/ha release	10 days interval 8 times at 30 DAT	Stapling	Pheromone trap catch data
Pyrilla perpusilla	*Epiricania melanoleuca*	2–3 egg masses or 5–7 cocoons in 40 selected spots/ha	Before onset of rainy season	Uniformly spread in 40 spots	Increase dosage by 10 times in endemic areas
Root grubs	*Metarhizium anisopliae*	10–12.5 kgs/ha	June–July	Mix with 500 kg FYM spread uniformly in the field	Increase dosage to double in endemic areas
Sugarcane Woolly Aphid	*Micromus igorotus, Dipha aphidvora*	1000–1500/ha pupae 1000–1500/ ha Larvae /Pupae	Once during August–September	Place cocoons in dried leaves	Detrashing should be avoided
Rice					
Yellow stem borer *Scirpophaga incertalus*	*T. japonicum*	50,000/ha release	30,37 and 44 DAT	Stapling egg card bits	Pheromone traps
N. lugens (BPH)	*Cyrtorhinus levidipennis*	50–75 nymphs/M2	After noticing the pest	Infested spots	If ratio is 1:4, No need
	M. anisopliae	200g 2x10 cfu/g	After noticing the pest	Infested spots – by Knapsack sprayer	

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Cotton					
All Bollworms *H. armigera* *E. insulana*	*T. chilonis*	50,000/ha per release	6 times after 40 DAS	Stapling egg cards	Use selective pesticides
	Ha NPV	500 LE/ha	After noticing the pest	Spraying	Spray during evening time add jaggery and UV protectant
Tobacco					
S. litura	*Telenomus remus*	50,000/ha per release		Release adults	Distribute uniformly in the nursery beds
	SI NPV 250 LE/ha	After noticing the pest	5 times at weekly interval	Spraying	Spray with Knapsack sprayer Add jaggery and UV protectants
Aphids	*C.carnea*	50,00/ha or 6/plant	4th week at weekly interval	2nd instar grubs	–
H.armigera	Ha NPV	250LE/ha	Four times	Spraying	Spray with knapsack sprayer Add jaggery and UV protectants

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Coconut					
Opisina arenosella (coconut black headed caterpillar)	*Goniozus nephantidis*	8–10/palm 3000–4000/acre	Need based for each generation	Releasing adults	Release when larvae are noticed in the field
	Bracon brevicornis	8–10/palm 3000–4000/acre	Need based for each generation	Releasing adults	do
	Bracon brevicornis	2:5 ratio	Need based for each generation	Releasing adults	do
	Elasmus *Nephantidis*	2:5 ratio	Need based for each generation	Releasing adults	Release when larvae are noticed in the field
Oryctes rhinoceros (Rhinoceros beetle)	Baculovirus	10 beetles	One inoculative release	Release in the middle of the field at night	Wide coverage better results
	M.anisopliae	$4x10^6$ conidia/M^3	Once in rainy season	Mix spores in manure pits	Wide coverage better results
Arecanut *Ischnaspis longirostris*	*Chilocorus nigrita*	20 or 50 beetles/ plant	Release after noticing the pest	Release adults beetles	Only to infested trees
Coffee					
Mealy bug pseeudococcus	*Cryptolaemus mantrouzeri*	8–10 beetles/ infested plant	After the blossom	Release adult beetles	Ant suppression should be adopted
Green scale	*M.anisopliae*	1 g/lit $2x10^8$ cfu/ml	–	–	Use knapsack sprayer for proper coverage

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Coffee berry borer	*Beauveria bassiana*	$2x10^8$ cfu/ml	120–150 days after blossom setting	Spray the conidia during evening time	Use knapsack sprayer for proper coverage
Apple					
Eriosoma lanigeruson	*Aphelinus mali*	1000 adults/ mummies/trees	Once, as soon as infestation noticed	Releasing adults or placing mummies	Effective in valleys on aerial population
Quadraspidiosus perniciossus (Sanjose scale)	*Encarsia perniciosi*	1000 adults/trees	Once, in spring	Releasing adults or placing mummies	In endemic areas repeat release
	Chilocorus infernalis	20 adults or 50 grubs/tree	Once in April–May	Releasing adults or placing mummies	In endemic areas repeat release
Cydia pomenella	*T.embryophagum*	2000 adults/tree	At weekly interval	Releasing adults	Pheromone catch
Citrus					
Icerya purchasi	*Rodolia cardinailis*	10 beetles/tree	Once on noticing adults	Releasing adults	Ant suppression
Planococcus citri (Mealy bug)	*Cryptolaemus montrouzieri*	10 beetles/tree	After the blossom	Releasing adults	Ant suppression
	Leptomastiz dactylopii	3000 adults/tree	Need based	Releasing adults	Ant suppression
Papilio demolius (citrus butterfly)	*B.t.k*	1ml/lit 0.5%ai	Single application for each generation		Spray with knapsack sprayer
Coccus viridis	*Verticillium lecanii*	$2x10^5$ cfu/ml	Single application onset of mansoon	Spray with knaspsack	Proper coverage

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Grapes					
Maconellicoccus hirsutus (Mealy bug)	*Cryptolaemus montrouzieri*	2500–3000 beetles/ acre 10 beetle/ infested vine	Once as soon infestation is noticed	Release adults	Ant suppression
	Verticillium lecanii	$2x10^5$ cfu/ml	Single application onset of mansoon	Release adults	Proper coverage
Guava					
Chloropulvinaria psidii (Mealy bug)	*C. mantrouzieri*	10–20 beetles infested/plant	Once as soon infestation is noticed	Release adults	Ant suppression
Mango					
Mealy bug	*C. mantrouzieri*	10–20 beetles infested/plant	Once as soon infestation is noticed	Release adults	Ant suppression
Vegetables					
Beans *Tetranychus* spp.	*Phytoseialus persimilis*	10 adults/pl	Once in 30 days after germination	Adults Release	Release in Brinjal and straw berry also
Cabbage *Plutella xylostella*	*Bt*	500g	Need based or weekly interval	Knapsack sprayer	Evening spray
	M.anisopliae	$2x10^8$ conidia/ml	Need based or weekly interval	Knapsack sprayer	Evening spray
	Beauveria bassiana	$2x10^8$ conidia /ml	Need based or weekly interval	Knapsack sprayer	Evening spray

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
S.litura *Trichoplusia ni*	*N.rileyi* *N.rileyi*	2x10^8 conidia /ml	Need based or weekly interval	Knapsack sprayer	Evening spray
Tomato *H.armigera*	*Trichogramma brasiliensis*	50,00/ha	Weekly interval 6 times from 25 DAT or egg laying period	Stpling parasitized egg card uniformly	Pheromone trap catches
	Ha NPV	250LE/ha	Thrice during growth period	Knapsack sprayer	Jaggery, teepol, boric acid
	N.rileyi	2x10^8 conidia /ml	Thrice during growth period	Knapsack sprayer	Jaggery, teepol, boric acid
Potato Agrotis spp. (cutworm)	*Stenernema carpocapsae*	5 billion infective juveniles per ha	On detection of cutworm larvae	Apply in soil thro irrigation water	Highly susceptible to descocation
Brinjal *Leucinodes rbanalis*	*T. chilonis*	50,00/ha	Weekly interval 6 times from 25 DAT	Staple parasitized egg card uniformly	Pheromone trap catches
Weeds *Eichhornia crassipes* (Water hyacianth)	*Neochetina eichhorniae,* *N. bruchi*	100–5000 beetles/ water body	Release weevils in water bodies at the onset of mansoon	Releasing adults or infested weed mats	Take up area wide operation
	Orthogalumna terebrantis	10,000 to 50,000 mites/water body	Release mites in water bodies at the onset of mansoon	Releasing adults or infested weed mats	Take up area wide operation

Crop	Biotic agent	Dosage/ha	Frequency of application	Method of application	Remarks
Salvinia molesta (Gaint waterfern)	*Cyrtobaugous salviniae*	100–5000 beetles/ water body	Release weevils in water bodies at the onset of mansoon	Releasing adults or infested weed mats	Take up area wide operation
Leucaena leucocephala (Subabul)	*Curinus coeruleus*	20–25 beetles per tree	Twice during July and October	Release adults	Inoculate as many places as possible
Parthenium hysterophorus	*Zygogramma bicolorata*	1000–2000 beetles/ ha	During June and July	Release adults	Inoculate as many places as possible

Predatory birds: Birds (both carnivores and omnivorous) are predators in various crop ecosystems. The capacity of the birds to locate the prey from certain distance due to their keen eyesight and modification of their beaks to catch the prey made them potential predators. Black drongo, Indian mynas, king crow, cattle egrets, sparrows etc., are efficient predatory birds. Attraction of birds to any crop ecosystem is possible by providing places (perches) for alighting/nesting providing food and water source. Bird perches can be inanimate like branched twigs, poles with cross *etc*., or animate like stray planting of tall growing cereal crops like maize, sorghum and stiff fiber plants like Mestha (pundi) and *Hibiscus cannabinus etc*.,

Insecticides: When nonchemical practices documented in the Organic System plans are not sufficient to prevent or control populations of insect pests from rising above a level that is economically damaging, a biological or botanical material or a substance included on the national list of synthetic substances allowed for use in organic crop production may be applied to prevent, suppress, or control pests. The National List of Allowed and Prohibited Substances provide information on allowed and prohibited synthetic and non-synthetic substances for organic crop and livestock production. A producer must know which organic pesticides are allowed, what materials are labeled for their crops, and the efficacy of those materials against the intended target pests. Pest control materials are classified as allowed, restricted, or prohibited for use in organic systems. To avoid the risk of losing organic certification, make certain you know if and under what circumstances the material that you are planning to use is allowed. Examples of types of materials that are currently allowed in organic production include allowed formulations of insecticidal soap, diatomaceous earth, Potassium or sodium biCarbonate, spinosad, various microbials, bentonite and kaolinite particle films, plant extracts and oils, and pheromones. Some products with allowable active ingredients may contain unacceptable adjuvants, so it is important to check the label with your certifying agency before using a material.

Despite the growth of organic agriculture, there has been a lack of research-based information to address the need for a greater understanding of the mechanisms operating in organic systems, including plant-pest interactions. The insect pest management approaches in organic farming systems that operate in a purely preventative manner to curative methods generally withheld as a last resort. However, the integration of methods from various phases is important. Such integration is apparent in the documentation for all organic standards but there is a need to better realize such integration in practice. The underlying principles of insect pest management in organic systems involve the adoption of ecologically sound practices specified by international and national organic production standards. Of highest priority, indirect, preventative measures should be considered early in the adoption process, followed by more direct and curative measures as required.

Finally, the volume of pest management research conducted on organic systems is small compared with the far wider literature on integrated pest management for conventional crops. Accordingly, there is a need for more research to be conducted on certified organic land and investigators may be usefully informed by mining the IPM literature. Although modern synthetic pesticides with narrow-spectrum activity and reduced environmental and human health risks are disallowed in organic agriculture, other biological and cultural methods developed for conventional crops may prove useful.

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Crop Production and Plant Protection in Organic Farming

S R Sundararaman

Awareness about organic farming is on the rise. Farmers have not yet recovered from the ill effects of the green revolution. Only if farmers stop using pesticides can they as well as others live a healthy life. How would we be able to eat healthy food when we inundate our fields with poisons? The ill effects of the green revolution demonstrated themselves right on our farm. As a result, we stopped using chemicals long ago and turned to organic farming. Organic farming brings self-reliance not only to the farmers who practice it but also to the entire nation.

Self-reliant agriculture: The use of chemicals (fertilizers and pesticides) has taken over crop production these days. Crops have lost their natural resistance and stamina due to the use of chemical fertilizers. Because of this they have become susceptible to diseases. As a result, farmers have to resort to increased use of pesticides. Chemical residues from these have hardened the soil like a rock. To overcome this, farmers are forced to use ever larger quantities of fertilizers. These factors make for more work and increase the cost of farming. Organic farming is the only recourse farmers have to save our health and the health of our soil. By using organic methods farmers save money. It is possible to convert one's own farmyard wastes into value-added products for crop production. We can also avoid poisoning our land. Our soils keep getting enriched. We would be able to provide healthy farm produce to our relatives, friends, and neighbours. Our environment will be saved. Diseases could be averted. We do not have to depend on others. Our self-reliance is thus protected. A large portion of our country's foreign exchange is used to pay for the import of petroleum products. By going organic we help our country save on valuable foreign exchange. Our land will keep giving us returns for extended periods of time. This is in contrast to the situation with the green revolution where the

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land stays productive for a short time and then becomes weak. This will not happen in organic farming. Prof. Dhabolkar, Dr L Narayana Reddy (Bangalore), and Mr G Balakrishnan (Ilankadu, Thanjavur) are our chief resource persons and guides. They give us energy and infuse enthusiasm, which are the driving force for us to think organically and to make a variety of organic cocktail preparations.

Raising a variety of crops for enriching the soil: The first step in enriching the soil organically is the growing of a variety of crops on our land. Using this method it is possible to enrich the soil in just two hundred days. Even land that has been depleted of all nutrients due to chemical farming can be restored in this manner. By growing the following crops for 50–60 days and then ploughing them in-situ we add balanced nutrients and micro-nutrients to the land. The soil will become enriched in two hundred days and micro-nutrient deficiency is eliminated. Dhabolkar, an organic farming expert in Maharashtra, has proved the efficacy of this method. This method helps us return to the soil many times more nutrients than what we take from the same soil. The following quantity suffices for one acre. Choose four of each of the following varieties of crops: 1) Grains. Example: 1 kg jowar, 500 gms pearl millet, 250 gms foxtail/Italian millet, 250 gms little millet. 2) Pulses. Example: 1 kg blackgram, 1 kg greengram, 1 kg pigeon peas, 1 kg bengalgram. 3) Oilseeds. Example: 500 gms sesame (gingelly), 2 kg peanuts (groundnuts), 2 kg sunflower seeds, 2 kg castor seeds. 4) Green manure seeds. Example: 2 kg daincha, 2 kg sunhemp, 1 kg horsegram.

Multiplying the nutrient mix of soil: Uproot a green plant, wash its root to remove all soil and weigh it. Suppose this green plant weighs one kilogram. Dry this plant well in the sun and weigh it again. It may now weigh only about 300 grams. Burn the dry plant and weigh the residual ash. It will be only about thirty grams. This is because water forms 70% of the total weight of a green plant, air forms 27%, and only the remaining 3% is due to the minerals that the plant took from the soil while it was growing. The water evaporated when we dried the plant in the sun. When we then burnt it, whatever carbon and nitrogen gases were there in it evaporated. What are left are the minerals. We may conclude from this that the plant takes very little from the soil and a lot more from the air and water, and uses sun light to grow. It is thus apparent that we enrich the soil considerably by not burning farm wastes and, instead, by giving them back to the soil. Sowing a variety of seeds in this manner is beneficial in many ways. The biomass of the soil increases. The physical and chemical properties of the soil are enhanced. The natural cycles of growth and decomposition take place unhindered. We incur very little expense because we minimize the use of external inputs like fertilizers. The water retaining capacity of the soil improves, thereby minimizing the need for irrigation. The leaf area is increased leading to the maximum harvesting of light energy for photosynthesis. This leads to increased yields. Addition of biomass is important for improving the organic carbon content of the soil.

To maintain soil fertility, protect from pests and diseases, minimize water usage in irrigation, and achieve optimum yield levels the organic carbon content in the humus is the basis. Organic carbon ensures that the soil is enriched with 90–95% nitrogen, 15–80% phosphorous, and 15–20% sulphur. Apart from this, all kinds of minerals like calcium, magnesium, potassium, and trace elements are also added to the soil. Organic acids like humic acid, fulvic acid, ulmic acid, and many other acids that would normally not be available to the roots are made directly available. It also maintains soil acidity and alkalinity to a neutral level. This enhances the physical structure of the soil, thereby improving water retention and increasing aeration. This helps earthworms and all kinds of soil flora and fauna to do their job effectively and efficiently. It prevents rain water runoff and helps in groundwater recharge.

The humus is able to hold twenty times water by its weight. This creates an excellent environment for crops to grow. Dr. Andre Leu, chair, Organic Federation of Australia, did research regarding humus. According to his research, if 20 cm of topsoil has 1% organic carbon there will be 24 tonnes of humus per hectare of land. This will absorb 88 tonnes of atmospheric carbon, thereby sequestering it. Hence, organic farmers have scope for receiving carbon credits. So, even without having to export organic produce, we could earn foreign exchange. Dr. Leu has also estimated that organic carbon in one hectare of land absorbs carbon emitted by twenty automobiles in one year. Dhabolkar advises each farmer to do this on her/his farm according to facilities available on the farm itself. The population of microbes increases, thus softening the soil. This helps plant roots sink deeper so that they can draw nutrients that are farther down from the surface. Finally, we no longer need to depend on agricultural experts because we are now self-reliant.

Catalysts for growth

Preparation and use of a variety of growth promoters and catalysts is the second aspect of our self-reliant farming methodology. Healthy soils support healthy crops that have no need for growth catalysts. (This is similar to the fact that babies that are brought up on mother's milk have no need for formula milk.) But, in parallel to mother's milk, we give babies some solid food as well. Similarly, by giving our crops some catalysts like amudham solution, AvUttam, coconut-buttermilk solution, and buttermilk-arappu solution, we may hasten plant growth.

Amudham solution: Concentrated amudham solution: Ingredients: 5 liters cattle urine, 1 kg dung, 1 liter juice of any waste fruit. Preparation: Mix the dung thoroughly in urine and juice. Set aside the mixture for five days. This helps us avoid the usage of jaggery, which is an external input. Usage: This can only be used along with irrigation and not for spraying. Use 20–30 liters per acre of this solution. This solution gives excellent growth. Note: Earlier we used the (ordinary) amudham solution in irrigation. This solution acts rightaway as a catalyst for growth. With very little work we can create this solution within twenty four hours. Ingredients: 1 liter cattle urine, 1 kg dung, 250 grams jaggery in 10 liters water. Preparation: Mix the dung thoroughly in water. Add urine and mix well. Powder the jaggery, add to the above, and mix well. Make sure there are no lumps, cover the mixture, and set it aside for 24 hours. Usage: Add one liter of this solution to ten liters water (for a 10% solution) and spray. You must make sure to dilute the solution or else the leaves will get scorched. This solution helps growth of leaves directly. It also repels insects. Instead of using jaggery, you may use waste fruit in this manner: Tie one kilogram waste fruit into a nylon bag and immerse this in urine solution. Let it soak for five days. This helps the fruit ferment well. Add ten times water to this and spray or add 60–100 liters of this in irrigation water for one acre. But, we need to use 50–100 liters per acre. To reduce the quantity and work we developed this combination. It is essential that farmers thus develop simple processes. This is what Dhabolkar insists upon.

AvUttam (Panchakavya): This is a solution that has five products from cattle: milk, curds, ghee, dung, and urine. This solution helps increase the population of beneficial microorganisms and acts as a good catalyst for plant growth. Ingredients: 5 kg dung, 3 liters urine, 2 liters fermented curds, 2 liters milk, 500 ml ghee, 1 kg jaggery, 1 kg fruit, 3 liters tender coconut, 10–12 banana (or similar quantity of other fruit), and 3–5 liters water. Preparation: Mix dung, jaggery, and ghee that have been melted and cooled. Knead it well. Cover this mixture with moist cloth for four days. Knead it once daily. On the fifth day add the remaining ingredients to this and let it ferment for fifteen days. (Add sufficient quantity of cattle urine and water). In twenty days you will find nice-smelling AvUttam. Usage: Mix one liter of this with 35–50 liters water (2–3% solution) and spray. Or, mix 5–10 liters per acre with irrigation water. It provides all kinds of micro-nutrients, enhances plant growth, repels insects, and helps increase disease resistance in plants. Panchakavya given in temples is not fermented. Also, it only has the five ingredients from the cow. It is best to tie the fruit in a nylon mesh and leave it immersed in the solution. This obviates the need for filtering later. Also, the contents of the nylon bag could be reused a few times in subsequent solutions. And there is no need to mash the fruit when we use this technique.

Coconut–buttermilk solution: This easy_to_make solution helps enhance plant growth, repels insects, and increases resistance to fungal diseases. Also, it enhances flowering in plants. This solution has the same growth enhancing potential as that of cytozime/biozyme (These are trade names). Ingredients: 5 liters buttermilk, 1 liter tender coconut, 1–2 coconuts, 500 ml–1 liter juice from waste fruit (or 500 gms – 1 kg waste fruit, if extracting juice is not easy). Preparation: Break the coconuts and collect the coconut water in a vessel. Add buttermilk to this and mix well. Grate the coconuts, add to the mixture, and let it soak. Or, mix grated coconut and fruit (if not in juice form), put the mixture in a nylon mesh, tie it, and immerse it in the buttermilk solution. This solution ferments well in seven days. The contents of the nylon bag could be reused a few times in subsequent solutions by adding a small quantity of grated coconut everytime. Usage: Mix ten liters water with 300–500ml solution and spray. This can also be used in irrigation at the rate of 5–10 liters per acre.

Arappu–buttermilk solution: Ingredients: 5 liters buttermilk, 1 liter tender coconut, 1–2 kg arappu *(Albizia amara)* leaves (or, 250–500 gms leaf powder), 500 gms waste fruit or 1 liter juice from waste fruit. Preparation: Mix the buttermilk and tender coconut. Crush the leaves well. If using waste fruit, add it to the crushed leaves and put this mixture in a nylon mesh and tie it. Immerse the mesh in buttermilk – tender coconut solution. Let it ferment for seven days. By using the nylon mesh we avoid the need for filtering the solution while spraying. If you use arappu leaf powder, use fruit juice instead of waste fruit. Mix all four ingredients and let it ferment for seven days. All these years we've been trying to simplify our preparations. Hence, we no longer use the coconut–buttermilk and arappu–buttermilk solutions. In their place, we use medicinal plant leaves based on Siddha and Ayurveda principles. We collect tender plant leaves like neem, *Vitex negundo (nochi), Albizia amara (arappu), thulasi, Aloe vera,* custard apple and use these in the buttermilk solution in the following combination. *Ingredients:* Five liters buttermilk, one liter tender coconut, 250ml papaya pulp, 100gms turmeric powder, 20gms asafoetida powder, and 500gms each of any two of the above leaves (in crushed form). Allow these to ferment for a week before using. To keep this solution for a longer period we could add any fruit to it to provide food for the microorganisms. Lactic acid bacteria and yeast bacteria in the buttermilk solution increases the medicinal content of the leaves, thereby enhancing biodegradation. So, by using this combination, we're effectively controlling all kinds of fungal, bacterial, viral diseases and all types of rotting diseases that occurs in rhizosphere. Many plant parts when they ferment release a sticky, gum–like liquid. You may add this liquid to the buttermilk and let it ferment. Hibiscus leaves, kattukkodi *(Cocculus hirsutus)* leaves, pasalai klrai (greens), AvArai, tender betel leaves, and the thick peel (outer skin) of jackfruit are examples. Usage: Mix ten liters water with one liter solution and spray. This helps plant growth, repels insects, and adds resistance to fungal diseases. This solution has the same potential as that of gibberlic acid.

Plant growth promoting rhizobacteria (PGPR): It is no use to plants if we simply dump dung and other wastes next to the plant. We have to process them properly before plants can make use of these. Microorganisms exist precisely to carry out this task. Bacteria are such microorganisms. These thrive in anaerobic conditions and are considered to be the earliest microorganisms that came into being in the course of the evolution of life on earth. We could reap good harvests if we make use of these microorganisms in the proper manner. We will have no need to use chemical fertilizers at all. Preparation: This solution is easy to make using a simple device invented by Mr. G. Balakrishnan. *Ingredients:* 20 kg dung, 200 liters water, 3 kg jaggery, 100 Gms kadukkai (*Terminalia chebula*) powder, 10 Gms adhimadhuram (*Glycyrrhiza glabra* or Mulethi). Mix dung, jaggery, and water well in a container. Add kadukkai powder to it and mix well. Boil the adhimadhuram powder in 250 ml water and let it cool. Add the cooled adhimadhuram solution to the above solution. Fill the rest of the container with water so that there will be no air left inside and close it air-tight. Methane will be formed inside the container. Let the air to escape once in a while by slightly unscrewing the cap for a moment. The solution will be ready in ten days. It will be light brown in color. This enhances plant growth. We could use this to grow blue-green algae. Mr. G. Balakrishnan, the expert who invented this, has recorded 15–20% increase in the leaf area. Such an increase in area leads to a corresponding increase in photosynthesis (harvesting of solar energy) and enhances yield. 200–300 liters of this solution is sufficient for an acre.

Usage: Mix a liter of it with ten liters water to spray. Or, for use in irrigation, mix 200–300 liters per acre of this solution with one of the following solutions: (a) 30–50 liters concentrated amudham solution, (b) 5–20 liters AvUttam (Panchkavya), (c) 5–10 liters coconut-buttermilk / arappu-buttermilk / soap nut-buttermilk solution, (d) 3 liters fish extract. To control diseases which damage the rhizosphere/rhizomes and to control fussarium wilt, we have to use beneficial fungi like *Pseudomonas fluorescens*, *Trichoderma viride*, *Trichoderma harzianum*, and *Bacillus subtilis*. To control root knot nematodes use Paecilomyces lilacinus. To control root grubs use *Beauveria bassiana* and *Metarhizium*. We have developed specific solutions for specific crops and diseases. Farmers should select a subset of the above ingredients depending on the crop and the disease. Let the mixture (of the powders and the archaebacterial solution) ferment for a day before mixing with irrigation water. You may also use each of the above five mixtures one after the other. This is a very good and simple method of enhancing soil health and to increase the population of all beneficial organisms in the soil

Fish extract (Fish amino acid): Fish extract helps us give green manure in the most natural way. This is widely used by organic farmers in Japan, Korea, etc. Ingredients: 1 kg native fish, 1 kg jaggery. Preparation: Remove the fish intestines and chop into fine pieces. (Using intestines is not harmful but it smells bad.) Powder the jaggery. Add the two to a broad–mouthed glass jar (best) or plastic jar that is just the right size (not too big), cover the jar with the lid (cap), tighten it, and mix well by shaking the jar. Don't add water. In ten days this will have fermented. Filter it using nylon mesh to get 300–500 gms solution into honey–like syrup. This is a great nutrient for the plants. Usage: Add 5 ml of this with one liter water for spraying. It could also be mixed with irrigation water.

Egg extract (Egg amino acid): Ingredients: 5 eggs, juice of 10–15 lemons, and 250 gms jaggery. Preparation: Place the eggs in a jar and pour lemon juice in it until the eggs are completely immersed. Keep it for ten days with the lid closed. After ten days smash the eggs and prepare the solution. Add equal quantity of thick jaggery syrup to it and set aside for ten days. The solution will then be ready for spraying. This is a great nutrient for the plants just like Fish Extract and will boost plant growth. It was originally conceived by Ms. Veeriachinnammal of Theni district (TN) as medicine for asthma. Usage: Add one to two ml of this with one liter water for spraying.

Plant protection: In addition to ensuring that crops grow well, we must also protect them from insect pests and diseases. Due to indiscriminate use of pesticides in the past 30–35 years, we not only polluted our land, water, and air, but also brought ill health to everyone. We have fallen prey to a large number of diseases. Farmers spent all of their earnings in buying fertilizers and pesticides. If we farmers have to escape from these poisons, we must opt for organic ways of controlling pests and diseases. We must practice prevention rather than wait until the plants are attacked. Prevention is better than cure.

Disease and pest attack: Plants that do not get enough nutrients are sapped of their strength. That is when they fall prey to attacks. Pests and diseases attack plants. Diseases attack from within. On the other hand, if a plant gets too much nutrition and its leaves are dark green, it attracts pests that cause external damage. These pests not only feed on the leaves but they also destroy the entire plant. If we understand this we can easily prevent disease and pest attack.

Types of insect pests: Based on their food preference, we may classify insect pests into two groups: (1) vegetarians that only eat leaves and other parts of the plant and (2) Non–vegetarians that eat other insects. Of these, it is the vegetarians that harm our crops. The non–vegetarians help us control the population of the vegetarians. The population of non–vegetarian insects is much more than that of vegetarian insects. But, in our misguided attempts at destroying the vegetarians using chemical pesticides, we also destroy the helpful non–vegetarian insects. We thus destroy the natural balance and help increase the population of vegetarian insects. As a result our crops sustain severe damage. In organic farming our goal is not to kill insects. Our goal is to protect our crops from harmful insects and to make sure they stay away from our crops. So we need not use chemicals that kill. We can prepare, on our own farms, solutions that help prevent diseases and repel harmful insects.

Pest repellants: There are some natural solutions for this purpose and we should understand their basis of operation. If we do so, we will be able to help our crops withstand any pest attack. In organic farming we take the view that every life form helps us in some way. The following leaves help repel insect pests: Leaves those cattle don't eat. Example:- Adathodai *(Adathoda vasica),* nochi *(Vitex negundo);* Stems that secrete milky sap when broken. Example:- Erukku **(***Calotropis gigentia***),** Umaththai (Datura alba); Leaves that tastes bitter. Example:- Neem, aloe vera; Leaves that tastes salty. E.g. kAttAmaNakku *(Jatropha gossypifolia);* and Seeds that tastes bitter or salty. Example:- Seeds of neem, custard apple, etc. Fermented solutions and extracts made with such leaves and seeds act as excellent pest repellents by creating unpleasant odors. When sprayed, these solutions prevent pests from feeding on plants.

In general, worms and pests use their sense of smell to identify edible plants. When we spray solutions made with the above plants and with dung/urine, we disrupt the sense of smell of the worms and insects. So they avoid crops thus sprayed and either starve to death or, having eaten leaves sprayed with such repellents, die of stomach problems. This considerably lowers the number of egg–laying survivors. Those eggs that do get laid and hatched give rise to handicapped offspring that are easily picked by predator birds. Preparation: Take 2 kg each of leaves/ seeds (as the case maybe) from the five categories mentioned above. *Fermentation method*: Add 12–15 liters cattle urine to the above. (Add more if necessary, so the plant material is completely immersed in cattle urine.) Add 1 kg dung (mixed with cattle urine) and 100–250 gms turmeric powder (if available). Let it ferment for 7–15 days. Leaves get fermented and the solution is ready for use; Usage: Mix 500–1,000 ml with 10 liters water and spray. *Boiling method*: Chop 10kg leaves/seeds and soak in 25 liters water. Make sure the plant material is fully immersed in water. Boil this under steady heat. Filter and set apart in a separate container. Add 25 liters of water to the solid matter that is left over after filtering. Boil again. Filter it and add the liquid to the second container (to which the filtered solution was added earlier). Add 100–200 gms turmeric powder to this liquid and let ferment for 12 hours. Usage: Add sufficient water for a total of hundred liters solution and spray.

To control larva (caterpillar), leaf curl worm, leaf roller, or stem borer: Ingredients: (1) Solution prepared (using the fermentation method or the boiling method) as above for fungal disease control, (2) Powder one of the following seeds/fruits [listed in (a) through (h) below] and add to the solution: (a) neem (*Azadirachta indica*), pungum (*Pongamia* or Karanj), or malai vEmbu (*Melia dubia*) (1–2 kg), (b) kadukkai (*Terminalia chebula*) (250–500 gms), (c) custard apple (*Annona squamos*) or thanga arali (*Tecoma stans*) (200–250 gms), (d) etti (*Strychnos nux_vomica*) (100–250 gms), (e) suNdaikkAi (*Solanum torvum*) (1–2 kg), (f) green chillies (500–1000 gms), (g) vilvam fruit (*Aegle marmelos o*r Bael**)** (5–10 numbers), or (h) Umaththai fruit (*Datura stramonium*) (10–20 numbers). Preparation: Prepare the ingredients for the solution in (a). Powder one of the seeds/fruits listed in (b) through (e) and add the ingredients to the solution in (a). Let the entire mixture ferment for 12 hours. We now present another solution for controlling the above insects. Ingredients: (a) 100 gms custard apple seeds, 1 kg peechchangu (*Cleodendron inerme*), 500 gms siriyanangai (*Andrographis paniculata*), 500 gms Adathodai, 1 kg thanga arali, 1 kg nochi or custard apple leaves, 1 kg aloe vera, (b) 1 kg powdered tobacco, (c) 1 kg tobacco powder, and (d) soil from a termite hill (take enough soil to make the whole thing into a paste); Preparation: Grind into paste the ingredients in (a). Boil it in about 6 liters water. Add tobacco powder and let ferment for twelve hours. Add tobacco juice and let ferment for 2–3 days. It will acquire sour taste. Add turmeric powder and enough soil from a termite hill to bring the entire mixture into paste_like consistency; Usage: Mix 1 kg paste in 100–125 liters water and spray.

Sucking insects: aphids, thrips, and mites: This problem normally occurs in chillies, vegetables, and cotton. The pests attack the tender leaves and branches. They occur in thick colonies. Cut the heavily affected portions once a week and put them in the fermented or boiled solution prepared as explained earlier. This is physical removal and is one of the cultural practices of integrated pest management techniques. As a result of this attack the leaves start curling up and wither. The following concoction helps control this problem. Ingredients: (a) 2–3 kg of five of the following leaves: *Lantana camara*, neem, nochi, tobacco, siriyanangai, custard apple, peechchangu, *Aloe vera*, pirandai (*Cissus quadrangularis*), or vilvam fruit (5–10 numbers) or green chillies (2–3 kg) (b) 100 gms turmeric powder. Preparation: Chop the leaves into small pieces (if using vilvam fruit or chillies, crush them). Add turmeric powder. Use the fermentation method described earlier to make the solution. Let the mixture ferment for seven days. Usage: Add ten liters water to one liter solution and spray. Depending on the intensity of the attack, you may repeat the spray 2–3 times in 7–10 days interval.

Solutions for disease prevention – Fungal infection and leaf spot disease: Ingredients: (a) 3–5 kg aloe vera, (b) Any two of the following: 3–5 kg custard apple leaves, 3–5 kg bougainvilla leaves, 3–5 kg lantana camara leaves, 3–5 kg papaya leaves, (c) 100 gms turmeric powder, (d) 250–500 gms *Pseudomonas*, and (e) 10 liters archaebacterial solution. Preparation: Pound all the leaves, add enough water to immerse them, and boil it as explained above. Prepare 50 liters solution. It will have a dark color. Add turmeric powder to it. Let it ferment for about 12 hours. At the same time, mix the archaebacterial solution and pseudomonas and set aside for 12 hours. Usage: Mix the above two solutions, add sufficient water to bring the total to 100 liters, and spray. You will see long eye-shaped spots on leaves during the early stages of this disease. At the center of each of these spots are the fungal spores that cause this disease. As the disease progresses the spots grow larger and eventually all the spots combine into one. The leaves turn brown/yellow and ultimately wilt.

Blast, leaf blight diseases: Ingredients: 3–5 kg aloe vera, 200 gms ginger, 3–5 kg pudhina (mint), *Lantana camara* leaves, 100 gms turmeric powder, 500–1000 gms *Pseudomonas fluorescence*, and 10 liters archaebacterial solution. Preparation: (a) Add enough water to immerse the above ingredients. Boil it and let it cool down. Add turmeric powder as explained earlier, (b) In a separate container take the archae solution, add *Pseudomonas fluorescence*, and keep aside for 12–24 hours. Usage: Mix the above two solutions, add sufficient water to bring the total to 100 liters, and spray.

Bacterial diseases: Ingredients: (a) 3–5 kg aloe vera, (b) 3–5 kg tender leaves of two of the following: bamboo, pudhina, savukku (*Casuarina*), thulasi (*Oscimum*), or *Lantana camara*, (c) 100 gms turmeric powder, (d) 250–500 gms *Pseudomonas fluorescence*, (e) 10 liters archaebacterial solution. Preparation: Prepare 50 liters solution using the boiling method. At the same time, mix the archaebacterial solution and pseudomonas and set aside for 12 hours. Usage: Mix the above two solutions, add sufficient water to bring the total to 100 liters, and spray.

Powdery mildew: Ingredients: (a) 3–5 kg aloe vera, (b) 12–10 kg tender leaves of one of the following: bamboo, savukku, or *Lantana camara*, (c) 100–200 gms turmeric powder, (d) 250–500 gms *Pseudomonas fluorescence*, (e) 10 liters archaebacterial solution. Preparation: Prepare 50 liters solution using the boiling method. At the same time, mix the archaebacterial solution and *Pseudomonas* and set aside for 12 hours. Usage: Mix the above two solutions, add sufficient water to bring the total to 100 liters, and spray. When we spray the above for prevention, the above–mentioned quantities of *Pseudomonas* is enough.

Under unfavorable climatic conditions fungal diseases, bacterial diseases, and powdery mildew attack will be severe. In that case increase the quantity of *Pseudomonas* to 1–2 kg to achieve the knock down effect. It should be sprayed 2 times in 7–days interval; the third spray should be after ten days. This inevitably raises the cost of cultivation. But, the cost is still much less compared to the use of chemical pesticides. Besides, this organic method has no ill effects on our health or on the environment.

Efficient microorganisms (EM): Dr. L. Narayana Reddy introduced effective microorganisms to us. (These were discovered by Prof. Teruo Higa of Japan. In India these are marketed by Maple Orgtech (I) Limited.) Dr. Reddy cautioned that uncontrolled conditions during production of Effective Microorganisms by farmers may lead to the inclusion of harmful organisms because farmers lack the laboratory equipment to check quality. So, Dr. Reddy recommends that farmers buy effective microorganism from authentic laboratories. However, Mr. G. Balakrishnan has perfected a controlled method for preparing a similar solution that he called Efficient Microorganism solution. In Tamil we call it thiRa nuNNuyir (thiRami, for short). We will refer to it hereinafter as thiRami. We use this method in our laboratory in Madurai to prepare small quantities of thiRami and supply to trained organic farmers in our association (thamizhaga uzhavar thozhilnutpak kazhagam). In the past five years we have used it on a variety of crops under different conditions in twelve districts in Tamil Nadu and have been getting good results. Based on this experience, we now describe the preparation and use of the following solutions.

Extended thiRami (ET): Ingredients: (a) 20 liters potable water free from chlorine, (b) 1 kg jaggery, (c) 1 liter thiRami (EM) stock solution. Preparation: Mix these in a plastic drum and fill twenty one–liter plastic jars with this mixture. Tighten the bottle caps. Keep for 7–10 days for multiplication of the various microorganisms. Methane gas forms in each bottle. On the first or second day unscrew the cap to release the gas and close it tightly again. Repeat this as often as necessary. Each unopened bottle's contents may be kept for use in 3–4 months; Usage: Mix 1–2 liters of the ET solution in 100 liters water for spraying. This promotes growth and controls pests. It may also be used in composting at the rate of 500ml to 1 liter per 100 liters water to increase the rate of breakdown of crop residues. ET may be used in irrigation at the rate of 3–6 liters per acre.

thiRami–treated cow urine (TTCU): Ingredients: (a) 5 liters cow urine, (b) 250 gms jaggery, (c) 250 ml ET solution, and (d) 250 ml water. Preparation: Mix all and let ferment for 7–10 days. Usage: Use within 30 days. For spraying: Mix 1–2 ml in one liter water. For irrigation, use 20–30 liters per acre. This controls pests and diseases.

thiRami_fermented plant extract (TFPE) for rectifying micronutrient deficiency: Ingredients: Collect tender leaves of the following: (a) tamarind or vAdhanArAyaNan (*Delonix elata*) (source of zinc), (b) AvArai (*Casia auriculata*), *Hibiscus*, or vallArai (Brahmi) (copper), (c) curry leaf, drumstick leaf, or any other leafy greens (iron), (d) erukku (*Calotropis gigantea)* (boron), (e) all types of flowers (Molybdenum), (f) thuththi (*Abudigan indicum)*(Calcium), (g) gingelly or mustard plants (sulphur), (h) ladies finger (Okra) plant (iodine), (i) *lantana camara*, *casurina*, or bamboo (*Silica*), (j) neyveli kAttAmaNakku (*Ipomea*) (Mercury), (k) *Glyricidia* (Nitrogen), (1) thulasi, nochchi, neem, aloe vera (to build resistance to fungal, bacterial, and powdery mildew diseases). We have selected the above list based on the Siddha and Ayurveda systems of medicine. Preparation: (a) Collect 5kg leaves and plants from the above list. Choose any combination depending on micronutrient deficiency of the crops. (b) Chop into small pieces and crush. (c) Add 250 Gms jaggery in ten liters water. (d) Add 250–300 ml ET. (e) Set the mixture aside for 7–10 days for fermentation. This provides ten liters solution. Usage: Use within 90 days. Spray: 2–5% solution. Irrigation: 10–20 liters per acre. Benefits: Using EMFPE with other growth promoters as prophylactic measures solves all problems for any crop: (a) Rectifies micronutrient deficiency. (b) Acts as pest repellent. (c) Prevents pests from feeding and (d) Induces disease resistance.

Extended thiRami–5 (ET5): Since it contains five items, it is named ET5. Ingredients: (a) 100 ml organic vinegar, (b) 100 ml ET, (c) 100 gms jaggery, (d) 100 ml brandy, (e) 600 ml water, for a total of one liter. Preparation: Mix all and let ferment for 7–10 days. Usage: Use within 30 days. Spray: 1–2 ml per liter of water, along with any of the growth promoters. In case of severe infection use 5ml per liter of water. Benefits: Controls fungal, bacterial, and powdery mildew diseases. To prepare organic vinegar, use one of the following methods (taught to us by Dr. L. Narayana Reddy): (a) Add 500 Gms jaggery to 1 liter tender coconut and store in a container for a minimum of 15 days, (b) Mix 8 numbers rotten banana, 200 gms jaggery, and a small quantity of water; grind it to a semi-solid form. Add water to make it two liters. Keep it for a minimum of 15 days. Vinegar may be kept for a long time. With each passing day the quality improves due to fermentation. The older it is, the more effective it will be in ET5 preparation.

Microorganisms enriched mixture (MEM): Ingredients: Group 1: 60 kg fully digested compost or vermi compost, 20 kg ash or rice bran ash, and 20 kg saw dust. Group 2: (a) five liters AvUttam/panchakavya, (b) five liters concentrated amudham solution, (c) five liters coconut–buttermilk, arappu–buttermilk, or soapnut–buttermilk solution, (d) ten liters ETFPE, (e) five liters archaebacterial solution. Group 3 (to control root rot, rhizome rot, and fuzarium wilt): 500 Gms–1 kg each of *Pseudomonas fluorescence*, *Trichoderma viride*, *Trichoderma harzianum*, and *Baccillus subtilis*. Group 4 (to control nematode): 1–2 kg each of *Paeciliomyces*. Group 5 (to control root grub, white grub, rhinoceros beetle and other soil–dwelling beetles and grubs): 500 gms–1 kg *Beauveria brongniartii* and *Metarhizium* Preparation: 1) Mix well the items in Group 1; 2) Mix the solutions mentioned in Group 2; 3) Mix the powders in Groups 3, 4, and 5 well together; choose the powders based on your crop's condition; 4) Add the mixtures from steps (a) and (c). On this combination sprinkle the solutions mixture from (b) and mix thoroughly so the combined mixture is uniformly moist.

Note: MEM can be used at the rate of 100–500 kg per acre. The ingredients given above are for preparing 100 kg MEM. To prepare larger quantities increase the quantities in Group 1 accordingly maintaining the same ratio of the ingredients in that group. This increases the quantity of the mixture. To make this mixture uniformly moist add sufficient quantity of archae solution. Do not change the quantity of other items in Groups 2 to 5. Usage: Use within thirty days. When you need to store it for longer periods, store it in a heap that is about two feet broad and nine inches tall; the length could be chosen based on convenience. Cover it with wet gunny bags, coconut leaves, or sugarcane leaves. Take care to maintain uniform moisture, by sprinkling water as often as necessary. This heap should be in a shed or in the shade of a tree. This can be used as basal application or as a top dressing, depending on the need. Use it as a precautionary measure according to the condition of the crop. If the crop growth is not healthy and you cannot irrigate the crop because of rain, use the mixture at least twice in fifteen days interval. If the crop is healthy, use it once in 1–2 months during the growth period. For bed crops like vanilla, pepper, and cardamom, use MEM over the bed and cover it with leaves. In rainy season, move the mulch away from the stem for effective drainage and spread MEM over the feeder roots to protect these roots.

Fruit gaudi (Fermented fruit juices): We prepare and use fruit gaudi for enriching soil health and improving the population of microbes and beneficial fungi using fruit gaudi in irrigation. Ingredients: (a) 10–50 kg cattle dung, (b) 5–20 kg waste fruit, (c) convenient quantity of all kinds of leaves that decay fast, (d) intestine wastes from 1 cow or 2–4 goats, (e) 5–10 liters AvUttam/ panchakavya, (f) 5–10 liters any of the buttermilk solutions, (g) 5–10 liters concentrated amudham solution, (h) 5–10 liters TTCU, (i) 5–10 liters TTFPE, (j) 50–100 liters archaebacterial solution. Preparation: Mix all in 200–500 liters water in a tank. Allow it to ferment for a week. Add the beneficial microorganisms listed in MEM preparation. Allow it to ferment for a day. Usage: Use in irrigation for one acre. Use it once in 15–30 days.

Intercropping/Mixed cropping: This is a very important technique in controlling pest and disease attacks. As opposed to mono-cropping, we grow more than one crop at the same time. Farmers have seen for themselves that intercropping helps minimize pest and disease attacks. Here are some examples: a) Growing cowpea and black gram along with jowar, maize, or pearl millet like our ancestors used to do. b) Growing castor plants on the boundary ridges of paddy/ vegetable fields. We must plan the sowing such that all crops get enough sun light. Leguminous plants help fix atmospheric Nitrogen in their roots. This helps other crops get sufficient quantities of manure. We must identify the right mix of crops for intercropping. By doing this we could enhance yield and increase our income. Since intercropping is well known and also since it is location-specific, we have only given an outline of the practice.

Parasites: Insects go through the egg, larval, and pupa stages before emerging as insects. Helpful parasites exist that eat harmful insects in one or more of these stages. These are classified based on their eating habits. Let us now learn about a few parasites that are grown in labs. We use the parasites as follows. 1) (Paddy) to control leaf roller and stem borer: *Trichogramma japonicum* and *T. chilonis* at the rate of 2cc parasites per acre 4_6 times in 10_15 day interval. 2) (Sugarcane) To control inter-node borer: 2 cc *Trichogramma* wasps per acre, eight times from the third or fourth month onwards, in 15-day interval. To control the top shoot borer: Use 2cc *T. chilonis* per acre, 4-6 times in 15-day interval from the eighth month onwards. 3) (Vegetable crops, chillies, and cotton) to control sucking pests: *Crysoperla* wasps (2000 eggs per acre, two times in 15-day interval). To control mealy bug: cripolomus (200-300 per acre in two applications in 15-day interval). To control stem- or pod-borers and bollworm eggs: 2cc *T. japanicum* and 2cc *T. chilonis* (6-8 times in 15-day interval). To control the larvae of these pests: praconit wasps (800 insects per acre, two times). 4) (Banana) To control stem-borer: 2cc *T. japanicum* and 2cc *T. chilonis* per acre (four times in 15-day interval from the fifth month onwards).

Appendix: Botanical names of plants whose Tamil names are used in this article

Tamil word	Botanical Name	Tamil word	Botanical Name
AdAthOdai	*Adatoda justicia*	piraNdai	*Vitis quadrangularis*
adhimadhuram (sweetwood/ liquorice)	*Glycyrrhiza glabra*	pudhinA	*Mentha spicata*
arappu	*Albizzia amara*	saNappu	*Crotolaria intermedia*
arasu	*Ficus religiosa*	savukku	*Casurina*
AvArai	*Cassia auriculata*	siRiyAnangai	*Andrographis paniculata*
erukku	*Calotropis gigantea*	suNdaikkAi	*Solanum torvum swartz*
Etti	*Strychnos nux-vomica*	thanga araLi (oleander)	*Neerium odorum*
kadukkAi	*Terminalia chebula*	thuththi	*Abudigan indicum*
kAttAmaNakku	*Jatropha curcas*	Umaththai	*Datura metel*
narippayaRu	–	vAdhanArAyaNan	*Delonix elata*
nochchi	*Vitex negundo*	vilvam	*Aegle marmelos*
peechchangu	*Clereodendron inermi*		

Weed Management in Organic Farming

J P Saini

Weeds are considered to be a major problem for organic farmers. Organic farmers struggle with the weeds for developing effective and economical weed management strategies. Successful organic farmers continuously adapt their weed management practices as weed population's shift. Under organic weed management system the main aim is to reduce the weed competition and reproduction to an acceptable level rather than to eliminate them completely. Weed management strategies should reduce weed crop competition from the present and future weeds by preventing the production of weed seeds and perennial propagules. Consistent weed management can reduce the cost of managing the weeds and contribute to an economical crop management system. A brief overview of organic weed management has been described below:

Weed prevention: Many on-farm weed populations exist because of the natural movement of weed seeds and propagules from both neighboring and distant populations by wind, animals, people, and other carriers. Human activity is a major culprit in the introduction of weeds to a farm or to new areas on a farm. Paying close attention to sanitation and seed sources on the farm can help prevent the introduction and movement of weeds. Weed prevention comprises all measures such as; 1) Use of weed free crop seeds; 2) Avoid contamination of manure pits; 3) Prevent movement of weeds with other farm resources; 4) Keep vigilance; 5) Keep non-crop land clean and; 6) Invoke legal measures

This can be achieved through: i) Inspect seeds and transplants before planting. Crop seeds, especially grains, may be contaminated with weed seeds. Transplants may have weed seeds in the potting medium if it was not sterilized before use. Buy seeds and transplants from reputed suppliers, and always

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examine them before planting; ii) Compost animal manures properly. Animal manures often contain weed seeds, with the source of the manure affecting the number and species of viable weed seeds introduced. To kill weeds and other harmful organisms, compost manures properly before field application. To kill the majority of weed seeds in cattle manure, compost materials at a temperature of at least 180°F (82°C) for no less than three days (Wiese *et al*, 1998). This temperature is relatively easy to reach in most composting systems.

i) Apply mulch and compost that is free of weed seeds. Straw mulch, for instance, may contain seeds that will later be a nuisance. To avoid carrying weeds into a field with straw mulch, wet the straw and allow weeds to germinate. Once weed seeds have germinated, dry out the straw bale to kill seedlings by breaking it apart. ii) Limit the amount of off-farm traffic visiting production areas, either by vehicle or foot. iii) Clean farm equipment regularly. If machinery and tools are used in more than one location, they should be thoroughly cleaned before use in a different field. Cleaning is especially important when equipment is transferred between farms. These measures deny the entry and establishment of weeds in new area.

Good crop husbandry methods: For weed control on an organic farm there is no substitute to good crop husbandry methods. These methods are also sometimes referred to as Ecological methods. Good crop husbandry is more than half the weed control envisaged on any farmland. While directly it induces a healthy growth of crops, indirectly it maintains a crop environment that is as detrimental to weeds as possible and thus, indirectly help in improving the efficacy of other methods of weed control. Some important crop husbandry practices that can lead to suppression of weeds are proper crop stand and early seedling vigour, selective stimulation of crops, crop rotations, Inter-cropping, stale seedbed preparation, applying mulch, cover crops, summer fallowing

Proper crop stand and early seedling vigour: Uniform germination of crop seeds and their development into vigorous crop seedling leave less space for weeds to grow amongst the crop plants. A vigorously growing crop aids weed control by offering competition. Important steps in obtaining good germination, optimum stand and spatial uniformity of crops are: Selection of most adapted crops and crop varieties: Crop cultivars vary in their abilities to compete with and adapt to weeds. Several characteristics can enhance a cultivar's ability to compete with weeds, including its physical structure. Tall grain crops, for example, are generally more competitive with weeds because they intercept light. A large leaf area and high biomass production can also contribute to a cultivar's competitive abilities; The use of high viability seeds; Adequate seed rates and; Proper planting time and method: For many row and horticultural crops, rapid growth and early canopy closure can result in the suppression of weeds. For this reason, using transplants when possible for horticultural crop production is advantageous. Use of transplants will increase production costs, so the economic benefit of using transplants must be weighed against cost. When it is economically viable, as is the case with many vegetable crops, use of transplants should be considered. Research indicates that the planting date, density, and spatial arrangement of a crop can maximize the space it occupies early in the season and put competitive pressure on weeds

Selective crop stimulation: Weeds inflict much more damage to crops than the crops to weeds. This imbalance can be manipulated by man in favour of crops by suitably modifying their soil and cropping conditions, leading to selective stimulation of crop growth. Vigorous crop plants compete with weeds more effectively and cover the ground quickly. Selective stimulation can be achieved by: 1) Correction of soil condition to favour crop growth by the application of soil amendments like gypsum or lime. This is an important step towards favouring crop growth; 2) Addition of FYM or any other organic manure may be useful in improving crop growth over the weeds, when applied as banded or side dressed; 3) Inoculation of crop seeds with suitable N-fixing and P-solubilizing cultures; 4) Proper planting strategies i.e. suitable cultivar, date, density and spatial arrangement of a crop can maximize the space it occupies early in the season and put competitive pressure on weeds.

Crop rotation: Organic farmers often use mixed cropping systems and long rotations to enhance soil fertility and economic diversity. Crop rotation can also be a cornerstone in a weed management plan. Through long-term variations of crop species and planting times, rotations create a changing environment and prevent the dominance of a particular weed species. Researchers have compared emerged weed densities in test crops grown in rotation versus continually grown test crops. For most of the crops studied, weed densities were lower when a crop was grown in rotation (Liebman and Dyck, 1993). Knowledge of potential weed problems allows a farmer to select the rotation best suited to a particular field. When making a crop production plan, a farmer should design rotations for each field with weed management and potential weed problems in mind. For example, when a crop with a dense, closed canopy, such as potatoes, is grown prior to growing a crop that is less competitive with weeds, the dense crop reduces the development of weeds. Where late-germinating weeds are a concern, an early crop can be followed with tillage and a vigorous, competitive summer annual crop to suppress these weeds.

Inter-cropping: Intercropping involves growing a smother crop between rows of the main crop. Intercrops are able to suppress weeds. However, the use of intercropping as a strategy for weed control should be approached carefully. The intercrops can greatly reduce the yields of the main crop if competition for water or nutrients occurs.

Stale seedbed preparation: This weed management strategy consists of preparing a fine seedbed, allowing weeds to germinate (relying on rainfall or irrigation for necessary soil moisture), and directly removing weed seedlings via light cultivation or flame weeding. Seeds or transplants can then be planted into the moist weed-free soil. This technique helps to provide an opportunity for crop emergence and growth before the next flush of weeds. If time allows, this can be done twice before planting.

Applying mulch: Applying mulch after planting can offer some benefits in many cropping systems. Mulches reduce weed competition by limiting light penetration and altering soil moisture and temperature cycles. Although black plastic is commonly used as a mulching material, its environmental impacts conflict with the goals of regenerative and sustainable production. Synthesized from petroleum, plastic represents a significant use of non renewable fossil fuels. In addition, the disposal of plastic mulch has contributed to current landfill problems throughout the United States. The discussion in this chapter will be limited to organic and reusable or biodegradable inorganic mulching materials.

Cover crops: Cover crop residues as mulch: Annual cover crops may be killed or left to die naturally and used as mulch. By altering light, soil moisture, and soil temperature, mulches limit the germination and growth of weed seedlings. Dead cover crop residues serve as excellent mulch for no-till and reduced-tillage systems when left in a field. Cover crop residues may also be moved from one field to another. There is, however, a risk of transporting weeds into a field with mulch, including cover crop residues that are moved from one field to another. If cover crop residues will be used as mulch for no-till production, a farmer must consider the market crop that will follow the cover crop. For instance, if the market crop will be planted in early spring, it is best to choose a winter annual cover crop that will die back early, such as a mixture of oats and crimson clover. If the market crop will be planted in late spring or early summer, a mixture of longer-lived species, such as rye and hairy vetch, is preferred. Another key to the successful use of cover crop residues is effective cover crop kill. Many no-till systems now used in the midwestern United States rely on chemical herbicides to kill cover crops. Organic farmers, however, must kill crops mechanically, which can be a considerable challenge. Mechanical methods of killing cover crops that will be left on the soil surface include mowing, rolling, roll-chopping, and undercutting. The success of these methods depends, in part, on the species and growth stage of the cover crop. Optimal mechanical management promotes rapid desiccation and limits the regrowth of the cover crop species while leaving residues intact for mulch. Because mowing generates small pieces of residue that decompose quickly, this may not be the best method of mechanical kill. Rolling and undercutting cover crops can create long-lasting surface mulch that can provide extended weed suppression. Rolling also can be accomplished at higher speeds, with lower machinery maintenance costs and reduced fossil fuel consumption compared to mowing. Various methods have been tried for rolling and roll–chopping cover crops. Depending on conditions, an effective kill can result from breaking, cutting, crushing, or crimping stems (Creamer and Dabney, 2002; Creamer *et al*, 1995).

Cover crops as living mulch: Certain cover crops also may be used as living mulches (this is often referred to as intercropping). Living mulches can be established before planting, or they can be seeded with or after the main crop has been planted. Seeding with or after the main crop is referred to as interseeding or underseeding. Living mulches may be annual or perennial cover crops, and they can be used with both annual and perennial cash crops. Researchers have demonstrated that living mulches can effectively suppress weeds when grown with a cash crop. In 51 research trials in which main crops grown with living mulch were compared to the main crop grown alone, weed biomass was lower in the living mulch system in 47 cases (Liebman and Dyck, 1993). In most instances, the researchers attributed weed suppression to competition from the intercrops, although it is possible that allelopathy — the suppressive effect of chemicals emitted by one species on another – also played a role in some systems. The most significant challenge a farmer faces in using living mulch systems for crop production is competition between the living mulch and the market crop. Many examples of successful living mulch systems exist for vineyards and fruit orchards, but many attempts to use living mulches in annual cropping systems (Miura and Watanabe, 2002; Ateh and Doll, 1996; Mohler, 1995) or early in the establishment of perennial crops (Paine *et al*, 1995) have resulted in reduced growth and yields for the market crops.

Cover crops that are suitable for use as living mulches in intercropping systems should do the following: 1) Compete minimally with the market crop for resources, including light, water, and nutrients; 2) Have characteristics that control weeds; 3) Provide a regular and sufficient source of nitrogen; 4) Have low maintenance costs. The spatial arrangement, seeding rate, and planting time of living mulches should also create favorable conditions for the main crop. For most crops, it is best to confine the living mulch to between-row spaces.

Summer fallowing: Farmers in India, as in many other tropical countries, have used for decades hot months of April, May and June to expose their lands to sun in order to control many soil-borne pests, including weeds. Roots, rhizomes, and tubers of shallow rooted perennial weeds like bermudagrass and nutsedge are desiccated when these are brought to surface by tillage and exposed to air temperatures of 40 to 45°C. However, to be really effective, summer fallows must be managed properly. The land should be opened by deep ploughing immediately after harvesting winter crops and it should be left in a cloddy condition. A sod mouldboard plough is very suitable for this purpose. As the soil clods bake in hot sun, the weed roots and rhizome embodied in them are desiccated. To expose the vegetative propagules of the weeds hidden beneath the clods, as well as to break the dry clods and further expose the contained weed propagules to the hot sun, land should be ploughed subsequently once or twice at an interval of fortnight, with a heavy wooden plough or blade harrow. During all this process of exposure of weeds to soalr energy, one must ensure that the field under treatment does not get any water, say from leaking irrigation channels. In the hot sun the weed roots and rhizomes are killed by desiccation and not by any direct effect of high temperatures on the cell protoplasm. Summer fallowing for the control of perennial weeds is unadvisable on light soils for fear of erosion. Also, such soils cannot be turned into dry clods required for effective desiccation of the weedy rhizome. Weed control through summer baking should be followed by cropping of the land with narrow row crops. If a wide row crop must be planted, it should be inter cultivated hard. Intensive cropping with 3 to 4 crops a year which is opposed to summer fallowing, is prone to heavy infestation with perennial weeds.

Physical methods of weed control: Physical methods utilize manual energy, animal power or fuel to run the implements that dig out weeds. The physical methods of weed control are safer to crop, environment and to the users. The implements used for the physical control of weeds vary from simple hand tools to complex, multilined weeding machines run with tractors.

Manual weeding: Many organic farmers do some manual weeding to clear around vegetable crops and perennial plants where cultivation and slashing is risky. This is time-consuming and costly, but is effective and gives you an opportunity to observe your soil and crops closely – a vital aspect of good organic management.

Mechanical weeding: Mechanical weeders include cultivating tools such as hoes, harrows, tines and brush weeders, cutting tools like mowers and stimmers, and dual-purpose implements like thistle-bars. The choice of implement and the timing and frequency of its use depends on the morphology of the crop and the weeds. Implements such as fixed harrows are more suitable for arable crops, whereas inter-row brush weeders are considered to be more effective for horticultural use. The brush weeder is mainly used for vegetables such as carrots, beetroot, onions, garlic, cerely and leeks. The optimum timing for mechanical weed control is influenced by the competitive ability of the crop and the growth stage of the weeds. Hand hoes, push hoes and hand-weeding are still used when rouging of an individual plant or patch of weed is the most effective way of preventing the weed from spreading. Hand-weeding may also be used after mechanical inter-row weeding to deal with weeds left in the crop row. Blind, 'over-the top' cultivation controls very small weeds, just germinated or emerged, before and sometimes after planting. The entire surface of the fields is worked very shallow using flex-tine cultivators (e.g. Lely weeder or rotary hoes, Inter-row cultivations with a rotary hoe in pinto beans (*Phaseolus vulgaris* L.) gave adequate weed control without reducing plant stand or injuring the crop. The hoe-ridger is specifically designed to achieve intra-row control in sugar beet, Thistle-bars are simple blades used to undercut perennial weeds with minimal soil disturbance. The brush weeder, or brush hoe, is used primarily for inter-row weeding of vegetable crop.

Biological weed control: Little research has been conducted on using predatory parasitic micro-organisms or insects to manage weed populations. However, this may prove to be a useful management tool in the future. Control of an aquatic weed *Salvinia* with a Weevil *Opuntia* sp. 'pricklypear' in Australia and that of *Lantana camara* in Hawaii with certain insect bioagent are the important examples. *Zygogramma bicolorata* is another insect bio-agent for the control of *Parthenium hysterophorous*. There is also considerable research effort aimed at genetically engineering fungi (myco-herbicides) and bacteria so that they are more effective at controlling specific weeds. Myco-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment. Weeds are subject to disease and insect attacks just as crop are. Most biological control of weeds occurs in range or non crop areas. As a result, biological control has little relevance for field crops.

Geese have been used for weed control in trees, vine, and certain row crops. Most types of geese will graze weeds, but Chinese weeder geese are considered the best for row crops. Chinest weeder geese are smaller than other types and tend to walk around delicate crop plants rather than over them. Geese prefer grass species and rarely eat crops. If confined, geese will even dig up and eat Johnson grass and Bermuda grass rhizomes. Care must be taken to avoid placing geese near any grass crops such as corn, sorghum, or small grains, as this is their preferred food. Fruiting vegetables, such as tomatoes when they begin to color, might also be vulnerable, so geese would have to be removed from tomato fields at certain times. Geese require drinking water, shade during hot weather, and protection from dogs and other predators.

Soil solarization: Solarization consists of heating the soil to kill pest organisms, including fungi, bacteria, and weed seeds. It also reduces populations of various pathogens and nematodes. Soil is covered in summer with clear or black polyethylene plastic and moistened under the plastic, which is left in place for six to seven weeks or longer. Weed seeds and young seedlings are killed by the heat and moisture and through direct contact with the plastic, which causes scorching. Research has demonstrated that solarization from July to October with clear or black plastic provides weed control comparable to methyl bromide fumigation in strawberries without reducing fruit yield (Rieger *et al*, 2001). Solarization can also be used to produce weed-free soil or potting mix for container production in warm climates (Stapleton *et al*, 2002), and it has been used in Mediterranean climates to reduce weed competition and increase yields of field-grown cauliflower and fennel.

Tillage: Deep and frequent tillage may be useful for some reasons, but it serves to (i) bring more of dormant weed seeds and rhizomes to the soil surface, and (ii) preserve the new ones deep inside the soil for the future. Both these things are undesirable. One should aim at keeping the weed seeds as close to the soil surface as possible so that they germinate in large numbers at any one time and, thus can be killed with a suitable herbicide in one operation. In this context, tillage should be no deeper and more frequent than is absolutely necessary for growing crops. Zero tillage planting of crops, as practised in some countries like USA and UK, completely avoids burying of weed seeds and reduces persistence of annual weeds. But it often induces vigorous growth of perennial weeds. Of late, zero-tillage has gained popularity in Northern and Western India in wheat-rice cropping systems. From the weed dynamics point of view, the zero tillage cultivation in rice-wheat cropping system has been of advantage to our farmers in reducing incidence of one of the most problematic weeds, *Phalaris minor*, in wheat. Several research results have reported positive impact in this respect, particularly in U.P. and Haryana.

Flooding and drainage: Flood kills weeds by excluding air from their environment. Some weed species are more susceptible to it than the others. Flooding is a worldwide crop husbandry method of controlling weeds in rice fields. In some parts of Madhya Pradesh (India), deep flooding of fallow fields with rain water is practised continuously for 2–3 months. After that the water is let out and the winter grains are planted. The practice, locally called Havelli, is considered very effective in controlling weeds, besides conserving moisture. The technique however, can be used as weed suppression measure only in limited situations In variance with flooding, drainage is used for controlling aquatic and semi-aquatic weeds in rice fields, channels, canals, and ponds. In rice fields, where both terrestrial and aquatic weeds may be common a judicious combination of the two can be practiced.

Thermal weed control

Flamers: Flamers are useful for weed control. Thermal weed control involves the use of flaming equipment to create direct contact between the flame and the plant. This technique works by rupturing plant cells when the sap rapidly expands in the cells. Sometimes thermal control involves the outright burning down of the weeds. Flaming can be used either before crop emergence to give the crop a competitive advantage or after the crop has emerged. However, flaming at this point in the crop production cycle may damage the crop. Although the initial equipment cost may be high, flaming for weed control may prove cheaper than hand weeding. Propane fuelled models of flamers are the most commonly used. Flaming dose not burn weeds to ashes; rather the flame rapidly raises the temperature of the weeds to more than 130°F. The sudden increase in temperature causes the plants cell sap to expand, rupturing the cells walls. For greatest flaming efficiency, weeds must have fewer than two true leaves. Grasses are difficult to impossible to kill by flaming because the growing point is protected underground. After flaming, weeds that have been killed rapidly change from a glossy appearance to a duller appearance. Flame weeders can be used when the soil is too moist for mechanical weeding and there is no soil disturbance to stimulate further weed emergence.

Integrated weed management on organic farms requires extensive planning and management. Crop rotations are the basis for successful organic farming and are necessary for breaking weed, insect, and disease cycles. Cultivation must be completed with properly set equipment under soil conditions that are not conductive to compaction. Monitoring weed growth stages also is critical in determining ideal cultivation times. Trial and error will govern many decisions in the first years of organic farming. Learning from other organic farmers may assist in the transition.

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Organic Seed: Traditional Varieties and Technologies

K Vanangamudi

Organic farming is not new to Indian farming community. Several forms of organic farming are being successfully practiced in diverse climate, particularly in rainfed, tribal, mountains hill and resource poor areas of the country. It safeguards/improves quality of resources and environment. It is labour intensive and provides an opportunity to increase rural employment. For a product to be called and labelled 'organic', it should have been produced from start (seed) to end (the produces, the consumer is buying) in an organic way. International Federation of Organic Movement (IFOAM) has clearly laid down the condition that in order to get organic certification to the produces, the seed used for sowing should also have been produced organically. To enter into Organic Agriculture, timely research has been warranted to study the strategies and efficacies of organic seed production to fulfill the global organic seed demand. Organic seed production system involves use of organic seed quality enhancement treatments, integrated organic nutrient management practices *viz.*, organic manures, green manures and biofertilizers etc., and integrated organic plant protection *viz.*, agronomic practices, crop rotation, growing border/trap crops and use of botanicals, biopesticides and biocontrol agents apart from encouraging natural parasites, predators and parasitoids etc.

Traditional varieties: Traditional farmers constantly search for and promote novel variation in their crops. They acquire new varieties by exchange, while travelling, through purchase from markets and natural hybridization. This is actually one of the key features of traditional farming systems; the interaction between domesticated varieties and their wild relatives. The promotion of natural hybridization and introgression has, over

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time, increased the genetic diversity available to farmers. This constant experimentation and breeding has created the diversity of crops upon which we now depend.

Indian farmers rediscover advantages of traditional rice varieties: During the Green Revolution, the seeds of high yielding varieties of crops (HYVs) had appeared as a great new hope for the farmers of the Terai region in Nainital district of Uttar Pradesh. But in recent years, this hope has been killed to a large extent, especially in the case of rice cultivation, by an emerging agro-ecological crisis. While several farmers had started growing the Pant-4 HYV (and some other HYVs) recommended to them, high demands of irrigation as well as chemical fertilisers are proving a problem. This problem was particularly acute in the drought year. As a result of heavy exploitation of water, nearly half of the artesian wells (the most important sources of irrigation in the terai) had dried up. In the remaining wells too the pressure had reduced considerably. Even in rivers, the water level declined steeply. The water level in the Haripura dam on Bhakhra river and the Bore dam on Bore river has receded so much that the farmers could not seek any solace from these structures.

Initially, when water abundance had made this a particularly good land for growing HYVs of rice traditional paddy varieties lost the race. However, one far-sighted farmer, Inder Singh continued to grow and preserve several diverse traditional varieties having different properties with respect to disease and pest susceptibility, climate tolerance, yield, flavour, aroma, etc. As the water level receded and the HYVs ran into some other problems as well, some farmers started learning for traditional seeds and happily they could get these from Inder Singh. His best variety was named Indarasan – as a tribute to his farsightedness in preserving and improving it. Owing to high productivity and low costs of cultivation (in terms of fertilisers and water), this variety became popular among farmers. The small farmers least capable of coping with the high cost of HYVs especially found Indarasan a very useful variety. In just about six to seven years nearly half of the land in the district was covered by Indarasan, and even some big farmers adopted this variety.

During the recent drought season, Indarasan coped much better than Pant-4. In fact the yield of Indarasan paddy this year has gone up, reaching a peak of 32 quintals per acre from the earlier average of 25 quintals per acre. On the other hand Pant-4 has stagnated at 20 quintals per acre, and where irrigation could not be arranged, this HYV has been destroyed almost entirely. What is more, the Indarasan variety is fetching a better price on the market – its rate of Rs. 208 per quintal in Gandarpur mandi (market) compares very favourably with the Rs. 175 per quintal for Pant-4.There is a big rush among farmers to get the Indarasan seed for next year's crop. The Indarasan variety also has good flavour and scent, and its threshing is much easier. In comparison the threshing of Pant-4 requires much more effort. In addition the proportion of unbroken grains is higher in Indarasan. In terms of flavour Indarasan is vying with popular types of rice like Basmati and Hansraj for a place of honour. It also yields more dry fodder for cattle compared to the dwarf HYVs.

Notification of traditional varieties: Under the Seeds Act, certified seeds can be produced only of notified varieties and certification is compulsory. Seed Law Enforcement agency can draw and test samples of seeds of notified varieties. The morphological characters of notified varieties are documented by the Central Seed Committee so as to curtail the bio-piracy. Subsidies are being considered basing on the notification status. Seed planning/programmes are being undertaken basing on the notification of statistical data.

Indigenous varieties: Based on the literatures, we documented 98 farmer's varieties (Table 1). For details, refer the book 'Organic seed: Traditional varieties and technologies'.

Table 1. Number of traditional varieties documented

S.No.	Crop	Number	S.No.	Crop	Number
1	Rice	41	10	Tomato	2
2	Sorghum	2	11	Bhendi	2
3	Bajra	2	12	Chilli	3
4	Finger millet	7	13	Bottle gourd	5
5	Red gram	3	14	Sponge gourd	2
6	Green gram	2	15	Pumpkin	4
7	Horse gram	3	16	Ridge gourd	2
8	Sesamum	3	17	Cucumber	2
9	Castor	5	18	Beans	8
				Total	98

Organic seed production – Choice of crop and varieties: Any crop or variety/hybrid except genetically modified organisms/ crops which suits to the location shall be grown. Pest and diseases resistant varieties are mostly preferred

Table 2. 'Organic' Choice of varieties

Permitted	Prohibited
• Traditional breeding • Conjugation • Hybridization • Fermentation • In vitro fertilization • Tissue culture	• Cell fusion • Micro and Macro encapsulation and recombinant DNA technology • (including gene deletion, gene doubling, intro–duction a foreign gene and changing the positions of genes when achieved by recombinant DNA technology)

Organic seed treatment: Size grading and upgrading: Grading is the conversion of heterogeneous into homogenous one, through stringent removal of discoloured, off coloured, shriveled, immature, diseased, insect and fungal damaged, broken and mechanically damaged seeds. This is an ecofriendly and low cost technology that can be adopted for all the crops. Further homogenization can be achieved through size grading (Cereals, pulses, oilseeds) and specific gravity separation, using water floatation technique (Brinjal, pulses, cotton). For removal of ill filled, immature and insect damaged seeds in paddy, egg floatation technique using common salt (NaCl) solution of 1.03 specific gravity is used. Even in tree species particularly in *Pinus*, incubation, drying and separation technique (IDS) is highly useful for the removal of less vigorous and dead seeds. PREVAC method can also be used for the removal of mechanically damaged seeds of *Pinus.*

Pre-germination technique: This simple eco-friendly technique is practiced in paddy and groundnut. In this technique, seeds are soaked in water and then, incubated in between gunnies for protrusion of radicle. Care should be taken to restrict the radicle growth only to light visual observation of the radical and breaking of the seed coat, otherwise the treatments will have adverse influence and seed management and population maintenance. This treatment does the dual purpose of selection germinable seeds and elimination of dead seeds.

Dormancy breaking: Simple eco-friendly treatment like water soaking and drying could be successfully employed to break the dormancy and to improve the germination of the seeds. It is useful for hard seeds species.

Pre-sowing treatments: Pre-sowing seed treatment is simple techniques where in the seeds are soaked/coated in water/botanical leaf extract or powder for a given period of time followed by shade drying. This process will modify the physiological and biochemical nature of seeds, so as to get the characters that are favourable for drought tolerance (Table 3).

Table 3. Organics, botanicals and biofertilizers used for presowing treatment of organic seed

Botanicals	Biofertilizers	Cow's product	Others	Biocontrol agents
Neem leaf extract	*Azotobacter*	Panchakavya	Coconut milk	*Pseudomonas* spp.
Mint leaf extract	*Azospirillum*	Cow's milk	Tender coconut	*Trichoderma* spp.
Sarani leaf extract	*Rhizobium*	Curd	Vermicompost	
Prosopis leaf extract	Phosphobacteria	Cow's urine	Vermiwash	
Arappu leaf powder		Cowdung		

Organopriming: Presently, a new term 'organopriming' is coined to denote the seed priming using organics. Eventhough the term is new, the practices are ancient and are essentially identical in principle to current invigouration techniques. Evenari (1980) reported that ancient Greak farmers soaked cucumber seeds in water or milk and honey before sowing to increase germination rate and emergence.

Rice: Sundaralingam (2005) in rice hybrid ADTRH 1 and its parental lines, reported that organopriming with 100% coconut water for 16 h (1:0.5) registered higher germination in IR 58025 A and ADTRH 1 (Figure 1). Whereas, panchakavya 5% solution recorded higher germination in IR 66 R. Speed of germination was the highest in panchakavya 4% treatment in all the genotypes.

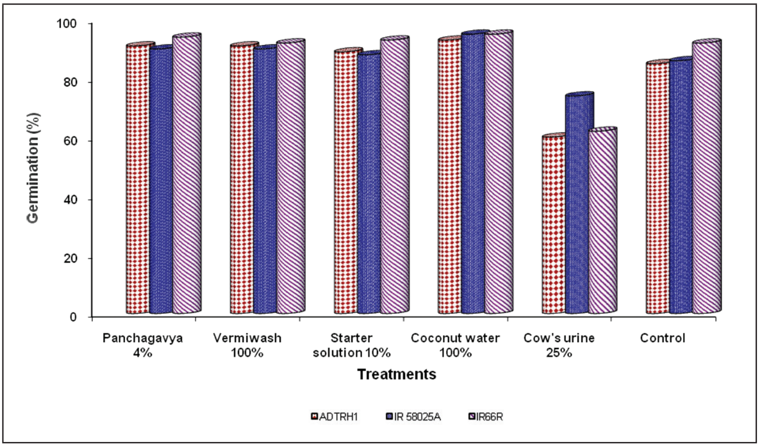


Figure 1. Influence of orgopriming on seed germination of rice hybrid ADTRH 1 and its parental lines

Vijayan (2005) stated that soaking in coconut water 75% for 16h proved to be the best in enhancing germination and vigour of ADT 43 rice (Figure 2.). Panchakavya 3% and vermiwash 75% were also effective.

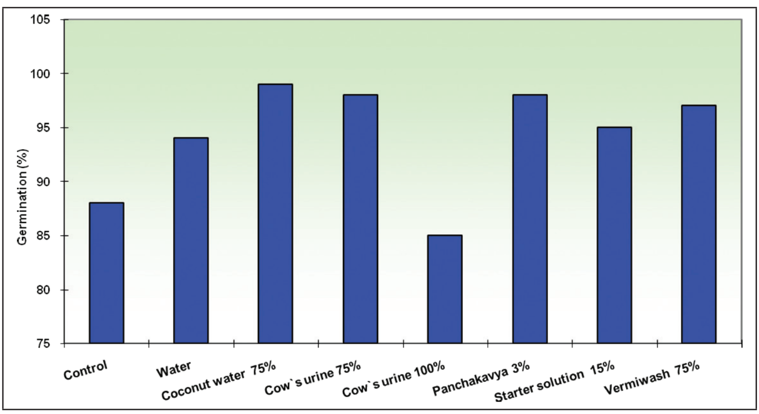
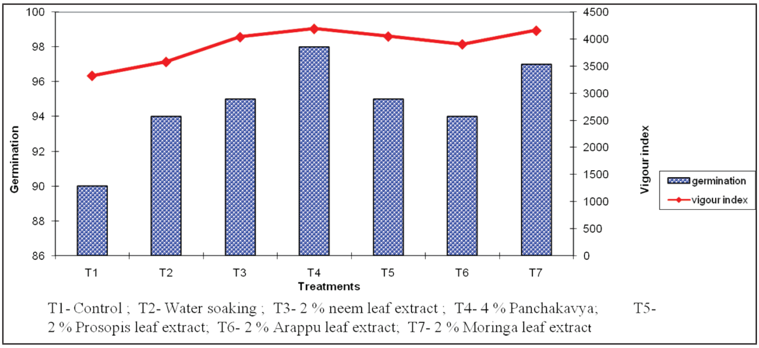


Figure 2. Effect of organic seed treatment on seed germination of rice cv. ADT 43

Blackgram: For improved germination and seedling vigour, the seeds of blackgram could be soaked in 4% panchakavya or 2% moringa leaf extract for 4 h (Figure 3)



T1– Control; T2– Water soaking; T3– 2% Neem leaf extract; T4– 4% Panchakavya;

T5– 2% Prosopis leaf extract; T6– 2% Arappu leaf extract; T7– 2% Moringa leaf extract

Figure 3. Effect of organic seed invigouration on germination and vigour index in black gram cv. APK1

Table 4. The plants and parts used for botanical treatment

Common name	Scientific name	Parts used	Common name	Scientific name	Parts used
Arappu	*Albizia amara*	Leaf	Drumstick	*Moringa oleifera*	Leaf
Pungum	*Pongamia pinnata*	Leaf	Tamarind	*Tamarindus indica*	Leaf
Neem	*Azadirachta indica*	Leaf/ Seed	Bougainvillea	*Bougainvillea* spp.	Leaf
Karuvel	*Acacia nilotica*	Leaf	Basella	*Basella ruba*	Leaf
Prosopis	*Prosopis juliflora*	Leaf	Beetroot	*Beta vulgaris*	Leaf
May flower	*Delonix regia*	Leaf	Marigold	*Tagetus erectus*	Leaf
Hariyali grass	*Cyanodon dactylon*	Leaf	Opuntia	*Opuntia* spp.	Leaf
Hibicus	*Hibiscus rosasinensis*	Leaf	Garlic	*Allium sativum*	Rhizome
Mint	*Mentha spicata*	Leaf	Turmeric	*Curcumba longa*	Rhizome
Milk weed	*Calotropis procea*	Leaf	Vasambu	*Acorus calamus*	Rhizome
Mahendi	*Lowsonia inermis*	Leaf	Chilli	*Capsicum annum*	Seed
Notchi	*Vitex negundo*	Leaf	Sikkai	*Acacia concinna*	Seed
Sambangi	*Telosma minor*	Leaf	Soapnut	*Sapindus trifoliatus*	Seed
			Jamun	*Syzygium cuminii*	Seed

Tomato: In tomato cv PKM 1, Alex Albert (2004) suggested that, organopriming of seeds with 50% coconut water was the best in enhancing germination. Organopriming with panchagavya 1%, vermiwash 25% and starter solution 10% were also effective in enhancing the germination.

Seed pelleting: Seed pelleting is enclosing the seed with foreign material to obtain a standard size and it has influence on seedling growth at seed soil interface. It can be done by the stamping, coating and rolling. The seeds are uniformly coated with adhesive and then, the filler materials are sprinkled. The botanicals can be added as a filler material to increase the size, shape and weight of seeds as well as an active ingredient for improving the physical, physiological and health qualities of seed (Table 4).

Parameswari (1999) with tamarind reported that pelleting with arappu + pungam leaf powders was beneficial in production of elite seedlings at nursery (Table 5).

Table 5. Effect of seed pelleting with botanicals on germination and vigour index

Treatment (T)	Germination (%)	Vigour index		
		30 Days after sowing (DAS)		90 Days after sowing
Control	77	3829		4178
Pelleting with				
Arappu leaf powder	88	4771		5148
Pungam leaf powder	87	4607		4977
Prosopis leaf powder	80	3996		4296
Arappu + Pungam	93	5125		5539
Arappu + *Prosopis*	85	4386		4727
Pungam + *Prosopis*	85	4360		4748
		T	DAS	Tx DAS
CD (P = 0.05)	1.74	159.6	164.7	154.3

Neem seeds pelleted with *Albizia amara* @ 250 g kg^{-1} of seed excelled other pelleting treatments and unpelleted seeds in respect to germination and seedling vigour (Figure 4).

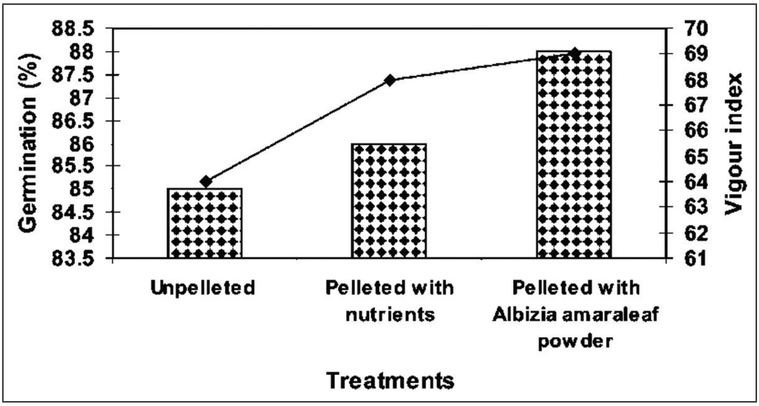
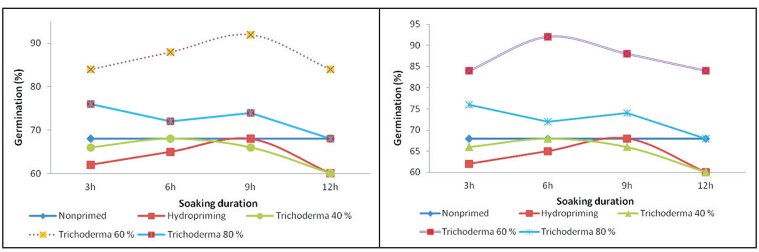


Figure 4. Effect of seed pelleting on germination and seedling vigour of neem

Seed biopriming: a) Biocontrol agents: Kalaivani (2010) reported that maize hybrid COH (M) 5 seeds bioprimed with 60% *T. viride* for 12h had higher germination (88%) with an increase of 7% over nonprimed seed and 6% over hydropriming. She has also reported that the seeds bioprimed with *P. fluorescens* at 80% for 12h showed higher germination and vigour. Karthika and Vanangamudi (2012) reported that seeds of maize COH (M) 5 hybrid bioprimed using enriched humic acid with *T. viride* 80% for 12 h outperformed others by recording an increase of 10.0, 15.6, 8.4, 14.4, 29.5 and 36.4 per cent for germination, root length, shoot length, drymatter production, vigour index I and vigour index II, respectively over the nonprimed seeds. Kavitha (2011) stated that in rice, *T. viride* 60% bioprimed seed for 18h was found to increase the speed of germination by 55 per cent, germination by 12 per cent, root length by 4 per cent, vigour index I (G x SL) by 15 per cent and vigour index II (G x DMP) by 18 per cent over nonprimed seed, followed by *P. fluorescens* 60% for 12h which showed an increase over the nonprimed seed of 46, 2.4, 9 and 21 per cent for speed of germination, germination, shoot length and vigour index II (G x DMP), respectively.

Mariselvam (2012) reported that bhendi seeds bioprimed with *T. viride* 60% for 12h was found to increase the speed of germination by 81 per cent, germination by 18 per cent, root length by 13 per cent, shoot length by 13 per cent, vigour index I (G x SL) by 44 per cent and vigour index II (G x DMP) by 123 per cent over nonprimed seed. Seed biopriming with *P. fluorescens* 60% for 12h also showed a higher percentage of increase over the nonprimed seed and they were 44, 10, 7, 28, 51, 31 and 69 per cent for speed of germination, germination, root length, shoot length, drymatter production, vigour index I (G x SL) and vigour index II (G x DMP), respectively. Dhanalaksmi (2013) concluded that tomato and chilli seeds bioprimed with *T. viride* at 60% concentration for 9 and 6h, respectively enhanced the speed of germination (25 and 27 per cent), germination (35 per cent), root length (41 and 53 per cent), shoot length (106 and 91 per cent), drymatter production (157 and 167 per cent), vigour index I (G x SL) (111 and 119 per cent) and vigour index II (G x DMP) (250 and 271 per cent) over nonprimed seed (Figure 5). She has also reported that both the seeds bioprimed with *P. fluorescens* at 80% concentration for 3h, showed a higher percentage of increase over the nonprimed seed and they were 35 and 33, 24 and 35, 57and 35, 77 and 76, 180, 101 and 80, 235 and 236 per cent for speed of germination, germination, root length, shoot length, drymatter production, vigour index I (G x SL) and vigour index II (G x DMP), respectively.



a. Tomato b. Chilli

Figure 5. Germination of tomato and chilli seeds bioprimed with *Trichoderma viride*

Biofertilizers: Kalaivani (2010) reported that maize seeds bioprimed with 20% *Azospirillum* for 12h had higher germination (95 per cent) with an increase of 20 per cent over nonprimed seed and 10 per cent over hydropriming. She has also reported that the seeds bioprimed with phosphobacteria at 20% concentration for 12h recorded higher germination of 95 per cent. Kavitha (2011) found that rice (ADT 43) seed bioprimed with liquid *Azospirillum* 20% for 12h expressed high values for speed of germination and vigour index over nonprimed seed. Seeds bioprimed with phosphobacteria 15% for 12h was also found to improve the speed of germination, germination, root length, drymatter production and vigour index compared to nonprimed seed.

Mariselvam (2012) reported that bhendi seed bioprimed with liquid *Azospirillum* 15% for 12h expressed high values for speed of germination and germination, which accounted for 61 and 13 per cent increase, respectively over nonprimed seed. However, hydropriming for 12 h also increased the speed of germination. With respect to root and shoot length, an increase of 18 and 16 per cent was noticed in the seed bioprimed with *Azospirillum* 15% for 12 h, respectively. The seeds bioprimed with *Azospirillum* 20% for 12 h also showed increased vigour index I (G x SL) and vigour index II (G x DMP), which accounted for 32 and 107 per cent increase over the nonprimed seed, respectively. Dhanalaksmi (2013) reported that in tomato and chilli, seeds bioprimed with *Azospirillum* at 15% concentration for 9 and 6h, respectively excelled others. A significant improvement in speed of germination (27 and 25% increase, respectively), germination (22%), root length (30 and 27%), shoot length (73 and 71%), drymatter production (218%), vigour index I (G x SL) (65 and 51%) and vigour index II (G x DMP) (300%) was noticed over nonprimed seed. She has also reported that biopriming of seeds with phosphobacteria at 20% concentration for 6 and 3h were found to increase the speed of germination (28 and 26%), germination (17%), root length (54%), shoot length (64 and 50%), drymatter production (218%), vigour index I (G x SL) (49 and 45%) and vigour index II (G x DMP) (300%), over nonprimed seed in tomato and chilli.

Muthurani (2013) concluded that biopriming with *Trichoderma viride* 80% for 3 h or *Pseudomonas fluorescens* 80% for 3 h or liquid *Azospirillum* 20% for 12 h or liquid phosphobacteria 20% for 3 h was found to be the best seed biopriming treatment to enhance the germination rate, total germination percentage, seedling growth and vigour.

Organic Nutrient Management for seed production: Similar to organic production, seed production also involves similar management practices for nutrient management. Organopriming of seeds in combination with other organic nutrient management practices have yielded good results. Jayanthi (2008) revealed that spraying of pulse (cowpea 2%) extract recorded more number of panicles plant^{-1}, panicle length (cm), number of seeds panicle^{-1} and 1000 seed weight (g) (Figure 6).

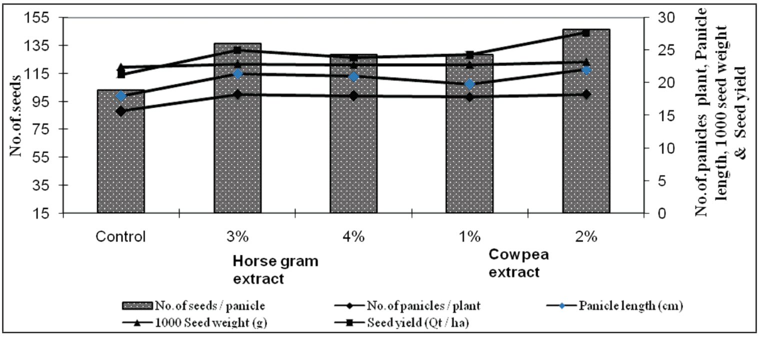


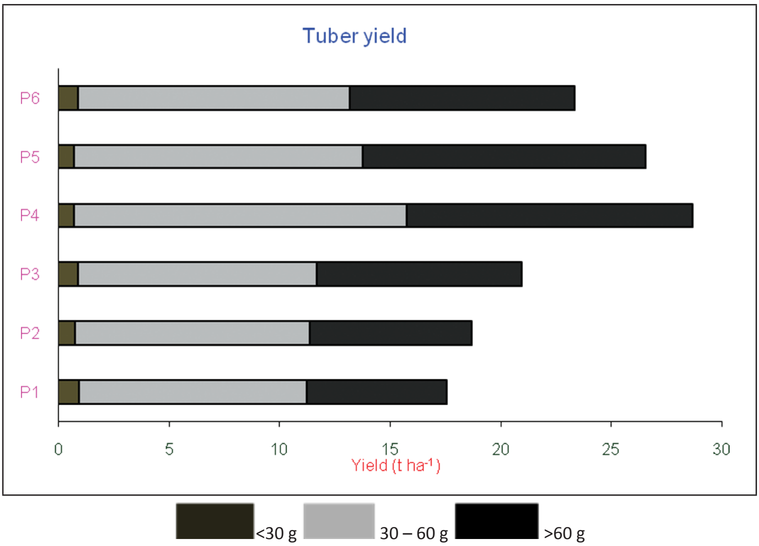
Figure 6. Effect of foliar spray with pulse sprout extract on yield attributes and seed yield of rice – (R line of CORH 3).

Alex albert (2004) expressed that FYM + vermicompost combination proved to be the best for tomato seed production (Table 6).

Table 6. Organic nutrient management in tomato seed production

Treatments	Seed yield ha^{-1} (kg)	Seed recovery (%)
Control (Inorganic source)	227.6	0.730
Vermicompost + Panchagavya	177.4	0.623
FYM + Panchagavya	174.9	0.630
FYM + Vermicompost + Panchagavya	200.7	0.683
Composted coirpith + Panchagavya	172.4	0.660
FYM + Herbal leaf extract	166.9	0.620
Vermicompost + Herbal leaf extract	198.3	0.680
FYM + Vermicompost + Herbal leaf extract	202.7	0.660
Composted coirpith + Herbal leaf extract	198.2	0.670
Mean	191.0	0.662

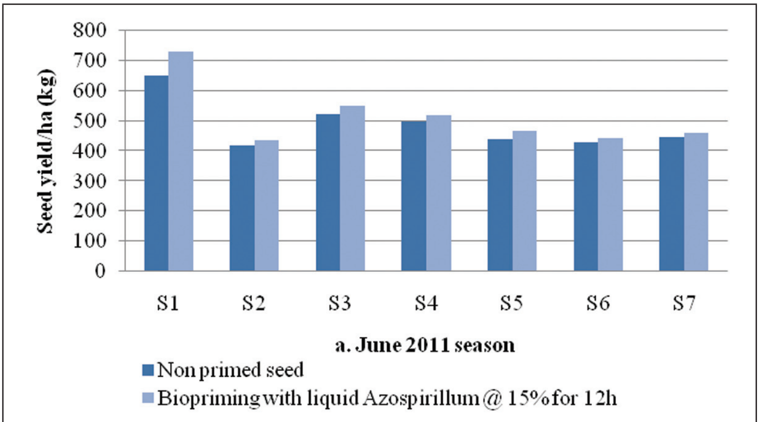
When panchagavya spray was tried in potato seed production to increase seed sized tubers, it evidenced that the application of panchagavya 3% solution on organically grown potato by spraying at 15 days interval is advantageous as it resulted in better performance both in terms of seed as well as total tuber yield (Figure 7)

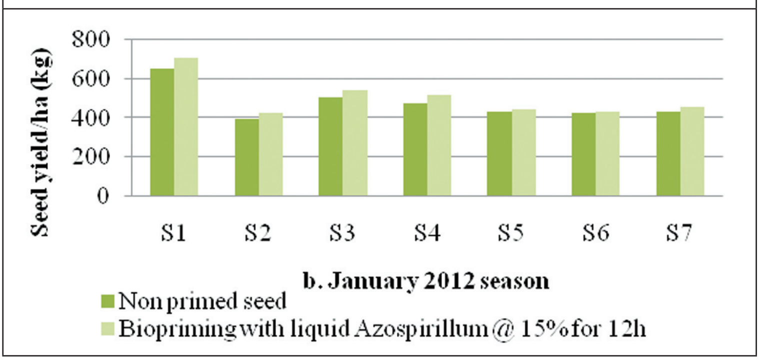


P1 : Seed tuber soaking in panchagavya (3%) + spraying panchagavya (3%) at 8 days interval (12 sprays);P2 : Seed tuber soaking in panchagavya (3%) + spraying panchagavya (3%) at 15 days interval (6 sprays);P3 : Only spraying panchagavya (3%) at 8 days interval (12 sprays);P4 : Only spraying panchagavya (3%) at 15 days interval (6 sprays);P5 : Recommended cultural practices + spraying panchagavya at 15 days interval(6 sprays);P6 : Recommended cultural practices (Control) (90:135:90 NPK kg ha^{-1}).

Figure 7. Effect of panchagavya foliar spray on potato tuber yield.

According to Karthika (2013), the organic seed yield was the highest by recording 729.4 and 706.5 kg ha^{-1}, respectively during June 2011 and January 2012 in the treatment involving seed biopriming with *Azospirillum* 15% for 12h and recommended dose of fertilizer which accounted for 12 and 8 per cent increase, respectively over the control. Among the organic manures, seed biopriming with *Azospirillum* and 100% RDF through poultry manure ranked first in terms of higher yield of organic seed (550.7 and 545.5 kg ha^{-1}, respectively in June 2011 and January 2012) with an increase of 6 and 7 per cent, respectively (Figure 8) and B:C ratio of 1:2.1. However, the seed quality in terms of germination and vigour index was higher in the resultant organic seed harvested from the plants grown from bioprimed seed under 100% RDF through poultry manure, followed by those seed grown under 100% RDF through vermicompost.

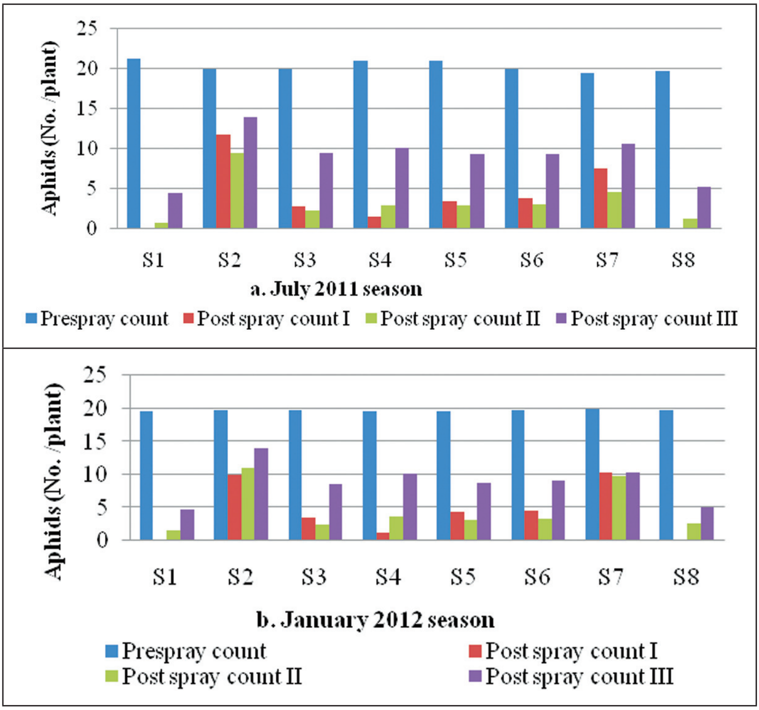




S_1 – RDF; S_2 – 100% RDF through farm yard manure (FYM); S_3 – 100% RDF through poultry manure (PM); S_4 – 100% RDF through vermicompost (VC); S_5 – 50% FYM + 50% PM; S_6 – 50% FYM + 50%VC; S_7 – 50%PM + 50%VC

Figure 8. Influence of seed biopriming and organic nutrition on organic seed yield of bhendi

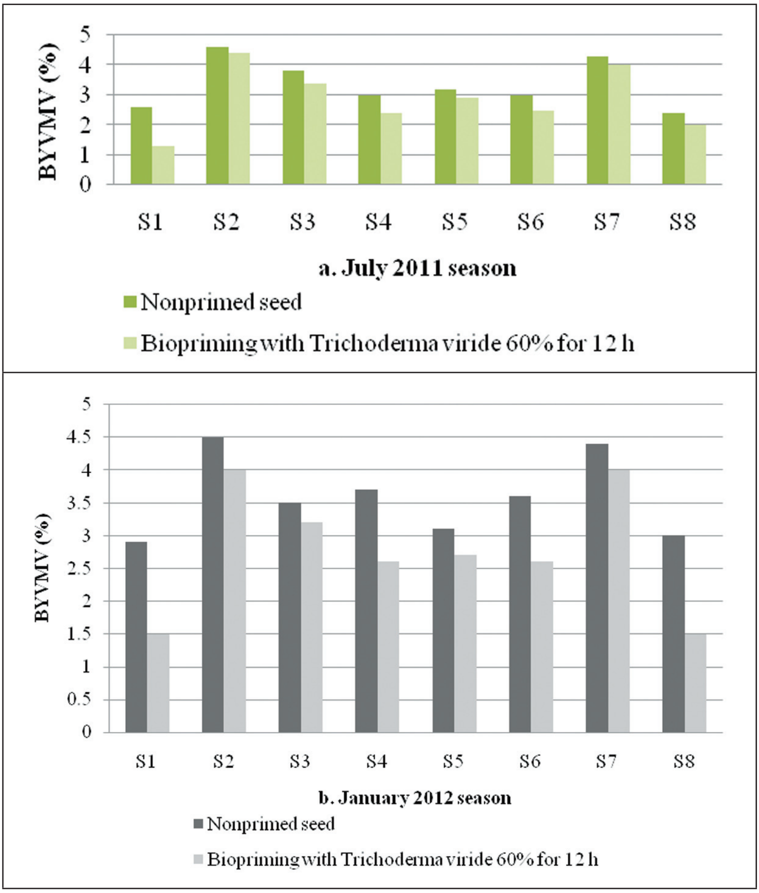
Organic management of pests and diseases: For management of aphids and leafhopper, seed biopriming with *T. viride* and imidacloprid spray followed by seed biopriming with *T. viride* and neem seed kernel extract 5% spray, were found effective when counts were taken on first, second and seventh day after first, second and third spray with good residual effect (Figure 9). However, for management of mites, whitefly and fruit borer, either imidacloprid 0.5 ml lit^{-1} or neem seed kernel extract 5% or dashparni 10% or brahmastra 5% or cow's urine 5% or panchakavya 3% was found effective with good residual effect (Karthika, 2013).



S1 – Imidacloprid @ 0.5ml/lit. of water; S2 – Panchakavya 3%; S3 – Dashparni extract 10%; S4 – Neemastra 10%; S5 – Agneyastra 3%; S6 – Brahmastra 5%; S7 – Cow's urine 5%; S8 – Neem seed kernel extract 5%

Figure 9. Effect of seed biopriming with Trichoderma viride and biopesticides spraying on aphid population in bhendi cv. Arka Anamika during July 2011 and January 2012 seasons

She also observed that the seeds bioprimed with *T. viride* 60% for 12h and neem seed kernel extract 5% spray protected the natural enemies like syrphid fly, spider and coccinellid beetle with an increase in population from 124 (syrphid fly in July 2011) to 1300 per cent (coccinellid beetle in January 2012) when compared to seed biopriming and imidacloprid spray. The diseases like *Bhendi yellow vein mosaic virus,* root rot and powdery mildew were effectively controlled by biopriming seed treatment with imidacloprid spray, followed by these treatments with neem seed kernel extract 5% spray. The good control of BYVMV might be due to effective management of virus transmitting insect vector, the whitefly (Figure 10).

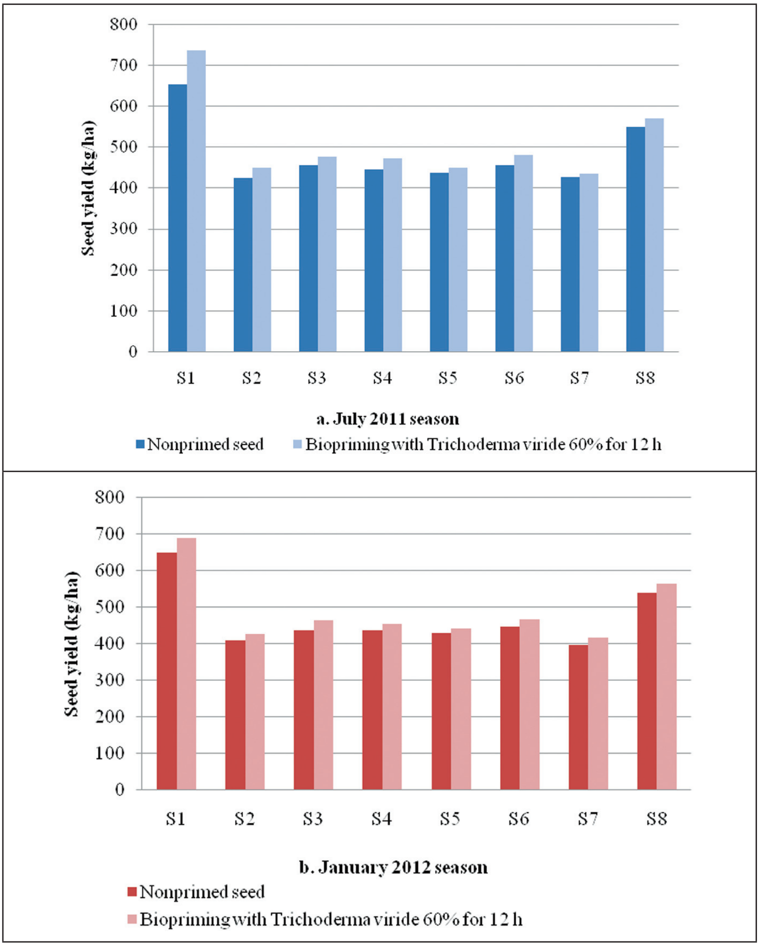


S1 – Imidacloprid @ 0.5ml/lit. of water; S2 – Panchagavya 3%; S3 – Dashparni extract 10%; S4 – Neemastra 10%; S5 – Agneyastra 3%; S6 – Brahmastra 5%; S7 – Cow's urine 5%; S8 – Neem seed kernel extract 5%

Figure 10. Effect of seed biopriming with *Trichoderma viride* and biopesticides spraying on *Bhendi Yellow Vein Mosaic Virus* incidence in bhendi cv. Arka Anamika during July 2011 and January 2012 seasons

The seed yield was higher in the treatment involving seed biopriming with *T. viride* @ 60% 12h and imidacloprid spray @ 0.5 ml/lit.of water by recording 737.7 and 690.9 kg ha^{-1}, respectively during

July 2011 and January 2012, which accounted for 29.1 and 22.5 per cent increase over the second best treatment (Figure 11). The second best treatment was seed biopriming with *T. viride* and neem seed kernel extract 5% spray which showed an yield decrease of 22.5 and 18.3 per cent, respectively during July 2011 and January 2012 with B:C ratio of 1:2.3 when compared to the best performing treatment.



S1 – Imidacloprid @ 0.5ml/lit. of water; S2 – Panchagavya 3%; S3 – Dashparni extract 10%; S4 – Neemastra 10%; S5 – Agneyastra 3%; S6 – Brahmastra 5%; S7 – Cow's urine 5%; S8 – Neem seed kernel extract 5%

Figure 11. Effect of seed biopriming with *Trichoderma viride* and biopesticides spraying on organic seed yield ha^{-1} in bhendi cv. Arka Anamika during July 2011 and January 2012 seasons

Seed storage: Kalaivani (2010) stated that storability of *Pseudomonas fluorescens* 80% bioprimed seed maize hybrid for 12 h was high and they could be stored well with minimal loss in vigour and viability upto 6 months of storage in cloth bag under ambient conditions. Revathi (2013) revealed that seeds bioprimed with *T. viride* 80% for 12h could able to store better in 700 gauge polyethylene bag which registered 73 per cent germination at 18 months of storage. *T. viride* survived on bioprimed seed upto 2 months of storage only. Organic seed treatment for rice, maize, tomato, chilli, bhendi and marigold indicated that seed biopriming with biocontrol agent and liquid biofertilizers was found good. Organic nutrient management of bhendi seed crop with vermicompost or poultry manure could be recommended. Organic biopesticide namely NSKE 5% could able to control major pests and diseases of bhendi on par with imidacloprid. Organic seed could be stored better with Trichoderma and Pseudomonas biopriming.

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Safety, Quality and Certification in Organic Agricultural Produce

Bobby Issac

Organic agriculture has been gaining lots of momentum in the recent years. The market for organic products has also increased as more consumers engage in organic products purchases. More and more consumers are becoming aware of safety in food. Consumers prefer to buy foods that are free from pesticide residues and harmful chemicals. The need for certified organic products have increased many folds as it is required to establish the trust between the consumers and the farmers who are separated by a distance. With this background Organic certification becomes important and inevitable. Certified organic products are grown in most effective environment friendly way and are verified and confirmed as per the various national and international standards. Dependence on external inputs for manuring, pest, disease and weed control are minimized or even excluded. Thus the cost of cultivation is minimized and the resultant products are nutritionally rich and have better keeping quality.

Organic certification addresses a growing worldwide demand for organic food. It is intended to assure quality and prevent fraud, and to promote sustainable business. While such certification was not necessary in the early days of the organic movement, when small farmers would sell their produce directly at farmers' markets. As organic products have gained popularity, more and more consumers are purchasing organic food through traditional channels, such as supermarkets. Hence the consumers start relying on third-party regulatory certification.

LACON was first officially accredited according to EN45011 for organic inspection and certification in the European Union in 1992 in Germany for performing inspection and certification

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activities. LACON is accredited by DAkkS and by the Ministry of Economy and Employment in Vienna, Austria and also by USDA based on US-NOP (National Organic Programme). LACON is one of the leading certification bodies operating in India, which accredited by the National Accreditation Board having its secretariat at APEDA. The registered Indian office is in Kerala and has branch offices in other states of the country to provide the local services to the farmers. Lacon certifies project across 24 states, including North-Eastern states of India. The brand value of LACON has helped the farmers to access international market in addition to the growing domestic market.

The Organic certification efforts of small holder groups helped the small farmers, especially in India, to participate in the organic certification and this has impacted upon the livelihoods of producers, and on the environment. Third party certification of small farmers is based on effective functioning of the internal control system (ICS) which is a similar verification system practiced internally by the group members. ICS help individual small farmers to interact and invoke group dynamics. Thus the group can build on their strength and opportunities for collective marketing and gain better price. The Certification body LACON builds the trust to develop and broaden the external links with major buyers and or exporters. An efficient supply chain transforming raw products to value added products will surely increase the income of farmers. Richness of biodiversity in organic field will also contribute in enhancing the livelihood of members in the group. Organic certification thus helps individual small farmers to empower themselves to adopt strategies to secure their livelihood. Certification refers to the confirmation to compliance to respective regulation. This confirmation is often, but not always, provided by some form of external review, education, assessment, or inspection.

Organic certification: It is a third party verification check and confirm the compliance level of the farm or the chain of activities involved in the production processing and trade with the respective organic standards. In general, any chain of activity directly involved in organic food production can be certified, including agricultural production of individual farms or group of farms, processing, packing, labeling and transport

Requirements vary from country to country, and generally involve a set of production standards for growing, storage, processing, packaging and transportation that include: 1) Avoidance of synthetic chemical inputs as per the NPOP standards (e.g. Soil Conditioners, Plant protection products, Fertilizers, food additives etc.), genetically modified organisms, irradiation, and the use of sewage sludge; 2) Use of farmland that has been free from prohibited synthetic chemicals for a number of years (often, 2–3 years); 3) Keeping detailed written documentation on agricultural production, processing and sales records (audit trail); 4) Maintaining strict physical separation of organic products from non-certified products; 5) Undergoing periodic annual on-site inspections.

For organic producers, certification identifies suppliers of products approved for use in certified operations. For consumers, 'certified organic' serves as a product assurance on the food safety which confirms that there are no harmful substances or artificial preservatives. Certification is essentially aimed at regulating and facilitating the sale of organic products to consumers. Individual certification bodies have their own trade mark, which can act as branding to consumers–being a reputed German brand, LACON's logo has high consumer recognition value and gives a marketing advantage to the farmers.

For first-time farm certification, the soil must meet basic requirements of being free from use of prohibited substances (synthetic chemicals, etc.) for a number of years. A conventional farm must adhere to organic standards for this period, often two to three years. This is known as Conversion period– 'in conversion'. In conversion crops are not considered fully organic. The perennial crops require 3 years of conversion period, whereas the annual crops require 2 years of conversion to get the organic status. Certification for operations other than farms follows a similar process. The focus is on the quality of ingredients and other inputs, and processing and handling conditions. A transport company would be required to detail the use and maintenance of its vehicles, storage facilities, containers etc.

In addition, short–notice or surprise inspections can be made, and specific tests (e.g. soil, water, plant tissue) may be requested. In India, Agricultural and Processed foods Export Development Authority (APEDA), regulates the certification of organic products as per National Standards for Organic Production (NPOP). 'The NPOP standards for Agricultural production and accreditation system have been recognized by European Commission and Switzerland as equivalent to their country standards. Similarly, USDA has recognized NPOP conformity assessment procedures of accreditation as equivalent to that of National Organic Prgramme (NOP) which is the organic standards of USA. With these recognitions, Indian organic products duly certified by the accredited certification bodies of India are accepted by the importing countries, especially in Europe and USA. Organic food products manufactured and exported from India are marked with the 'India Organic' certification mark which is the registered trade mark of Indian organic products.

Rapid Growth of Eco-friendly Low Cost Sustainable Organic Agriculture Production Systems in the World

R Srinivasa Murthy, P Mazumdar, Manisha Rani, Sahina Tabassum and Krishan Chandra

The term organic was first used in relation to farming by Nothbourne (1940) in his book 'Look to the Land'. The term organic farming is referred to a agricultural production management system which improves soil health, biological diversity of micro flora, macro fauna and animal husbandry through the use of organic inputs like composts, vermicompost, farmyard manure, biofertilizers, green manure, poultry manure, crop residues, botanical agents for control pest and diseases, natural energy conservation practices and low cost agronomic practices. The organic agriculture improves soil production capacity, soil biological cycles and biological activity which contribute for sustainable agricultural production (Reganold *et al*., 1993; Letourneau and Goldstein, 2001; Mader *et al*., 2002, Bhattacharya, 2004; Bhattacharya and Chakraborty, 2005, Suresh Reddy, 2010; Ram, 2003 Lampkin *et al*, 1999).

Scenario of global organic production: Organic agriculture production is emerging as major agricultural sector in the world. The Research Institute of Organic Agriculture FiBL and International Federation of Organic Agriculture Movements (IFOAM) carried a survey across the world about organic production in the year 2012–13. The data revealed that more than 162 countries are actively engaged in organic agriculture production and shares 0.86% agriculture land. The growth of organic agriculture production land has been raised from 29.0 to 37.2 mh and organic producers have increased from 695 to 1798 thousand from 2005 to 2011. A total of 1.8 million producers were reported in 2011 where as in 2010 it was 1.6 million. The

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organic industry has grown from $3.6 billion in 1997 to $31.5 billion in 2011. The global market reaches 62.8 billion US dollars and 86 countries have an organic legislation. Oceania occupies 1st place with an area of 12.2 million hectares followed by Europe (10.6 million hectares) and Latin America (6.9 million hectares). Among the countries, Australia covers highest area of organic land fallowed by Argentina and United States in the second and third place respectively (www.fibl.orghttp, www.ifoam.org).

Organic market growth at global level: In a major survey in seven European Union (EU) countries shift for organic agriculture is accounted for more than 50% of the EU's agricultural area. It found that between 0.8 and 3.1% of farmers in each country were registered as organic. The National Organic Agricultural Movement of Uganda (NOGAMU) was established in 2001, started with four exporter companies and it has 44 export companies in the year 2012 that has accomplished through change in market promotion and linkages. It is exporting its produce to Europe, Japan and the Middle East countries. More than 1.2 million farmers adopted and accepted organic production systems. The new trends of organic outlets in towns in central Uganda started to increase the accessibility of organic products in local markets. Around the world certified organic food markets were concentrated in North America, Europe and Japan and covers around more than 95% of the global market. The organic market is expanding its wings to more than one hundred countries. The organic produce exporting countries Turkey, Brazil and China used only to export organic produce but now a days it is finding local market demands too. Since People are getting more conscious about quality and value of organic produce. Organic produce is also getting better access in specialized health food shops, supermarkets and restaurants. There are organic restaurants in Nairobi, Rio de Janeiro, Shanghai, Tehran and New Delhi. The global market for organic food and drink almost tripled between 2000 and 2011 and is now worth more than 60 billion USD (Ploeg, 2002; Peter, 2013; Willer, 2013).

Organic farming status of India: As per world statistics, India may be far behind other countries in total land under organic and 2nd in Asia after China, but in terms of total cultivated land, India leads with 1.08 m ha under regular cultivation. The area under organic agriculture production has increased from

42,000 to 10, 85,648 ha during the period from 2004 to 2012. Total area under organic certification process, including wild harvest collection area has grown from 4551899 ha to 5211141 ha form 2009–10 to 2012–13. (http://ncof.dacnet.nic.in), (www.fibl.org; www.ifoam.org). India produced approximately 2.95 million tons (mt) of certified organic products which includes all varieties of food items namely Sugarcane, Cotton, Basmati rice, Pulses, Tea, Spices, Coffee, Oil Seeds, Fruits and their value added products. The production is not limited to the edible sector organic cotton fiber, functional food products are also important commodities. Among states, Madhya Pradesh covered largest area under organic certification followed by Rajasthan and Uttar Pradesh. The total organic production increased from 1.7 mt to 2.95 mt during 2009–10 to 2011–12.

India exported 135 products in the year 2012–13 with the total volume of 165262 MT including 4985 MT organic textiles. The organic agriculture export realization was around 374 million US $ including 160 US $ organic textiles registering 4.38% growth over the previous year. Among the different products exported, Soybean Oil seeds – (41%) lead the tally followed by Cane Sugar (26%), processed food products (14%), Basmati Rice (5%), other cereals and millets (4%), Tea (2%), Spices (1%), Dry fruits (1%) and others. Organic products are exported to EU, US, Switzerland, Canada, South East Asian countries and South Africa (http://www.ifoam.org/).

Promotion of organic farming in India: To promote organic agriculture system Government of India launched National Programme for Organic Production (NPOP) in the year 2001. NPOP defined the standards, accreditation procedures and established a credible certification system which is now well established nationally and internationally. The standard fallowed and adopted for the assessment and certification by NPOP for organic agriculture production system have been recognized and accepted by the European Commission, Switzerland and United State Department of Agriculture (USDA). For promotion of organic farming National Centre of Organic Farming (NCOF) was established in the year 2004 at Ghaziabad (Headquarter), Uttar Pradesh with its six regional centres located at Bangalore, Nagpur, Jabalpur, Bhubaneswar, Panchkula, and Imphal.

NCOF is actively engaged in implementing objectives listed below to facilitate, encourage and promote development of organic agriculture in the country (http://ncof.dacnet.nic.in). 1) To encourage production of organic inputs like biofertilizers/ biopesticides, Fruit and Vegetable Market Waste compost etc; 2) To act as nodal agency for implementation of quality control regime for bio-fertilizers and organic fertilizers, as per the requirement of FCO; 3) To formulate and define standards for other unregulated organic and biological inputs and bring them under quality control mechanism, define/upgrade standards and testing protocols; 4) Develop, maintain, undertake regular efficacy testing and ensure steady supply of mother cultures of bio-fertilizer and other beneficial micro-organisms for nutrient mobilization and plant protection to the biological input production industry; 5) To run short term certificate courses on organic system and on-farm resource management; 6) To organize regular trainings and refresher courses for State Governments' quality control analysts/inspectors associated with implementation of Fertilizer (Control) Order 1985 (FCO); 7) To impart trainers' training on certification systems, organic management, input production and on other related aspects to certification and inspection agencies, extension agencies, farmers, industries and organizations engaged in the production, and promotion of inputs and organic farming; 8) To initiate research on validation of established indigenous practices, inputs and technologies leading to development of package of practices; Publication of training literature, Quarterly Organic Farming Newsletter, Half yearly Biofertilizer Newsletter and validated and documented indigenous practices; 9) Technical support to existing certification systems in terms of standards formulation, designing implementation protocols, evaluation and surveillance. Policy, implementation and surveillance support to alternative farmers' group centric low-cost certification system such as Participatory Guarantee System; 10) Awareness creation through seminars/conferences/trade fairs and publicity through print and electronic media and; 11) Support Central and State Governments in evaluation, and monitoring of various organic agriculture schemes.

NCOF is also supporting various financial schemes which are going to be implemented for promoting organic production in the country. The details of funds proposed/available for different activity in the 12th plan are as follows: (Source from Director, NCOF). 1) Promotion of Organic Inputs on Farmers' field (Manure, liquid Manures, Vermicompost, Biofertilisers, municipal solid west and agro-west compost, Herbal Extracts etc.) for increasing soil organic Carbon: Financial assistance of 50% of cost subject to a limit of Rs. 5000/- per ha and Rs. 10,000 per beneficiary. Propose to cover 1 million ha area; 2) Setting up of biofertilizer/ bio-pesticide production units with financial assistance of 100% to State Govt./ Govt. Agencies upto a maximum limit of Rs. 160.00 lakh /unit and 25% of cost limited to Rs. 40 lakh/unit for individuals/private agencies through NABARD as capital investment subsidy for 200 TPA production capacity; 3) Setting up of Vegetable and fruit market waste compost production unit with financial assistance of 100% to State Govt./Govt. Agencies upto a maximum limit of Rs. 190.00 lakh/unit and 33% of cost limited to Rs. 63 lakh/ unit for individuals/private agencies through NABARD as capital investment subsidy for 3000 TPA production capacity; 4) Adoption of organic farming through cluster approach by Participatory Guarantee system (PGS) certification, financial assistance of Rs. 20,000/- per ha subject to maximum of Rs. 40,000/- per beneficiary for 3 year term; 5) Support to PGS system for On-line data management and residue analysis @ Rs. 200 per farmer subject to maximum of Rs. 5000/- per group/ year restricted to Rs. 1.00 lakh per Regional Council. Upto Rs. 10,000/- per sample for residue testing (Residue analysis to be done in NABL Labs); 6) Organic Village adoption for manure management and biological Nitrogen harvesting, financial aids of Rs. 10 lakhs/village for adoption of integrated manure management, planting of fertilizer trees on bunds and promotion of legume intercropping through groups/SHGs etc. (Maximum 10 village per annum/State will be supported)

Organic village: The new models of agriculture that humanity will need in the immediate future should include forms of farming that are more ecological, bio-diverse, local and sustainable and socially just. Therefore, they will necessarily have to be rooted in the ecological rationale of traditional small-scale agriculture, which represent long-established, successful and adaptive forms of agriculture. The basic attribute of agricultural sustainability is the maintenance of agro-ecosystem diversity in the form of spatial and temporal arrangements of crops, trees, animals and associated biota. Increasingly, research suggests that agro-ecosystem performance and stability is largely dependent on the level of plant and animal biodiversity. Biodiversity performs a variety of ecological services beyond the production of food, including recycling of nutrients, regulation of microclimate and of local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals. Because biodiversity-mediated renewal processes and ecological services are largely biological, their continued functioning depends upon the maintenance of biological integrity and diversity in agro-ecosystems.Therefore, for sustainable agriculture and for adoption of organic farming, educating farmers about organic agriculture practices, creating awareness about hazards of indiscriminate use of synthetic chemical fertilizers and pesticides and also about other ecological issues and to educate farmers to go on with the sustainable eco friendly organic farming methods, educating the farmers about the possibility of growing different crops suitable to the land and increase their income, promotion of organic consumer movement so that the farmers get better returns for their farm produce. Keeping this philosophy in mind, Ministry of Agriculture under National Mission on Sustainable Agriculture has proposed to develop such model organic villages and for setting of such model organic villages across the country, states shall be supported with financial assistance for adoption of organic villages for manure management and biological Nitrogen harvesting.

Mode of selection of villages for adoption: State Government shall identify farmers who are not covered for adoption of organic farming under any other scheme of Central/ State Government. Vulnerable mountains and hills, floodplains, exposed hillsides, arid or semi-arid lands, rainfed area where more and more people those at lower income levels, are at risk from the negative impacts of climate variability will be preferred. The implications for food security could be very profound, especially for subsistence farmers living in remote and fragile environments that are likely to produce very low yields. This is particularly beneficial to small-scale farmers – especially women – who have low or no access to credit, also lack capital and access to fertilizer distribution systems, particularly since the private sector is unlikely to invest in the most remote areas where communication routes are poor and where few economies of scale can be achieved. Suitable efforts may be taken for selection of Women farmers, SC/ST farmers and PRIs/SFAC may be involved for selection of such farmers.

Policies towards organic farming: Ministry of Agriculture, Government of India is making policies to promote rapid growth of organic farming which is technically sound, economically viable, environmentally sustainable, and socially acceptable with major emphasis on use of natural resources. Area expansion policies aims at increasing crop potential, sustaining soil fertility, conserving bioresources, strengthening rural economy and promoting value addition to expand the growth of organic market and to promote living standards of economically backward communities. Important features of the policy includes (http://ncof.dacnet.nic.in): Maintenance of soil fertility by encouraging and enhancing the biological cycle within farming systems involving micro-organisms, soil flora and fauna, plants and animals; Identifications of area and crop suitable for organic farming; Development of organic package of practices; Setting up of model organic farms for getting seed material for organic cultivation; Assurance of production and supply of quality organic input; Adoption of biological methods for pest and disease control; Adoption of biological and mechanical methods for weed management; Harnessing of traditional and indigenous knowledge relating to organic farming; Creation of awareness among farmers towards organic agriculture; Development of Domestic market for organic produce; Improvement of farmers' income through production of quality produce; Generation of rural employment opportunity; Simplification of certification system and recognition of adequate certification agencies, specially for domestic market; Promotion of group certification; Maintaining a diversity of plant and animal species as a basis for ecological balance and economic stability; Improvement in condition of livestock that allow them to perform all aspects of their innate behaviour; Development of regulatory mechanism for various organic input and organic produce.

As the basic attribute of agricultural sustainability is the maintenance of agro-ecosystem diversity in the form of spatial and temporal arrangements of crops, trees, animals and associated biota, plant and animal biodiversity. Therefore, Government policies primarily aims at soil health improvement and organic farming proposed to be effectively implemented by responsible Institutes at different levels at large scale with in a time frame. The National Centre of Organic Farming plays important role in implementing the various national programmes at different levels. The farmers and entrepreneur friendly policies will strengthen organic input production and consumption. Through organic farming economically backward also play a role in bringing revolution in the organic production of the country and organic farming system is our future secured sustainable agricultural production system.

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Role of Indigenous Liquid Organic Manures in Organic Crop Production

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Organic farming as a concept has existed in India since ancient period. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way as to keep the soil alive and in good health by use of organic ways and other biological materials along with beneficial microbes to release nutrients to crops for increased sustainable production in an eco-friendly pollution free environment. Green revolution technologies involving greater use of synthetic agrochemicals such as fertilizers and pesticides with adoption of nutrient-responsive, high-yielding varieties of crops have boosted the production output per hectare in most cases. However, this increase in production has slowed down and in some cases there are indications of decline in productivity and production. Moreover, the success of industrial agriculture and the green revolution in recent decades has often masked significant externalities, affecting natural resources and human health as well as agriculture itself. Nutrient supply in organic farming systems relies on the management of soil organic matter to enhance the chemical, biological and physical properties of the soil. One of the basic principles of soil fertility management in organic systems is that plant nutrition depends on biologically-derived nutrients' instead of using readily soluble forms of nutrients; less available forms of nutrients such as those in bulky organic materials are used. Improved soil biological activity is also known to play a key role in suppressing weeds, pests and diseases (IFOAM publication, 1998).

Animal wastes such as dung, urine, green manure, biofertilizers, wastes from agro and food based industries are some of the potential sources of nutrients in organic farming. The indigenous people in a given community have developed various formulations with such resources over time and still continue to develop (Grolink, 2005). It is based on the experience often tested over years of use, adapted to a local culture and

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environment and as their basis for natural resource management. In traditional agricultural practices, farmers evolved an efficient system of crop production through generations of experience and intimate knowledge of their environment. Indigenous liquid organic manures such as beejamrutha, jeevamrutha, panchagavya, Amruthpani, liquid biodigester, biogas slurry etc., play major role in improving growth and yield of crops. Besides they also improve soil physical, chemical and biological properties and also act as growth promoting and yield enhancing substances.

Preparation and use of liquid organic manures: Among indigenous technologies used by farmers, Panchagavya, Jeevamrutha and Beejamrutha are ecofriendly organic preparations made from cow products. Using of organic liquid products such as Beejamrutha, Jeevamrutha and Panchagavya results in higher growth, yield and quality of crops.

Beejamrutha: It is being used for treating seeds in traditional practice. Beejamrutha is a totally organic product helpful for plant growth and protects crop from harmful soil-borne and seed-borne pathogens. Presence of naturally occurring beneficial microorganisms predominantly bacteria, yeast, actinomycets, photosynthetic bacteria and certain fungi were detected in cow dung (Swaminathan, 2005). Beejamrutha is prepared by using local cow dung, cow urine, water and lime. Take 5 kg of local cow dung in a cloth and tie it with thread as a small bundle and hang it for a night (12 hr) in 20 liters of water. In another container dissolve 50 g of lime in 1 litre of water and keep it for a night. Next day morning squeeze the cow dung in water add handful of soil and mix well and to this add 5 liters of desi cow urine and lime water and stir well. Treat the seeds in beejamrutha, dry in shade and use for sowing. It protects the crops from harmful fungus, bacteria and other pathogens of soil borne diseases. It has hormones, alkaloids, which enhance the germination and gives protection to seeds and seedlings (Palekar 2005).

Jeevamrutha: Jeevamrutha is a miracle microbial culture and is not a fertilizer. The useful soil microorganisms, earthworms are activated when jeevamrutha given with irrigation water. Desi cow dung is the main base of jeevamrutha. Ingredients for jeevamrutha:

1. Water 200 liters
2. Desi cow dung 10 kg
3. Desi cow urine 10 l
4. Jaggery 2 kg
5. Pulse flour 2 kg
6. Handful of soil from farm/ forest/bund

Take a container/ plastic drum of 50 liters to which add 10 kg cow dung, 10 liters of cow urine and 10 liters of water and mix it thoroughly. To this add 2 kg pulse floor, 2 kg organic jaggery and handful of garden soil and add 10 liters of water and stir it clock wise to form homogenous solution. Transfer this solution to 200 liters plastic barrel and makeup the volume to 200 liters. Keep the drum in shade or in room and cover it with wet jute bag. Stir the solution daily in clockwise direction at morning, afternoon and evening. Incubate the solution for 9 to 12 days and use (Palekar 2005 & Devakumar *et al*, 2010). This solution is rich source of useful and effective microorganisms. About 200 to 400 liters of jeevamrutha to be used per acre at monthly interval and apply twice for better results. It can be used through irrigation water and along with FYM during land preparation or at the time of sowing. It acts as growth hormone, antifungal and anti bacterial and prevents many soil borne diseases. Jeevamrutha can also be used as spray after filtering at 5% concentration.

Panchagavya: Panchagavya, an organic product has the potential to play the role of promoting growth and providing immunity in the plant system. In Sanskrit, Panchagavya means the blend of five products obtained from a cow and they are; cow dung, cow urine, milk, curd and ghee. When these are suitably mixed and used in crop production has beneficial effects. Take a container to which add 7 kg cow dung and 1 kg cow ghee and mix it thoroughly and incubate for 3 days. After 3 days add 10 liters of cow urine and 10 liters water to the mixture and incubate for 15 days with regular mixing both in morning and evening hours. After 15 days add 3 liters of cow milk, 2 liters of cow curd, 3 liters of tender coconut water, 2 kg jaggery and 12 well ripened bananas to the mixture and continue mixing both in morning and evening for about a week. The container should be kept under shade and covered with wet gunny bag. Panchagavya solution will be ready in 30 days (Selvaraj et al, 2006). This is to be applied at 3 to 5% concentration twice a month till maturity of crops. Descriptions of this holy combination could be traced out in Vedas, the divine scripts of Indian wisdom. This promotes biological activities in the soil and makes nutrients available to crops. Panchagavya may be applied with irrigation water. Panchagavya contain macro nutrients, essential micro nutrients, many vitamins, essential amino acids, growth promoting factors like IAA, GA, and beneficial microorganisms (Natarajan, 2007; Sreenivasa *et al*., 2010). Panchagavya is used as a traditional method to safe guard plants and micro organisms and to increase plant production.

Biodigester: Biodigester is a device to prepare liquid organic manure in large quantity using animal wastes like dung, urine, cattle shed wash and other agricultural wastes. Cow urine and dung are placed over the agriculture based organic waste materials filled in the tank. The bio-gas slurry can also be used instead of cattle dung. Besides Agro-based Industrial organic wastes can be used along with other farm wastes. Fill the water till the organic wastes get immersed and allow it for fermenting for 15–20 days and ready liquid manure gets collected in collection pit. The principle behind is that low C: N ratio materials (legumes, weeds etc.) and wide C:N ratio materials (fibrous straws etc.) are co-composted and then the nutrients are quickly released to available form. Biodigester liquid manure can be used along with irrigation water and after filtration it can also be given with drip irrigation. It helps in recycling of organic wastes, improves soil fertility increase soil microbial population, growth and yield in many crops.

Amruthpani: Amruthpani is heavenly drink it invigorates the living soil and converts dead soil into living one. It is prepared by mixing 250 g desi ghee, 500 g honey, 10 kg fresh desi cow dung in 200 liters of water and keeps it for one–two days. This can be used with irrigation water and also use to treat the seeds and seedlings (Selvaraj *et al*, 2006).

Analytical studies: Beejamrutha and Jeevamrutha: Maximum CFUs of bacteria, fungi, actinomycets, N-fixers and P-solubilizers were observed on the day of preparation of beejamrutha and later on there is sharp decline in their number as the days elapsed (Table 1). Maximum CFUs of bacteria (623), fungi (22) actinomycets (2), N-fixers (71) and P-solublisers (52) were recorded on the day of preparation and there on it decreased progressively and it was minimum on 7th day after preparation. Higher colony forming units (CFU) in Jeevamrutha were recorded between 9th to 12th day after preparation (Table 2) and higher number of bacterial CFU's *viz.*, *Azotobacter* sp., *Bacillus* sp., *Beijerinckia* sp., *Chromatium* sp., *Chromobacterium* sp., *Pseudomonas* sp., *Rhodomicrobium* sp., *Serretia* sp., *Xanthomons* sp., were recorded. The different fungi observed were, *Aspergillus* sp., *Fusarium sp., Penicillium* sp., *Trichoderma* sp. Isolated P-solubilisers were fungi – *Aspergillus* sp., *Penicillium* sp., Bacteria like *Bacillus* sp., *Pseudomonas* sp. and N-fixers like bacteria – *Azotobacter* sp., *A. chroococcum*, *A.beijerinckia*, *A. insigins*, *Bacillus* sp., *Beijerinckia* sp., Actinomycetes –*Streptomyces* sp. It clearly indicates that the jeevamrutha is enriched consortia of native soil micro organisms. It will give best results if it is used between 9th to 12th days after preparation.

Table 1. Microbial population of Beejamrutha between 1 to 7 days after preparation

Days After Preparation	Microbial populations (CFU's*)				
	Bacteria (10^5)	Fungi (10^4)	Actinomycetes (10^3)	N-fixers (10^3)	P-solubilisers (10^3)
1	623	22	2	71	52
2	435	11	2	40	42
3	371	11	1	39	34
4	259	9	2	39	34
5	208	2	1	28	25
6	190	2	1	19	20
7	171	1	1	15	10

*Colony farming units

Table 2. Microbial population of Jeevamrutha between 1 and 30 days after preparation

Microbes	Microbial Population									
	Days after Preparation									
	01	02	03	04	05	06	07	08	09	10
Bacteria (10^5)	213	351	269	271	361	495	692	780	813	855
Fungi (10^4)	11	2	6	2	1	6	7	31	32	29
Actinomycetes (10^3)	1	1	1	1	1	2	1	9	12	8
N-Fixers (10^3)	34	29	16	46	23	09	20	27	63	69
P-Solubilizers (10^3)	61	60	12	48	37	53	61	48	50	80

Microbes	Microbial Population									
	Days after Preparation									
	11	12	13	14	15	16	17	18	19	20
Bacteria (10^5)	843	727	447	526	562	551	402	367	339	292
Fungi (10^4)	36	17	08	21	18	14	17	06	05	04
Actinomycetes (10^3)	11	03	03	03	06	01	02	03	02	02
N-Fixers (10^3)	67	58	49	34	40	118	90	64	43	30
P-Solubilizers (10^3)	52	79	67	32	34	131	40	47	48	35

The presence of beneficial microorganisms in these liquid formulation might be due to their constituents, which are mainly from cow such has cow dung, cow urine and legume flour, jaggery, they contain both macro nutrients and essential micro nutrients, many vitamins, essential amino acids, growth promoting substances like indole acetic acid (IAA), gibberlic acid (GA) and beneficial microorganisms (Palekar, 2006; Sreenivasa *et al*, 2010; Neelima and Sreenivasa, 2011). For jeevamrutha a handful of soil from the field for which it has to be used is also added at the time of preparation. These will serve as initial inoculums of bacteria, fungi, actinomycetes, N-fixers and P-solublisers. Hence, the higher beneficial microorganisms were found in these organic formulations and it is in confirmity with Papen *et al* (2002) Sreenivasa *et al* (2010).

The nutrient content of beejamrutha, jeevamrutha and their constituents are presented in Table 3. It was found that beejamrutha, cow dung and cow urine is alkaline and jeevamrutha is highly acidic. Hence, these formulations would serve a long way in supplementing many of the biofertilizers and biocontrol agents used in crop production in rural areas. This is also in conformity with Devakumar *et al* (2011) who have reported that both jeevamrutha and panchagavya have enhanced the growth of Nitrogen fixers in locally available substrates such as FYM, pressmud, compost and digested biogas slurry.

Table 3. Nutrient composition of beejamrutha, jeevamrutha and their constituents

Sample	pH	N	P	K	Mg(ppm)	Cu(ppm)
Beejamrutha	8.02	2.38	0.127	0.485	16	36
Jeevamrutha	4.92	1.96	0.173	0.280	46	51
Local cowurine	8.16	1.67	0.112	2.544	6.3	20.00
Local cowdung	8.08	0.70	0.285	0.231	9.33	3.60
Pulse flour	6.70	1.47	0.622	0.910	12.6	12.40

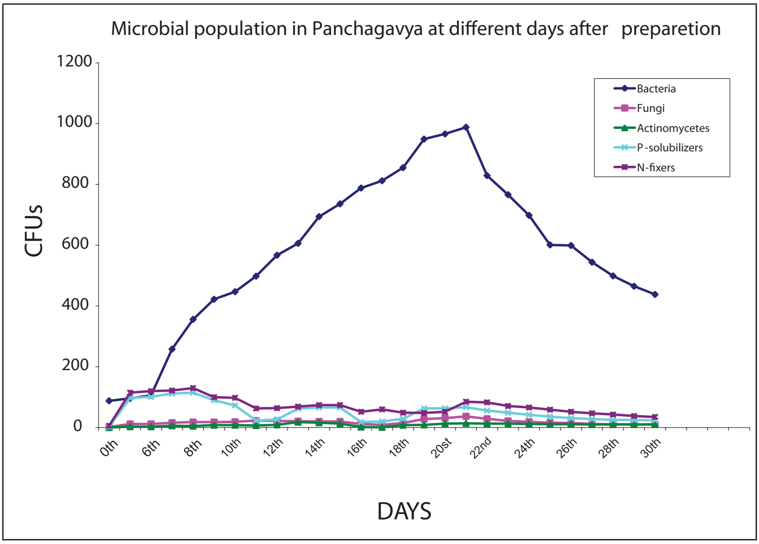

Figure 1: Graphical representation of microbial population of Panchagavya during the fermentation period

Different microorganisms and their number during fermentation period in panchagavya are depicted in Figure 1. It was observed that bacterial count was higher during 19th to 22nd days after preparation and later declined. Somasundaram *et al* (2003) have found that under higher acidity more number of beneficial microorganisms was recorded in panchagavya. They not only enhance microbes in the environment but also act as catalysts with a synergistic effect to promote all useful microbes of the environment. These microorganisms secrete proteins, organic acids and antioxidants in the presence of organic matter and convert them into energy thus, the soil micro flora and fauna change from a disease inducing soil to a disease suppressive soil.

Nutrient contents in liquid biodigester manure are presented in Table 4. The pH is neutral and it contains major nutrients in lesser quantity and fairly higher micronutrient content.

Table 4: Nutrient content in Liquid Biodigester Manure

Parameters	Value (range)	Parameters	Value (range)
pH	7 - 7.55	Mg (mg/litre)	10.9 - 12.6
EC (dSm^{-1})	0.20 - 0.26	S (mg/litre)	0.32 - 0.48
Av. N (%)	0.2 - 1.05	Zn (ppm)	211 - 214
Av.P_2O_5 (%)	0.06 - 0.81	Cu (ppm)	20.1 - 22.3
Av.K_2O (%)	0.05 -0.65	Mn (ppm)	43.8 - 45.9
Ca (mg/litre)	42.0 - 54.1	Fe (ppm)	22.2 - 23.0

Performance of Beejamrutha, Jeevamrutha and Panchagavya on different crops: In an experiment conducted with different liquid organic manures such as beejamrutha, cow urine, panchagavya and liquid biofertilizers under palekar's method and organic method, it was observed that these treatment increase in paddy yields. The increase in yield varied between 5 to 11% by seed treatment with these formulations. Similarly overall increase in paddy grain yield was higher under organic cultivation than palekar's system (Devakumar *et al*, 2008). Application of 9% panchagavya has increased yield of field bean to an extent of 29%. Similarly, when jeevamrutha was used at 200–500 liters per acre has resulted in increased yield of 15 to 40% in field bean (Anon, 2010).

The studies conducted on tomato indicates that use of beejamrutha, jeevamrutha and panchagavya along with recommended fertilizers at flowering and crop harvest stage resulted in increased plant height, root length, dry matter accumulation, number of fruits per plant and fruit yield per plant (Nilima Gore and Sreenivasa, 2011). This might be due to higher microbial load and plant growth promoting substances present in the liquid formulations which helped in improving plant growth and metabolic activities. Muthuvelu (2002) has reported higher bhendi yield with four sprays of panchagavya (3%) and moringa leaf extract spray at 25 ml/plant. Mamaril and

Lepez (1997) have reported that panchagavya includes tender coconut water which contains kinetin and it might have helped to increases the biomass and yields of crops. Beneficial micro organisms present in beejamrutha produced IAA and GA which resulted in improvement in seed germination, seedling length and seedling vigor in soybean (Sreenivasa *et al*, 2009).

In maize significantly higher number of leaves, plant height, grain and stover yields were obtained with the application of 3% panchagavya and 5000 liters/ha of cow urine application at 30th and 60th days after sowing (Anon 2008). Sathiyamoorthy (1997) has reported higher leaf area index, nutrient uptake and yield in maize by application of biodigester liquid, panchagavya and cow urine spray. Incorporation of green manures and foliar application of panchagavya twice on the standing crop resulted in better growth and development of crops which increased grain yield of maize. Cob length and cob girth were significantly higher in biodigester, followed by cow urine and panchagavya liquid manures (Meena and Bheemavat, 2009). Liquid cattle manure applied to soil did not affect the seed germination but resulted in significant increase in plant height, number of green leaves and dry biomass of maize (Masti *et al*, 2003). Seed treatment with beejamrutha and panchagavya has enhanced the yield of maize compared to control. Panchagavya (3%) sprayed at 30 and 60 DAS has resulted in higher maize grain and stover yield under different fertility management systems (Anon, 2008). Muthuvelu (2002) and Devakumar *et al* (2008) have also reported increased yield in bhendi, field bean and finger millet crops with panchagavya.

Plant dry matter accumulation, number of pods per plant, shelling percentage and pod haulm yield in groundnut were increased with soil application of 1 liter per m^2 to 3 liters per m^2. The increase was progressive with the increase in panchagavya application (Kumawat *et al*, 2012). Selvaraj (2003) also observed 36% increased yield of frenchbean with application of vermicompost and panchagavya due to restoration of soil fertility with these sources. Higher dry matter accumulation (g/plant), pod length number of pods per plant, pod weight per plant, seed weight per plant and yield of cluster bean were recorded with foliar application of fermented panchagavya compare to control during 2006 and 2007 (Kumawat *et al*, 2011).

Application of vermicompost at 5 tonnes per ha, groundnut cake at 250 kg per ha along with 4 applications of panchagavya 3% four times recorded highest plant height, number of branches, number of fruits per plant, fruit length, fruit girth and dry fruit yield of hot pepper was comparable and at par with inorganic fertilizers application (Maheshwari and Haripriya, 2008). This might be due to supplementation of organic Nitrogen, P and K along with micro nutrients besides the growth promoter's effect of vermicompost (Jasveer singh *et al,* 1997).

Soil enzymes such as dehydrogenase activity are one of the indicators of soil fertility. Naseby and Launch (1997) considered that, enzymatic determinations are more useful than microbial measures. The dehydrogenase enzyme is involved in the respiratory chain of micro organisms and often used as a parameter to evaluate the overall microbial activity of soil (Serra-Wittling, 1995). Dehydrogenase activity was found to be significantly higher with FYM equivalent to RDF + FYM and control (Recommended dose of fertilizer only) and with liquid manures it was highest with application of beejamrutha + Jeevamrutha + Panchagavya. Increased dehydrogenase activity in liquid manure treatments might be due to presence of naturally occurring beneficial micro organisms in panchagavya that improves soil quality (Xu and Xu, 2000). Jeevamrutha contained higher microbial load which multiplies in the soil and act as a booster to enhance microbial activity in soil (Palekar, 2006 and Devakumar *et al*, 2008). Higher uptake of NPK were observed in chilli when liquid manures i.e., beejamrutha, jeevamrutha and panchagavya were used with FYM (Chandrakala. *et al,* 2007). Boraiah (2013) has observed increased capsicum yield with application of jeevamrutha and panchagavya and with increased FYM levels. Higher availability of nutrients might be due to build up of soil micro flora resulting in increased enzymatic activity. Increased nutrient uptake with foliar spray of panchagavya was ascribed to increased biological efficiency of crop plants and creating greater source and sink in the plant system (Boomathi *et al*, 2005).

In preliminary studies conducted during 2008–09, (Anon, 2010) there is need for producing liquid organic manures in bulk to meet the high crop demand. The bio-digester is used to prepare liquid organic manures in large quantity using animal waste, crop waste, weed and all other permissible organic nutrient sources. Further, studies carried out during 2011 and 2012 revealed that the bio-digester liquid manure (BDLM) varies in its composition: 0.2 to 1.05 per cent N, 0.06 to 0.81 per cent P_2O_5, 0.05 to 0.65 per cent K_2O and besides it also contained other nutrients *viz*., Ca (42 to 54.1 mg/l), Mg (10.9 to 12.6 mg/l), S (0.32 to 0.48 mg/l), Zn (211 to 214 ppm), Cu (20.1 to22.3 ppm), Mn (43.8 to 45.9 ppm) and Fe(22.2 to 23 ppm). Further, at Balajigapade agricultural research station after enriching bio-digester liquid manure with Pongamia cake, castor cake and neem cake, nutrient content of bio-digester liquid manure were raised. It enhanced Nitrogen (0.43%), Phosphorus (0.28%), Potassium (0.66%), Ca (2.0%), S (0.21%), Mg (0.73%), Fe (6325 ppm), Mn (522 ppm), Cu (42 ppm) and Zn (68 ppm) content. Siddaram (2012) reported that application of FYM 12.5 t ha^{-1} along with bio-digester liquid manure equivalent to 125 kg N ha^{-1} for aerobic rice and FYM 10 t ha^{-1} with bio-digester liquid manure equivalent to 30 kg N ha^{-1} for fieldbean found to be the best organic nutrient management practices for getting higher yields under aerobic rice – field bean cropping sequence in low fertile soils. Sudheendra Saunshi (2012) reported that biodigester liquid manure contained 0.91 to 1.0 per cent N, 0.24 to 0.53 per cent P_2O_5 and 0.53 to 0.60 per cent K_2O after enrichment with poultry manure. Application of FYM 10 t + BDLM enriched with poultry manure and rock phosphate equivalent to 60 kg N ha^{-1} produced significantly superior growth and yield parameters and recorded significantly higher grain yield (3893 kg ha^{-1}) and straw yield of finger millet (7228 kg ha^{-1}).

Economics: Manjunatha *et al* (2009) reported application of FYM at the rate of 7.5 t ha^{-1} + 100 per cent RDF recorded highest gross returns (Rs. 35 551 ha^{-1}) and it was on par with the treatment FYM at the rate of 7.5 t ha^{-1} and Jeevamrutha (Rs.34 729 ha^{-1}). Prabhu *et al*. (2010) recorded highest benefit: cost ratio of 2.71 with application of 2 per cent Panchakavya + 0.20 per cent Humic acid + 2 per cent moringa leaf extract at 30 and 60 days after planting in sacred basil. Higher net returns and B: C ratio was recorded with application of FYM and coir pith compost along with panchagavya (3 to 6%) spray for capsicum. Similarly, application of jeevamrutha, cow urine and panchagavya (3 to 6%) spray to capsicum recorded higher net returns and B: C ratio during kharif 2008 and summer 2009 (Boraiah, 2013).

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Potential Demand for Organic Products/Farming in India and Abroad: An Overview

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Farming is believed to have originated in the river valleys of the subtropical regions of the world which had access to water and fertile soil where food could be grown. Over the period, several agricultural systems developed throughout the world and productivity of the crops increased manifolds. Green Revolution in agriculture which brought spectacular increases in production and productivity in the country during late sixties started showing symptoms of fatigue from the unwanted side effects on natural resources like soil, water and biodiversity and thus human health. As a result the vast areas of soil once fertile have degraded as a result of soil erosion, salinisation or a general loss of soil fertility. Water resources have been over exploited and polluted due to excessive requirement of irrigation water and intensive use of agro-chemicals for high yielding varieties. Residues of harmful pesticides in food and drinking water have endangered both farmer's and citizen's health and excessive use of external inputs consumes lot of energy from non-renewable resources.

Organic farming is a way of conserving the soil, maintaining its fertility, protecting soil flora and fauna diversity thus preventing pollution of ground water, lakes and rivers. It does not utilize non-renewable external inputs and energy. Since, no chemical pesticides are used for crop production there are low chances of pesticide residues in food. At the same time the organic products are believed to be more healthy and better in quality characteristics like taste, aroma and storage. Thus organic farming has emerged as a dynamic alternate farming system that is believed to produce nutritious food of high quality with good employment opportunities for rural population. The concept of organic farming is, however, being understood variously. To

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some it simply implies non-application of any chemical inputs, while a balanced approach suggests identifying inputs based on necessity, nature and way of production and their effect on human health and environment. In addition to this, socio-economic and ethical aspects are also required to be kept into consideration. In simple terms, it is a form of food production system where traditional wisdom and ancient knowledge are amalgamated with modern practices without much dependence on off farm resources.

Other similar systems: There are a variety of organic farming systems prevalent worldwide. Biodynamic agriculture started in 1924 by Rudolf Steiner embraces holistic and spiral understanding of nature where the farm is a self-contained evolving organism, which keeps external inputs to a minimum. In this system, biodynamic preparations are used and requirements include, among others, harmony of cultivation with cosmic rhythms, fair trade and promotion of associative economic relations between producers, processors, traders and consumers. In this system, energies from cosmos, earth, cow and plants are systemically and synergistically harnessed.

Homa farming involves agnihotra, which meant crop husbandry with the help of burning of whole rice grains mixed with cow-ghee in a copper made pyramid of a specified size, along with chanting of mantras at sunrise and sunset based on the local timing. This practice is based on the assumption that, tremendous energy is gathered in atmosphere with the holy smoke while chanting mantra and it comes back to the soil and ensure dramatic benefits to the crop growth and productivity. Panchgavya consists of five products from cow, i.e., dung, urine, milk, curd, and ghee mixed together with sugarcane juice, coconut water, ripe banana and toddy and then incubated for 15 days and stirred daily. The above mixture is diluted in 1:10 ratio with water and filtered. It is believed to have wonderful effect on vegetative and reproductive growth of plants. Bill Mollison developed the concept of 'Permaculture' in 1970s. It is a social design system that works to conserve energy on-farm promising to generate more energy than it consumes for agriculture.

Nature farming introduced by Mokichi Okada in 1936 rests on the belief in universal life-giving powers that the elements of fire, water, and earth confer on the soil. Utilizing the inherent power of the soil is the underlying principle of this farming. Ecological Farming is a labour intensive system based on techniques of crop cultivation, involving promotion of renewable source of energy (draught animal, power and electrical energy through garbage and biogas from organic waste). It also involves water use efficiency through conjunctive use of rain, tank and underground well and river water. IPNM and IPM are the essential components of ecological farming. Finally there is the Traditional agriculture. Owing to its nature, the traditional system does not use synthetic agricultural inputs. Many, though not all traditional systems, meet the production standards for organic agriculture. However, many of these systems though reported to be useful in organic crop production by many individuals and organizations are yet to be adequately researched to establish their quantitative and qualitative effects on production crops and environment.

Global initiatives: In spite of being an age-old practice, systematic efforts to develop organic farming are only three and a half decade old. In 1972 the International Federation of Organic Agriculture Movement (IFOAM) was started by bringing together all the global organizations involved in organic production, certification and promotion. The concept of organic farming took off with increased consumer interest in countries like USA, Canada, Australia and Japan. Their strong concern and interest to be supplied with wholesome, environment friendly products has been largely responsible for the growth of the sector in the West. In 1998, IFOAM basic standards for organic farming and processing were formulated which summarize methods of production and processing of organic products. The IFOAM also set up a European Union regional group for undertaking constant dialogue with the European Commission on this issue.

In 1999, Codex Alimentarius Commission of FAO formulated and adopted Guidelines for the Production, Processing, Labeling and Marketing of Organically Produced Foods. These guidelines set out the principles of organic production from the farming stage through the preparation, storage and transport, labeling and marketing of crop products. They are intended to enable member countries (including India) to draw up their own rules, on the basis of these principles, while taking account of specific national features. The same year it also embarked on an organic farming work programme, mainly concerned with promoting organic farming in the developing countries. India is a beneficiary of this programme, while Switzerland, USA, and Germany can be considered as pioneers in organic farming. In 2003, an International Task Force on Harmonization and Equivalence in Agriculture was launched in Nuremburg, Germany. This is a joint initiative of FAO, UNCTAD, and IFOAM. In 2005, EU's revised draft was circulated to member countries.

Indian initiatives: In traditional India the entire agriculture was practiced using organic techniques. Even presently much of the forest produce of economic importance like herbs, medicinal plants, etc., by default come under this category. However, there has been consistent increase in the number of certified farmers in the country every year. Many Organic Farmer's Association, have taken the lead in adopting and spreading technology. Institutional support for organic production was created by launching a National Programme for Organic Production (NPOP) by Agriculture and Processed Food Export Development Authority (APEDA), Ministry of Commerce. The NPOP supports promotional initiatives, accreditation of inspection and certification agencies, and offers support to agri-business enterprises to facilitate export. APEDA has been interacting with European Union (EU), United States Department of Agriculture (USDA), Japan and IFOAM for recognition of equivalence of Indian quality assurance system. While the country follows IFOAM basic standards, it has been provided equivalence recognition by EU.

In 2004, Ministry of Agriculture, Government of India, launched a nationwide initiative, 'National Project on Organic Farming (NPOF) with a budg*et al*location of Rs. 57 crores with the objective to promote organic farming in India. The project aims at promoting organic farming through facilitating access to organic inputs, streamlining production, facilitating certification and developing domestic markets for organic commodities. In 2004–05 a National Centre for Organic Farming was established under the Ministry of Agriculture at Ghaziabad to provide institutional support and to facilitate farmers to move into organic crop production, by providing suitable logistics of knowledge and materials inputs like bio-fertilizers. The National Horticulture

Mission launched by DOAC in 2005 offers assistance for taking up organic farming of horticultural crops.

Organic farming is catching up fast with the Indian farmers and entrepreneurs, especially in low productive rainfed regions, with the increasing realization that there are no diminishing returns to the continued use of production inputs under organic regime. Organic farming could also be easily adopted in agro-eco regions like rainfed zones, hilly areas and North eastern states where fertilizer consumption is less than 25 kg/ha/year. Most of these areas are characterized with low productivity. Green manuring is practiced rarely due to farmer's unwillingness to sacrifice crops. Conversion of farms into organic production system in such areas is a real challenge worth attending. Eleven states of India have drafted policies and programme on Organic Farming. While, Uttarakhand made organic a thrust area for improving mountain agriculture based farm economy and livelihood. Mizoram and Sikkim declared the intentions to move forwards total organic farming, even without necessary infrastructure, human resources and programmes. Karnataka formulated organic policy and Maharashtra, Tamil Nadu and Kerala supported public private partnership for promoting organic farming. From the view point of commodities, India today produces range of organic products from fruits and vegetables, spices to food grains, pulses, milk and organic cotton. In addition Indian produce also includes wild harvest of medicinal, aromatic and dye plants. Some of these are organically cultivated and exported. While data for export commodities is available the data on domestic availability of organic commodities still relies on best guesses of stakeholders. Organic foods are definitely emerging, with organic retail stores, super markets and packaged deliveries visible in big cities and small towns.

Potential crops and products: Most of the area under organic farms in the world is under fresh fruits, vegetables and plantation crops. Commodities produced organically and traded worldwide are avocado, banana, pineapple, walnut, cashew-nut, vegetables, spices and most plantation crops e.g., Tea, coffee and cocoa. Among other produce, rice, cotton, sugarcane, sesame seeds, horticultural products like dried fruits, herbs, aromatic plants like vanilla and honey are also important. From a recent study conducted by Agriculture Department Western Australia various commodities identified as having excellent potential for organic production were carrots, wine, beef, wheat, sugar and canola. Other products with strong opportunities included: apples, dairy products, eggs, herbs, oranges, oats, poultry, rice, and safflower. These were followed by asparagus, banana, broccoli, fish, sunflower, grape, honey, nectarines, pear, onion, palm, and potato.

Input management: The major inputs in organic farming required to be addressed are nutrient management, insect pest management and disease management. Soil is the most important organic crop production factor. A healthy soil contains millions of organism the most important being earthworm, bacteria, fungus, algae and protozoa. These main macro and micro organisms help to decompose organic material and build up humus. Earthworms dig tunnels which encourage deep rooting of the plants and good aeration of the soil. Micro-organisms act as bio-fertilizers and bring the insoluble and bound forms of nutrients into soluble forms. Some microbes also control pests and disease organisms affecting the roots of crops. It is important that soils are harnessed properly to maintain proper yield and quality of produce under organic system. Farmers can improve the fertility of soil by various management practices which include soil cultivation and tillage, use of green manure and cover crops, mulching, crop rotation and mixed cropping, appropriate tillage, sound nutrient management strategies and protection of soil micro-organisms etc.

One of the major ingredients of nutrition in organic farming is compost which is the result of bioconversion of heterogeneous organic substrates under controlled conditions. It offers several advantages such as improved soil texture and fertility, biodiversity, higher productivity and safe environment. A wide range of composting technology is available; the choice of composting methods depends on the substrates. Traditional methods are based on passive composting approach, which involve stacking the material in pits or heap to decompose and take longer time (1–2 years) for the final product. The rapid composting involves pulverization, addition of water, mechanical stirring, aeration and use of microbial inoculants. The prepared compost should have no particles of the original residue present.

The organic matter content of the compost should be at least 80% (on oven dried basis), moisture content between 30–35%, water holding capacity of (150–200%), and a pH 5.5 to 6.5. The nutrient content would vary depending upon the raw material used for composting, however, 1.0 to 2.5% N, 1.0 to 1.5% $P_2 O_5$ and 1.0 to 1.5% K_2O is ideal composition of the compost.

Phosphate rich organic manure (PROM) is prepared by using indigenously available rock phosphate, cattle dung and farm waste etc. A range of diverse types of substrates viz., paddy/wheat straw, farm wastes from sugar or fruit juice industry, FYM, oil cake, green manure, distillery waste etc. are used for preparing PROM. Vermi-composting refers to ex-situ conversion of degradable organic residues into nutrient rich composted material for external application by the activity of selected species of earthworm. This technology allows quick transformation of substrate/organic residues/waste into mineral-rich compost (vermin compost) that could readily be used in the field. Vermi-compost is highly mineralized organic manure based on off-soil earthworm action. Then there are biodynamic preparations. Cow dung forms the basis of various biodynamic preparations. The following biodynamic preparations are used for nutrient management which includes Cow Pat Pit, Biodynamic Composts, Liquid Manures, BD 500, BD 501 and Vedic Preparations. In addition several bio-fertilizer preparations are now available which can effectively reduce the requirement of fertilizer as well as to some extent, the pesticides by inducing plants tolerance to certain diseases and pests.

Safety and quality of produce: There is a growing demand for organic foods primarily driven by the consumer’s perceptions of the quality and safety of these foods and to the positive environmental impact of organic agriculture practices. However, the organic label should not be considered as a health claim as it is only a process claim. It has been demonstrated that organically produced foods have lower levels of pesticides and veterinary drug residues and in many cases lower nitrate contents. No differences have, however, been established in terms of organoleptic quality between organically and conventionally grown foods. Reviews of organic vs conventional product sensory analysis studies have reported results that do not clearly substantiate claims of superior organic product tastiness. There is, therefore, scope to generate reliable information on the quality of produce generated on organic farms in future studies. There are, however, claims that food produced by organic methods contains a better balance of vitamins and minerals than conventionally grown food. However, there is no clear scientific evidence. Even quality after storage has been reported to be better in organic products relative to conventional products. To reap the desired economic gains from organic farming in the global market strict phytosanitary measures have to be followed. To achieve this, weak links in the certification system have to be identified and removed. These are also needed for proper grading, packaging, and storage of organic produce before marketing. There is thus need to set up laboratories to monitor the quality of organic produce so as to prevent the sale of sub-standard material to promote confidence in organic produce.

Marketing opportunities: Since mid1990s, the market for organic foods has been expanding rapidly and retail sales have been increasing. However, to create the domestic market not only steady supply of organic produce is missing but there is also lack of awareness among consumers. Organic producers are looking for the market to get good price and quick sales but are only partially successful. The organic retailers are looking for constant supplies, especially of fruits, vegetables, and food grains, which they do not know from where to get, and the prospective organic consumer does not have an easy access to organic products so far. In Asia, while most sales take place in Japan, other countries are witnessing a rapid expansion of their organic market. These countries include China, India, the Republic of Korea and Singapore. The main markets of organic produce or products are the United States, followed by Germany, the United Kingdom, Italy, France, Switzerland and Japan. The fruit and vegetables rank first in total organic sales and offers opportunities for developing counties.

Organic farming and biodiversity: Organic farming increases biodiversity at every level of the food chain – all the way from lowly bacteria to mammals. This is the conclusion of a review of studies from around the world comparing organic and conventional agriculture. The study reviewed data from Europe, Canada, New Zealand and the US. According to the researchers, organic farming aids biodiversity by using fewer pesticides and inorganic fertilizers, and by adopting wildlife-friendly management of habitats where there are no crops, including strategies such as not weeding close to hedge, and by mixing arable and livestock farming. Mixed farming particularly benefits some bird species. One of the reviewed studies from the UK also points to benefits for bats.

Organic agriculture in context to Indian farming: A lot of debate has been going on about various aspects of organic farming in India at various forums. The total arable land in India is about 144 million hectares. Out of this only 35% land is irrigated and remaining 65% is mainly rainfed. In the rainfed regions, fertilizer use is very low and in most of the areas negligible amount of fertilizers is used or organic manures are used as source of nutrients. Similarly in north and north-eastern region of country where low quantity of fertilizers and pesticides are used, there is scope and opportunity for continuing organic farming for improved production and quality through suitable interventions. About 18 million hectare of land is estimated in North-East for exploitation under organic production. There is thus ample scope in India to produce organic produce through a cluster approach in the above mentioned areas of the country without loss in productivity.

Since organic farming relies on the inputs produced at farm, it cuts down the cost of inputs. Further, the expenditure on pesticides is reduced as pest management is addressed through preventive and botanical and microbial pesticides which are cheaper. Some times higher input costs due to the purchase of compost and other organic manures have also been reported. The production or yield in most of the cases is at par with the conventional system after the few initial years while the price premium is related with organic farming. Organic agriculture thus offers comparative advantages in areas with less rainfall and soil fertility levels. The products are sold at a premium over the conventionally grown products.

Benefits of organic farming: The various benefits of organic farming all over the world and small farmers in India (http://www.organicfacts.net) are:

High premium: Organic food is normally priced 20–30% higher than conventional food. The premium is very important for a small farmer whose income is just sufficient to feed his/her family with one meal.

Low investment: Organic farming normally does not involve capital investment as high as that required in chemical farming. Further, since organic fertilizers and pesticides can be produced locally, the yearly costs incurred by the farmer are also low. It should also be noted that while shifting from chemical farming to organic farming, the transition might be costlier.

Traditional knowledge: Small farmers have abundance of traditional knowledge with them and within their community. Most of this traditional knowledge cannot be used for chemical farming. However, when it comes to organic farming, the farmers can make use of the traditional knowledge. Further, in organic farming, small farmers are not dependent on those who provide chemical know-how. In India, more than 80% of the farmers are small and marginal farmers and many small farmers are practicing organic farming, however, since they are unaware of the market opportunities they are not able to reap the benetits of organic farming mentioned above. Hence, necessary steps need to be taken to address this issue.

Limitations of organic farming: Though there are several benefits in adapting the organic farming, certain barriers hinder the adoption at farmers' level. Although the land resources can move freely from organic farming, they do not move freely in the reverse direction. Initial crop loss is one of the major constraints while transforming the land from chemical to organic agriculture. The bio-control agents may take 3 to 4 years to build up in a crop eco-system. Moreover, their rate of success is in general, more in horticultural ecosystem but, in annual ecosystem their establishment is always questionable. Above all, farmers may be afraid to adopt the organic agriculture without adequate support from the government and premium price for their produce. Thus, organic agriculture has its own limitations.

The limitations were studied by the Office of Evaluation and Studies, International Fund for Agriculture Development. Organic farming is labour intensive. Hence, it is beneficial for a small farmer who has abundant labour in his/her family; Organic farming may also turn out to be expensive, given the situation when a small farmer has to carry out the transition, modify the soil structure drastically or get a certification; Though a farmer can use a good deal of traditional knowledge in organic farming, since the practice is not as common as chemical farming, it is difficult for good scientific organic farming practices to be propagated to the small farmers; Since organic produce is not traded in many markets, marketing the organic produce may be difficult for a small farmer; In organic farming, soil fertility needs to be replenished with application of organic fertilizers regularly. If the organic fertilizers are not produced locally, it might be difficult for the small farmer, who would purchase the fertilizers in small quantities to obtain them from elsewhere. Further due to low economics of scale, there might be a huge transportation cost associated with the organic fertilizers obtained from long distances. It has also been observed that organic food prices are not stable and keep fluctuating from time to time. In such a scenario a low price might affect a small farmer drastically. Since the volume of organic food production is low (about 1–2% of total food production), it is difficult to implement social security measures such as minimum support price, and certification is also an important aspect of organic farming. In many cases, providing education related to necessary certifications and the guidelines that need to be followed for obtaining the certifications may be difficult. Since certification cost is exorbitantly high and inorganic input use is prohibited in the nearby areas, organic farming may not be so easy to practice by the small and marginal farmers who constitute about 80% of the Indian farming community (Fertilizer Association of India, 2004)

"A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it does otherwise. Conservation is a state of harmony between men and land."

Aldo Leopold

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Organic Farming from Farmers' Perspectives

Deepak Suchde

Farming communities have been under pressure to meet the ever expanding needs of a modern society. Modern methods of farming across the world are relying increasingly on the use of chemicals, robust machines, 'mono crop' methods, genetically modified seeds, 'industrial farming', soil-less farming, etc. While all such methods have delivered increased 'gains' over the short run, they have created (and continue to create) irreversible damage and/or adverse effects on farm and human life itself for whose benefits these methods were generated.

A few examples of such adverse effects are: toxic food production, a severe loss of soil fertility, contamination of water resources, disturbances in the natural cycles and biodiversity of farms, dependence of farmers on commercial organizations for seeds, fertilizers, pesticides etc. These effects have surfaced after a considerably prolonged use of many farming innovations. All these effects have paralyzed the farmer and his farm today in more than one way. Based on these growing concerns in 'modern' agriculture, the agricultural institutes are now shifting their methods to more natural ways of farming.

Among all the methods of farming available today (traditional/conventional/contemporary etc), the only method which ensures holistic success (as mentioned in the following paragraphs) for a farmer, his farm and for the consumers of the produce is the 'Natueco' farming method. The word 'Natueco' is born from a combination of two words: 'Natural' and 'Ecological'! The Natueco method of farming is, in fact, a culture of farming based on imitating and collaborating with Nature through critical scientific methods to strengthen the produce and the ecology of a farm.

Natueco has been conceived as a holistic way to meet the needs of farming and food today. It addresses typical issues in farming like how to work in synergy with Nature without burdening it, how to reduce a farm's dependency on external

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inputs, how to work scientifically and within the local resources available in the surroundings of a farm, how to farm without harming its ecology and, at the same time, gaining the highest benefits from it, etc. The features of Natueco culture distinguish it from 'Natural Farming' and/or 'Organic Farming'.

Natueco is 'Beyond Organic': 'In natural or organic farming, farming is done trusting Nature through the empirical wisdom of the ages. In Natueco Farming, on the other hand, farming is done by knowing Nature (more and more and better and better!) through critical scientific inquiries and experiments. It is an ever growing, novel, unique, participatory tryst between man and Nature! Natueco culture and Critical Scientific Agriculture became synonymous words. The major features of scientific farming were also the basic features of Natueco Culture!' Sri S.A.Dabholkar. ('Plenty for all' section 5.1)

When we talk about the success of a farming method, let us first understand what success means to a farmer? The parameters of a farmer's success can be put forward as: (a) Generating maximum farm output from minimum input; (b) Harvesting maximum sun light per square foot area of earth; (c) Self-reliance on resources within their local availability; (d) Independence from external resources; (e) Minimum use of energy (per unit of produce) in farming; (f) Creating abundance in the ecology of a farm throughout the farm's life cycle; (g) Working to become self sufficient in terms of knowledge, resources and approach; (h) Working for the highest good of the farmer community; (i) Enjoying the five Ls of the farming occupation: Learning, Living, Livelihood, Love and Laughter; and (j) Living a rich life with grace and dignity.

Such holistic success would be achieved by a farmer by performing his/her duties in the following order**:** 1) Protecting the delicate balance of Mother Earth and her environment; 2) Taking care of the wellbeing of his/her family; 3) Offering the harvest of his/her labor to the world; and 4) Creating a model farm which is self-sustainable in all the above aspects.

Success of Natueco in terms of productivity of a farm: The productivity of a farm (also called visible productivity) is a combined effect of 'primary productivity' and 'secondary productivity'. It is measured in terms of dry-mass per hectare. The primary productivity of a farm is the key factor in determining the quality of the visible productivity (yield). Soil with good primary productivity helps in harvesting optimum sunlight. This helps in efficient photosynthesis in a plant. Hence the plant gives better yield with quality nutrients available in the crop. With these fundamental scientific requirements of a plant in focus, Natueco teaches us how to create our own soil which is called Amrut Mitti. Soil so created helps a farmer to do quality farming irrespective of the quality of the original soil naturally available on his farm. Thus Natueco farming enhances the primary productivity of the soil and establishes a firm correlation with use of energy and water as a resource.

Natueco vis-à-vis conventional farming in terms of 'farm productivity': With conventional methods of farming, our efforts have been to increase the 'visible productivity' of a farm. The 'Green Revolution' was introduced as a consequence of this mindset. The fundamental approach of the Green Revolution was to enhance the visible productivity of a farm through its 'secondary productivity'. This is apparently a sensible thing to do. However, over a long period of time, by considering the visible productivity of a farm as its only measure of success (and hence rigorously enhancing its secondary productivity), we neglected and gradually forgot about the farm's primary productivity. We derived a false sense of pride from the enhanced visible productivity of a farm without realizing the silent degradation of the soil's primary productivity! In the beginning, with conventional farming, 'visible productivity' can be easily increased by external inputs. However, over a long period of time, this impairs a farm's 'primary productivity'. We start seeing a gradual decline in 'visible productivity', even though external inputs remained the same or even increased.

Natueco science focuses completely on enhancing the primary productivity of a farm. It concentrates on enriching the Carbon value of soil, and also enhancing the quantum and diversity of varieties of microbial life found therein. In other words, it works to increase the output of dry mass per hectare per kiloliter of water consumed. In our initial understanding, working to increase the output of dry mass might appear to be a very subtle factor in farming. However, this is an extremely important variable because the energy of the Sun can only be harvested optimally if the output of dry mass from a farm is maximized.

If land is harvested at its most optimal levels of 'Primary Productivity', it will give a maximum yield per hectare (for ever) with the least input cost! Thus such farming becomes financially viable. With an increase in the Primary Productivity of the farm, farmers' dependence on external resources reduces gradually. It empowers the farmer to create a knowledge base and data base of experience on his own, and even create his/her own seed bank. Such farming, thus, becomes sustainable for a longer period of time. Today's markets of the supplements for conventional farming unfortunately do not offer anything to enhance the Primary Productivity of a farm.

Natueco farming emphasizes 'Neighborhood Resource Enrichment' by 'Additive Regeneration' rather than through dependence on external and/or commercial inputs. It addresses the four main determinants of crop yield: 1) Soil: Creating soil with the best primary productivity, by recycling biomass and by establishing a proper energy chain; 2) Roots: Focusing on the development and maintenance of feeder root zones of the plant for efficient absorption of the nutrients in the soil; 3) Canopy: Focusing on harvesting sunlight by proper management and cultivation of the plant canopy for efficient photosynthesis; and 4) Minimizing External Resources: Focusing on minimizing the use of external resources including water; and reducing dependency on the secondary productivity of the soil.

Natueco Farming maximizes farm output with a minimum input of energy. Its goal is to maximize organic Carbon or biomass of the soil (factors of Primary productivity). Certain points of focus in the Natueco system are: (a) The mother (soil), and not the child (plant); (b) Long term and strategic thinking, rather than short cut/short term actions; (c) Developing holistic and positive values in farming as an occupation; (d) Uniting the community of farmers; (e) Self-sustenance and self-learning; (f) The creation of a localized 'prosumer' society (i.e., a closed society of producers and consumers); and (g) Enriching biodiversity. Important components of a Natueco farm are the creation of Amrut Mitti, and a Knowledge/Data base; seed treatment; enhancing biodiversity and live fencing.

Prosperity with equity: Today, the sharing of equity in agriculture has been reduced to the practice of a few land owners giving their farm land on contract to farmers (for one or more seasons) and getting returns in the form of a certain percentage of the production. The wealth and prosperity that abound in society today are the outcome of the progress of modern science. But till today, the benefits of the best of modern science have failed to reach to the last person. It is always essential to hand over the essence of science to people at the grass roots. With this self-earned knowledge, they can build their own techniracies (technical literacy) to create their desired 'Plenty and Prosperity' within their local neighborhood. Their dependence on the Government and other institutions will reduce this way. Prosperity with equity would gain its true meaning then. Prof. Sripad Dabholkar, the founder of Natueco Science, had said that true prosperity can self-sustain itself, only if it is inclusive and equitable in nature. An equitable farm reduces poverty and inequality by ensuring a systematic re-distribution of the economic benefits of development. Prof Dabholkar suggested every farmer to bear a child's curiosity towards his/her farm. Each one of us as a child is gifted by nature. We grow up with learning through why/how questions on every observation of ours. The same curiosity should be re-inculcated in a farmer. As a child's constant prattle on 'Why', 'How', 'How much', 'Why not this way' etc. gets him/her well acquainted with things, a farmer too should get acquainted with his/her farm and its surroundings through continued curiosity. The spirit of sharing the equity, sharing knowledge, sharing database is generated from this curiosity.

The success of a Natueco farm can also be assessed in terms of the quality and quantity of the farm produce.

Quantity/yield: Some notable examples include rice (40 quintals/acre, without flooding the field!), wheat (30 quintals/acre), soyabean (20 quintals/acre), groundnut (24 quintals/acre), tomato (120 tons/acre), sugarcane (100 tons/acre), coconut (400 fruits/tree/annum on maturity), grapes (16 tons/acre), banana (45 kg/plant), papaya (180 kg/tree/annum), potatoes (40 tons/acre), etc. All these yields start accruing from the very first year of operation.

Quality of Natueco soil: This was analyzed by ICRISAT and it was found that the organic Carbon percentage of this soil was at least 3 times more than normal soils. For the presence of micronutrients in available form, in Natueco soil the following was noticed: boron and sulphur 3 times; iron 1.5 times and zinc 6 times more than the normal farm soil. In addition to these elements microbial biomass C, microbial biomass N and dehydrogenase were present in higher percentages indicating the presence of very good total population of microorganisms in the Natueco soil.

Quality in terms of the nutritional value of food from Natueco farms: Bottle gourds from a Natueco farm and from the general market were analyzed for nutritional value. In addition to the presence of 5 times more protein and 20% more Calcium, the presence of magnesium, iron and vitamin B12 was noticed in the bottle gourd sample produced on the Natueco farm. Natueco culture teaches us that agriculture is not only a cultivation of flora and fauna but it is also a cultivation of prosperous culture, sharing of knowledge, labour, resources, etc. Every individual farm contributes to the Nation's prosperity providing a modern lifestyle with five 'Ls' and leading consciously to a scientific and holistic life forever. Going beyond mere short term commercial gains on farms to wholesome success (all-round success, in all relevant dimensions of farming over the short and long run), Natueco farming is a success story awaiting its rapid adaptation worldwide. It has the potential to bring about deep changes in society and the well-being of the human race and the nature together.

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B N Nandish

In 1998 I started farming in a conventional way; my only aim was to get more yields using machinery and chemicals. But by the year 2000 I was fed up with lots of regular unnecessary work, labour problems and inputs. I was looking for easier and simpler ways to cut man power and inputs. I came across an article on natural farming about the Japanese farmer Masanobu Fukuoka. I felt Fukuoka's way was the truthful, easier and beautiful way to seek permanent solutions and to overcome the problems of labour, input, energy and time. Health benefits, environmental concerns, premium price for organic products, organic farmer badge, all followed later.

A to Z of sustainable farming practices: Sustainable farming is expected to be ecologically sound, economically profitable, and socially just and humane. Each and every practice is based on useful knowledge of the way things work. Nothing is superior, fine and final; they can be used according to one's likes, needs and resources. Some farming practices – where sustainability is a primary goal – are listed below: Agrobiodiversity; alternative farming; biodynamic farming; Biointensive farming; conservation tillage; ecological farming; farmland preservation; holistic resource management; integrated farming systems; low external input sustainable agriculture; nature farming; organic farming; permaculture; regenerative agriculture; whole farm planning; zero tillage.

Legume culture: Over a hundred green manures are being used along with, before and after the crops on my farm. For all my crop demands and agricultural problems, I found and will seek solutions only through green manures. Mine is green culture instead of the usual clean culture. This is 'legume culture' for sustainable agriculture.

Legume-logic: Nitrogen is the first, necessary, nutrient required in a large quantity by plants. The atmosphere contains

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78% of Nitrogen, so using leguminous plants to fix free of cost biological Nitrogen is the logic. There are over 550 genera, 12,000 species of legumes in the world. There are plants for all seasons and zone conditions in them – some are annuals, bi-annuals and perennials. Apart from fixing biological free Nitrogen, these herbs, shrubs, twines, creepers, bushes, and trees, they provide food, fodder, timber, fuel wood, natural dyes, medicines, wind breakers, live fences, pest repellents, trap plants; highly toxic, fire resistant, biomass; oil seeds; slightly toxic, nematicidal properties, fibres, erosion control, gum, and make possible alkaline land reclamation.

Green manuring – cover crops: In nature where there is no human interference we can see monocot and dicot weeds in 2:1 ratio. The diversity and biomass are the index of the soil; there the soil works for itself. Clean culture destroys diversity and results in hardy perennial grasses. One or two varieties of monocot weeds or grasses do not enrich the soil faster or increase the crop yield. Destroying weeds is impossible; it is a nonsensical job and is also positively harmful.

Roots till the soil: Roots are the vegetal macro organisms of the soil. They play more important role than animal macro organisms of the soil like earthworms and termites. Some tree roots go as deep as the tree grows above the ground. They penetrate hardened layers deeper and with more volume than the aerial part of the tree. Tap roots pump up the nutrients from subsoil, dead roots leaves organic matter and root passages helps flow of air and water. Tubers make large holes and field mice dig tunnels in a roller coaster way like no man-made machines can do. Cultivation is to remove the weeds and to aerate the soil, but cover crops will do for the same purpose.

Diversity feeds all the creatures: Apart from biological Nitrogen fixation through legumes, gini grasses host VAM fungus. Niger, cockscomb are potash rich, eupatorium carries boron. Likewise each and every plant carries different nutrients and has medicinal properties. Diversity of plants becomes host for a variety of microbes, macro organisms, bees, birds and all other creatures. Diversity develops the food chain, creates ideal micro climate, variety of food for emerging insects and fungus. Plants require less irrigation due to development of humus in the soil.

During November and February, seeds are available along road sides, wastelands, river-pool sides and forests. Seeds brought by insects, birds, animals have very good germination and vigour in growth in comparison with our broadcast seed. So if we provide some food to these creatures, they bring back a lot of things to our farm. Plants like Castor, *Hibiscus*, Sunhemp, Lablab, Velvet beans, Indigo, *Lantana*, *Sorghum*, *Cassias*, just to list a few, have trap-catch-host ability, control-repels pests and some have nematicidal properties. Fast growing shrubs can be sown in the alleys, between the rows, as a wind breaker and to prevent the sun scorching the plants.

Climbing creepers produce profuse biomass and act as a first floor for live mulching. Leaves yielding milky sap and having a disgusting and bitter taste, serve as a live repellent for cattle and wild animals. Some are slightly toxic so animals will not eat them. A few others are highly toxic and can kill sheep in a few hours and cattle in days. Fast growing shrubs, trees and thorny species can be used for live fencing. Plants like *Stylo scabra* can be used along forest borders as a fire retardant. Every plant has its own characteristics and we must make use of them according to our need**.** In live mulching, roots till the soil, enhance aeration, and act as catch plants, host microbes, fix biological Nitrogen. These are added benefits when compared with straw (dead) mulching. Fertiliser, insects, fungus, weeds, cultivation, water, aeration, food, micro climate, humus, erosion, fencing, fire, wind, sun scorching, snails, alkalinity, rats/crabs and more were all my questions and I got solutions for them all. Now you dream; green will deliver. Cover crops always should feed our homes, provide food for birds and animals. Income from these must meet the expenses of the farm. Green mulches minimise maintenance, labour and time.

In green language, on entering into an ideal farm, we should always feel air conditioned atmosphere, soil, aroma, smell of flowers and fruits; colourful creatures; varieties of seeds, vegetables, and fruits to taste; the noise of bees, pests, birds, animals as in the forest: tak tak – zeakh... zeakh........ In one sentence, 'You should feel all your senses alive and fed.'

Yield factors: Growing crops according to our agro climatic conditions and seasons is important. Varietal selection, the sowing period, practices, layout, soil, spacing, alignment, seed rate, seedling age, sowing-planting depth, seedling numbers, aeration measures, water management, and finally manuring aspects, these are the priorities to look for. The average yield of our surrounding villages is to be targeted, not of other areas. The final output tonne or yield of the end product is the yield statement rather than the number of bags or weight of the produce we grow. For example, in the improved variety of paddy with high polished rice, we get 55 kgs of rice yield and 72 kgs of total output per quintal of paddy, whereas we get upto 82 kgs of rice in the case of an unpolished traditional paddy variety. The difference is 50%, more yield is just one factor. Dals, vegetable oils, essential oils, murmure, poova, likewise every crop's end product yield is more important. Yield is not based on one factor alone as an indicator of how much we grow.

Profit: First, we have to draw up a list of expenses we have made on the crop. Then we have to look for the alternates of everything in the list and whether they are necessary and the returns. Each and every step needs correction all the time and it helps in minimising inputs, low external input is the key to sustainability. Local varieties always give assured average yield. Their uniqueness of size, shape, colour, aroma and taste, medicinal and other aspects has to be encashed by marketing it in finished end products. Cash returns may delay for a season but the major profit lies here instead of growing the same crops more times a year. Organic label enables a premium price for the product. The unique, peculiar, rare, fanciful, wild, natural, medicinal and other qualities of the product get several times more price than the normal market. Finally, money left in our pocket is more important than what we receive from the sale. These factors help us to get profits several times more than the habitual way of doing things. In trade, commerce, industry they look for profits in percentages whereas here, several times in field crops, the profit comes in just in one season. Agriculture is the most profitable job if we take to it and look at it in an intelligent manner.

Climate change: It is the order of the day; nature is balancing of its own. It is correcting our mistakes but we need patience to understand what is happening. Science can produce no good without evil; science can be used to understand nature, not to go alone apart from it. When we move with nature we get more answers in the place of just one. Latest example of mine in this year is this: we transplanted IR-64 improved variety of paddy in 9 acres and two other traditional varieties of paddy in 4 acres. Due to the infamous Phailin cyclone's low pressure effect, it rained on my farm on 22nd October from 2 to 2:30 PM and on 23rd October 2013 from 11:30 to 12 AM. All the three varieties were at the stage where 65% upper part of the panicle had crossed flowering and remaining 35% below was yet to be pollinated.

Rain and foliar sprays while flowering during 9 am–3 pm disturb pollination, resulting in empty grains. We lost yield of flat 35% in IR-64 variety and 10–15% in traditional varieties. Paddy flowers open in the sunlight by 9 am and close by 3 pm. The improved variety developed by crossing. These varieties may be unable to close down in cloudy weather but local or traditional ones can sense cloud or rain and close down the flowers. This is called genotype-environment interaction. Whatsoever the reason the result is this. Climate change is the biggest challenge that we need to seriously look at. Sunlight, temperature, humidity, atmospheric pressure, snow, mist, fog, cool air, rain, lightening, thunder bolts and seasons – any slight changes disturb the entire system. Do we have any technology to establish control over on this and is there any wealth bigger than the seasons?

Observation-application-documentation: History of our place, talks with elders, interaction with professionals of different fields in a village, reading, walking around in nature, helps in lateral thinking and in visualising the things to adopt. An organic farmer deals with all living beings, he needs to move along with nature so he needs a lot of common sense to understand more than others in other fields. Many other fields deal with single subjects or with man-made dead objects. On every occasion, we need to shape up the things, apply our thoughts, then observe and monitor the things. In this process, curiosity is generated and by unknowingly will involve deeper insights, which leads to open all our senses to perception. Daily documentation of weather, work, expenses, observations, stories, notes, summaries helps us to know better, to recall, to coin side, to compare, to assume the things for fine tuning. Observation-application-documentation helps us to move further by knowing the things in depth or else one will follow copy and paste methods.

Food security and nutritional quality: We have forgotten that food acts as a medicine. Fresh, seasonal and local foods are missing on our plates. Actual size, texture, shape, colour, taste, aroma are all forgotten by everybody. The demand for white, clean, clear, glossy looks changed all other things. Refined, deodorised, bleached, polished plays a major role in removing nutritional quality and in consuming more quantity which leads to insecurity. Nowadays more and more chemicals are added at the time of processing than at the time of production. This is more dangerous to our health and environment. Agriculture is playing a major role in polluting our ecosystem. How we use the product is important than how to grow or how much we grow. These changes in food are the root cause of serious disorders in the health of the people. Now, some have started recalling traditional foods, with traditional methods of preparation. Non-agriculture sector people who live even in metros have started growing in windows, terrace, balconies, in empty sites, replacing lawns with fruits and vegetables. Uncultivated fruits, weeds as leafy vegetables, wild vegetables, and tubers are in great demand. Today millets have arrived in the rich man's plate. The diet, quantity, quality, all will get changed in the near future. The whole scenario that we are looking at will change and demand for some few cereals, pulses, vegetables will in fact decrease, which is the thumb rule of gauging food insecurity.

Adoptability and economic feasibility: Somewhere the hunger should start or we need to create. First government subsidies needs to be removed to change the pattern. There are many options for going into eco friendly practices. Mind preparation is more important than man-power, money and machines if one wants to switch over to organic. We can get average yield on our farms even during the first year of conversion into organic, results lies on how much we understand the subject. It's not the failure of the practice. My inputs rose to three times but income rose over ten times in the last ten years of paddy cultivation. Organic farming is an opportunity to be with all living beings and to feel with all our senses.

A P Chandrashekhar

It is very difficult or impossible to quantify success in organic farming. And it is not useful either, if I cannot define success as well as organic farming. It is natural that everyone may have different definitions for these words (concepts) according to their taste, space and time. It cannot fit into a single exclusive frame as the modern so-called scientific temperament expects. Science tries to look at the truth in repeatability, but nature's truth is changeability, diversity and decentralization. Therefore, if anyone tries to derive a 'package of practice' for organic farming, it will be a total waste of time and a failure. Similarly, if anyone tries to measure success in terms of money, it will be totally unnatural and it becomes unsuccessful.

The success lies in contentment and satisfaction. Content lies in meeting our needs and demands. If our demand is limited to our needs, content can be achieved easily, hence also success. In nature, money is not the demand. Work is the demand. Matter is the demand. Only work can produce matter, not money. Money is also matter, which requires a lot of work to earn and that leads to waste of matter. If we become intelligent enough to convert work into matter, without mediums like money or master or scientist, it is always better. Money is the indirect, lengthy, laborious process to acquire our needs. Nature and even science and economics do not expect this. Reduce; reuse and recycle are the truths everywhere. Hence, producing our needs by direct work is the definition of organic.

There is a lot of difference between the needs of the body and the needs of the mind. We can satisfy our bodily hunger easily but the hunger of the mind is unlimited. It can accommodate any amount of comforts and commodities. The stomach vomits if there is excess of food. Recognising and becoming less consumeristic is organic.

Let us take the example of a coconut orchard. People do not grow coconuts for their need. How much coconut is needed

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for a family for cooking? How many cooking processes have they learnt and are practising in this modern hotel and bakery managed lifestyle? I look to organic in strengthening our kitchen. By using coconut alone or in combination with other foodstuffs, one can make hundreds of dishes, either raw or cooked. Sabji, sambar, dosa, idli, roti, biscuit, chocolate, payasam, ice cream, tea and coffee are some of the result of the basics of cooking and we can extend this to any length. People know the usage of tender coconut, raw coconut and copra. But usage of sprouted coconut in bun and budded coconut tree in bread also has enormous taste value, food value, health value and even monetary benefits. Along with this, coconut has many curative properties. Even the dry, hard coconut shell can be used for cooking as well as in medicine. We can extract antifungal agents from the coconut shell. The shell Carbon can cure acidity and toothache. Low value, small and mite diseased coconuts can be grown into large plants and can be used for fodder and manure. This small knowledge adds high value not only to our coconut but also to us. But as farmers are non organic, they cannot be exposed to these truths. Organic is the capacity to see nature through bare eyes removing the goggles. Money, prestige and laziness are distorting goggles.

People think that by so many techniques, operations and applications (either chemical or organic), they can increase coconut yield and by selling them they can accumulate good money and purchase all their needs and comforts. But farmers fail to observe the fact that with increase in coconut yield, the input demand of the garden increases and also the comfort demands of the farmer. As already explained, the increase in coconut yields decreases the demand and obviously the market falls.

To understand and satisfy ourselves with the laws and limits of nature is organic and not merely applying organic manure. Ploughing and manuring are some of the practices of maintaining the coconut orchards by which, people think, the yield increases. But this is not true. Huge amount of money is wasted in ploughing which also leads to soil erosion. Let innumerable numbers of wild, local plants come on their own. Appreciating and observing the natural process of an area becoming a forest is one of the ways to become organic. Please observe the forest wherein there is no need for ploughing, manuring, sowing, watering, nurturing and medication for the growth of plants. But all this happens automatically. This happens because of plant intensity and diversity. I really wonder why people panic so much because of growth of weeds!

Weeds are one thing the use of which is unknown. But no doubt, all weeds have one or the other use. They are designed with a purpose or atleast we have to appreciate their capacity to photosynthesize by which they convert solar energy into matter, adding fertility to soils, preventing erosion of soil and so on. Our success and organicity lies in our understanding and utilization of weeds. A farm can be called a farm, if and only if, it is like a forest. On the contrary now, our modern farms are like playgrounds.

We have more than 2500 plant species in our 13 acres of land near Mysore where the average rainfall is only 25 inches. But nature has the capacity to form a forest everywhere. It is the characteristic of nature to become an adult by forming a forest. Hence now our farm is like a forest. We have big and small trees, bushes, herbs, shrubs, weeds, tubers, creepers, crawlers in various dimensions. They have increased the beauty of our land and have decreased our water and electricity demand. We do not add manure at all. Our farm is rich with about 300 leafy vegetables, about 50 root vegetables, about 200 fruit varieties, hundreds of vegetables and we have thousands of cooking techniques with us. We produce more than thousands of value added products like juice, jam, dry fruits, soaps, oils, powders, spices, medicines which add value to our life as well as money.

According to my understanding, organic is the process of proper utilization of our organs and also the organs of nature. All the animals and plants are the organs of nature. We humans are also one among them. It is clear that increasing plant intensity and diversity is organic. More and more utilization of animals in farming is organic. To understand that we humans are also animals and there is nothing special is organic. If at all there is something special with us, it is highly flexible legs, work efficient hands and analytical mind. Proper utilization of our legs, hands and mind is the crown to organic. But the pitiful thing is that we lost all these special capacities and degenerated as slaves to life-less money and machines. Hence there is monotony and melancholy everywhere.

Syed Ghani Khan

Agriculture is something more than a livelihood for our family. I started my life in agriculture when I was studying in the third standard, growing vegetables at home for consumption. My ancestors also belong to agriculture families. In 1991, when I was studying in the tenth standard, my father suffered a paralysis attack. I assumed some of the responsibility for the family agriculture because of that. Finally, when I enrolled for my Bachelor's degree, he suffered a severe brain haemorrhage. I had to discontinue my education because I was the eldest son in the family. Nonetheless, my aim was to get my degree. I joined night college but could not study because during day time I had to work in the field and in the evening had to travel to college in Mysore from our village. I finally managed to complete my Bachelor's degree in History, Urdu, Archaeology and Museology from Maharaja College in the year 2001.

Meanwhile, our garden was full of mango trees which had been planted by our ancestors. There are nearly 120 varieties which are different from the improved varieties we have today. We have mangoes which taste like mousambi (citrus fruits); or look like apples; some have very little sweetness (good for sugar patients) and there are other different types as well. Each one is different from the other.

My paddy journey started with conventional farming with hybrids and improved varieties. In 1998, I started the conservation of paddy with 40 grains which were unknown to me. I came to know the names of the paddy in 2001. Since then I have continued my paddy collection by visiting different places throughout Karnataka and India with the help of Sahaja Samrudha and Save Our Rice campaign. Now, I am conserving more than 700 varieties of paddy from India and abroad. I have varieties from Thailand, Myanmar, Pakistan, Malaysia and we are conserving paddy varieties which are suitable for dry land and deepwater conditions; varieties because seeds are the future of our next generation, especially the traditional varieties which

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are best suited for our climate. No genetically modified varieties and hybrids can sustain in our climatic conditions.

My aim is to give away the best of what we are conserving in our field. We are distributing these traditional best quality seeds to the farmers. Till today we have distributed seeds to more than 5,000 farmers. My aim is to give away these good quality traditional seeds. Since I have studied Archaeology and Museology, I wish to turn our garden into a museum. I have accordingly started India's first traditional paddy museum on the first floor of our house. I have also started a trust to save the traditional varieties of seeds.

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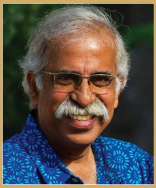

Dr. CLAUDE ALVARES

Dr. Claude Alvares did his Ph.D. at the University of Eindhoven, Holland in 1976. He has been involved in the promotion of organic agriculture since the mid–eighties. He was a founder member of APIGR then ARISE. He now heads the central secretariat of the Organic Farming Association of India (OFAI). He is the author of several books on organic farming including The Organic Farming Sourcebook, The Organic Farming Reader. He edits The Living Field on behalf of the association. He is also the Director of the Goa Foundation.

Dr. ASHOK KUMAR YADAV

Dr. A K Yadav, M.Sc. Ph.D. from Rajasthan University started his careeer as microbiologist and over the years was known as Biofertilizer expert and contributed to the development of biofertilizers technology, instrumentation, industrial fermenters designing and formulation development. During his association with Biofertilizers he served State Government of Rajasthan, NAFED and then Government of India as Regional Director of Regional Biofertilizer Centres at Bhubaneshwar, Imphal and Nagpur. With the launching of National Programme on Promotion of Organic Farming, he became an organic farming enthusiast and contributed to the development and promotion of organic farming in the country, first as Regional Director at Nagpur and then as Director at National Centre of Organic Farming. As Director, NCOF he was member to various policy planning committees of central and state Governments. Launching of farmer groups centric certification system known as PGS-India is one of the notable policy initiative of Dr. Yadav. After his superannuation from Government he is associated with many organizations and is contributing to the growth of organic farming in the country. He has written more than 12 books and several papers on biofertilizers and organic farming. Currently he is also the President of International Competence Centre for Organic Agriculture, a known organic agriculture promoting agency in the country.