Invited Paper

Status of Organic Farming and Research Experiences in Rice

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Abstract

India has tremendous potential to become a major exporter of organic rice in the international market. During 2008-09, around 5630 MT of organic basmati rice was exported from India through APEDA. Considering the importance of organic farming and to generate comprehensive scientific research data, field experiments were conducted for five years (2004-05 to 2009-10) covering ten crop seasons on a deep black clayey vertisol (Typic pellustert) at the Directorate of Rice Research farm, to compare organic and conventional farming systems with fine quality rice varieties. During the first two years, *kharif* grain yields in plots with inorganic fertilizers were superior to those with organics by 15-20%. However, during later years, grain yield improved in organics plots to parity with those with inorganics. During *rabi*, plots with inorganics were superior in grain yield to those with organics for the first four years but both the systems were on par during the fifth year. Most of the grain quality parameters were not influenced though moderate improvement in nutritional quality (protein, phosphorus and potassium contents) was recorded with organics, especially in brown rice and polishing reduced the quality improvement. In general, there was no significant difference in the insect pests incidence between the systems in most of the years with an exception in a few years where decreased pest incidence and increased parasitism was observed with organics compared to inorganics. Organic system significantly improved the soil quality and the sustainability index of the soil was maximum with organics (1.63) compared to inorganics (1.33) after four years of study. Benefit cost ratio was less with organics (by 26%) compared to inorganics in the first year which improved with organics over inorganics (by 22%) at the end of fourth year.

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Increased/indiscriminate use of chemical fertilizers and pesticides during green revolution period resulted in several harmful effects on soil, water and air causing their pollution. This has reduced the productivity of the soil by deteriorating soil health in terms of soil fertility and biological activity. The excess/indiscriminate use of pesticides has led to the entry of harmful compounds into food chain, death of natural enemies and development of resurgence/resistance to pesticides. Out breaks of insect pests have occurred after insecticides were over used and out break of brown plant hopper (BPH), *Nilaparvata lugens* in rice is an example of this over use (Wang *et al.* 1994). Hence, enhancement and maintenance of system productivity and resource quality is essential for sustainable agriculture. It is believed that organic farming can solve many of these problems as this system is believed to maintain soil productivity and pest control by enhancing natural processes and cycles in harmony with environment. Organic farming is defined as a production system which largely excludes or avoids the use of fertilisers, pesticides, growth regulators, etc. and relies mainly on organic sources to maintain soil health, supply plant nutrients and minimise insects, weeds and other pests.

World Scenario of Organic farming

Based on the global survey on organic farming carried out in 2009 by the Research Institute of Organic Agriculture (FiBL), the International Federation of Organic Agriculture Movements (IFOAM) and Foundation Ecology & Agriculture (SOEL), the organic agriculture is developing rapidly and is now practiced in more than 141 countries of the world. Its share of agricultural land and farms continues to grow in many countries. According to the latest survey on global organic farming, about 32.2 million hectares of agricultural land is managed organically as of 2007.

Oceania has the largest share of organic agricultural land (37%), followed by Europe (24%)

and Latin America (20%). The proportion of organically compared to conventionally managed land, however, is highest in Oceania and in Europe. In the European Union 4% of the land is under organic management. Most producers are in Latin America (Tables 1 and 2). The total organic area in Asia is 2.9 m.ha. This constitutes 9% of the world's organic agricultural land. The leading countries are China (1.6 mha) and India (1 mha). The country with the largest organic area is Australia (12 million hectares).

Global demand for organic products remains robust, with sales increasing by over five billion US Dollars a year. Organic Monitor estimates international sales to have reached 46.1 billion US Dollars in 2007. Consumer demand for organic products is concentrated in North America and Europe; these two regions comprise 97% of global revenues. Asia, Latin America and Australasia are important producers and exporters of organic foods.

Table 1: Organic agricultural land and farms by continent

Continent	Organic agricultural land area (ha)	Share of total agricultural area (%)	Organic wild collection area (m. ha)	Organic producers
Africa	875,370	0.10%	4.4	529,987
Asia	2,900,068	0.21%	2.7	234,565
Europe	7,627,915	1.87%	10.2	209,980
Latin America	6,380,996	1.02%	7.5	222,135
North America	2,197,042	0.56%	0.35	12,275
Oceania	12,110,758	2.61%	-	7,222
Total	32,092,149	0.78%	25.1	1,216,164

Source: FiBL and IFOAM 2009

Table 2: **Land area of major countries under organic agriculture**

S.No.	Name of the Country	Area under organic (ha)	% of total agricultural land	Number of organic farms
1.	Australia	12,023,135	2.7	1438
2.	Argentina	2,777,959	2.1	1578
3.	Brazil	1,765,793	0.7	7250
4.	USA (2005)	1,640,769	0.5	8493
5.	China	1,553,000	0.3	2150
6.	Italy	1,150,253	9.1	45231
7.	***India***	***1,030,311***	***0.6***	***195741***
8.	Uruguay	930,965	6.2	630
9.	Germany	865,336	5.1	18703
10.	Spain	804,884	3.2	18226
11.	UK	682,196	3.6	5506
12.	Canada	556,273	0.8	3782
13.	France	557,133	2.0	11978
	World total	**32,200,675**	**0.81**	**1,216,164**

Source: FiBL and IFOAM 2009

Indian Experience of Organic farming

Organic Agriculture is not a new concept to India and traditionally Indian farmers are organic. But, gradually changed to chemical based cultivation since 1950's and chemicals were increasingly applied during the Green Revolution period. Though the introduction of Green Revolution agricultural technology in the 1960's reached the main production areas of the country, there were still certain areas (especially mountain areas) and communities (especially certain tribes) that did not adopt the use of agro-chemicals. Therefore, some areas can be classified as *organic by default* though their significance and extent has been rather overemphasized. However, an increasing number of farmers have consciously abandoned agro-chemicals and now produce organically, as a viable alternative to Green Revolution agriculture.

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. In India about 2.8 million hectares area is under certified organic farming (this includes wild herb collection area of MP and UP) with about 1,95,741 farmers engaged in organic farming (Table 3). The Indian organic farming industry is estimated at US $ 100.4 million and is almost entirely export oriented. According to APEDA (2009), a nodal agency involved in promoting Indian organic agriculture, about 9,76,646 MT of organic products worth 498 crores rupees are being exported from India.

Table 3: Present status of organic farming in India as per National Programme for Organic Production (NPOP) - Source: APEDA, 2009

Status as per 2007-08 records	
1. Total Production	9,76,646 M.T.
2. Total quantity exported	37,533 M. T.
3. Value of total export	Rs. 498 Crores
4. Total area under certification (including wild harvest)	2.8 million hectares (28 lakh ha)
5. Number of farmers	1,95,741
6. Export value	100.4 Million USD
7. Share of exports to total production	4% approx.
8. Increase in export value over previous year	30% approx.

Certified Organic Products Produced & Exported from India

India has competitive advantages in the world markets due to low production costs and availability of diverse climates to grow a large number of crops round the year. The major products of organic farming in India are listed in Table 4. During 2008-09, India exported 86 items with total volume of 37,533 MT, valued around Rs. 498 crores worth and cotton (43% contribution) leads (16,503 MT) among the products exported followed by Basmati rice (15% contribution). Organic products are mainly exported to EU, US, Australia, Japan, Switzerland and middle East.

Table 4: Certified Organic Products Produced & Exported from India

Cereals	Wheat, Rice (Basmati)
Spices	Cardamom, Black pepper, White pepper, Ginger, Turmeric, Vanilla, Mustard, Coriander, Tamarind, Clove, Cinnamon, Nutmeg, Chilli
Beverages	Tea, Coffee
Pulses	Red gram, black gram
Fruits	Mango,Banana, Pineapple, Passion fruit
Vegetables	Okra, Brinjal, Garlic, Onion, Tomato, Potato
Oil seeds	Sesame, Castor, Sunflower, Groundnut
Others	Cotton, Cashew nut, herbal extracts

Organic rice cultivation

India has tremendous potential to become a major exporter of organic rice in the International market. Agricultural and Processed Food Products Export Development Authority (APEDA) made efforts to produce and export basmati rice, aromatic rice and other rice varieties by establishing model farms in states like Punjab, Haryana and Uttar Pradesh. During 2008-09, around 5630 MT of organic basmati rice was exported from India through APEDA.

Rice is the major crop that receives maximum quantity of fertilizers (40%) and pesticides (17-18%) and there are two major challenges in organic rice farming. They are: nutrient management and pest management.

1. Nutrient management

a) Nursery: Preferably, organically grown seed should be selected. From second year onwards, seed from the same organic farm can be used. In seed bed preparation, organic manures such as FYM, compost, vermi-compost can be used @ 5t/ha. For Seed treatment, azospirillum and phosphorus solubilizing bacteria (PSB) @ 10 g /kg seed can be used. Seedling root dipping can also be done in azospirillum and/or PSB suspension prepared with 600 g of culture for seedlings sufficient to transplant in a hectare of land.

b) *Main field:* Only organic manures/crop residues/green manures are to be utilized to supply plant nutrients based on soil test recommendations of the location. Nutrient concentrations and moisture content of organic manures, their contribution to plant uptake and crop nutrient requirement are to be considered to estimate the quantity of organic sources. During land preparation and puddling, 10 tons of FYM/ha along with 5 tons/ha of paddy straw and 10 tons/ha of *insitu* grown dhaincha/sunhemp green manure to be incorporated. In the last puddle, vermi-compost @ 2 t/ha may be applied. Through these organics, approximately 150 kg N, 40 -50 kg P_2O_5 and 100 – 120 kg K_2O will be supplied which takes care of crop NPK needs to a large extent depending on their mineralization and release of nutrients. In addition to NPK, these organics supply micronutrients also in required quantities.

Bio-fertilizers such as azospirillum or PSB @ 2 – 3 kg culture/ha can be mixed with 25 kg FYM or vermi-compost and applied to the soil just before planting. Blue green algae @ 10 kg/ha, 10 days after planting is also recommended. If possible, azolla @ 1 t/ha can be added 7 – 10 days after transplanting and incorporated after 3 weeks. Azolla can also be used as a green manure @ 6 t/ha and incorporated before transplanting. All these bio-fertilizers may add 30 – 40 kg N on an average. Combination of different organic sources based on their availability is preferred.

2. Pest management

Only bio-pesticides and botanicals are recommended. Herbicides should not be used. Only hand weeding or mechanical weeding is to be done. Further, other organic sprays such as panchagavya and amruthajalam, may also be used 2 – 3 times during active growth period of the crop @ 250 ml/ 10 litres solution as they have insecticidal properties and also supply plant nutrients. In the nursery, seed treatment with bio-pesticides like *Pseudomonas* and *Trichoderma* is also recommended @ 10 g/kg seed.

The major steps in management of pests are: 1. Cultivation of tolerant varieties 2. Cultural control 3. Mechanical control 4. Biological control 5. Use of pheromone traps 6. Use of Bio-pesticides.

Research experience at DRR

A field experiment was conducted for five years (2004-05 to 2009-10) covering ten crop seasons [five wet (WS, *kharif*) and five dry (DS, *rabi*)] on a deep black clayey vertisol (Typic pellustert) at the Directorate of Rice Research farm, to compare the influence of organic and conventional farming systems on productivity of super fine rice varieties, BPT5204 (WS) and Vasumati (DS), pest dynamics, grain quality and soil health. The experimental soil characteristics were: slightly alkaline (pH 8.2); non-saline (EC 0.7l dS/m); calcareous (free $CaCO_3$ 5.01%); with CEC 44.1 C mol (p+)/kg soil and medium soil organic carbon (0.69%) content. Soil available N was low (228 kg/ha); available phosphorus was high (105 kg P_2O_5 /ha); available potassium was high (530 kg K_2O /ha) and available zinc was also high (12.5 ppm).

The organic sources used were: green manure, dhaincha (*Sesbania aculeata*) + paddy straw during wet seasons (WS) and poultry manure + paddy straw during dry seasons (DS). The local recommended dose of inorganic fertilizers were given at the rate of 100-40-40 kg N, P_2O_5, K_2O/ha during WS and 120-40-40-10 kg N, P_2O_5, K_2O and Zn /ha during DS through urea, single super phosphate, muriate of potash and Zinc sulphate, respectively. Nitrogen was given in three equal splits at basal, maximum tillering and panicle initiation stages while P, K and Zn were given as basal doses only. Through organics, N dose was adjusted to recommended level based on their moisture content and 'N' concentration on dry weight basis. Organic fertilizers were incorporated one day before transplanting rice. All plant and soil parameters were estimated as per the standard procedures.

Results and Discussion

Grain yield trends **:** During *kharif*, grain yields in the inorganic fertilizer applied plots were near stable ranging from 5.2-5.5 t/ha and superior to organics during the first two years (2004-06) by 15-20% which improved with organics (4.8-5.4

t/ha) in the later years to parity with inorganics (Table 5). However, During *rabi*, inorganics were superior to organics for the first four years and both were at par in the fifth year. This could be due to mismatch of nutrient release from organic sources and crop demand as influenced by seasonal conditions in the initial years and once the soil fertility was built up sufficiently, organic system also produced equal yields as conventional system. Thus, slow and gradual release of nutrients from organics during the initial years of conversion to organic farming could not result in increased yields. But, repeated application of organics over the years built up sufficient soil fertility by improving soil biological activity.

Table 5. Grain yield (t/ha) as influenced by nutrient sources

Year	Wet season (*kharif*)		Dry season (*rabi*)	
	Inorganics	Organics	Inorganics	Organics
2004-05	5.47[a]	4.68[b]	3.79[a]	3.52[b]
2005-06	5.35[a]	4.59[b]	3.74[a]	3.10[b]
2006-07	5.20[a]	4.85[a]	3.81[a]	3.14[b]
2008-09	5.33[a]	5.23[a]	3.76[a]	3.27[b]
2009-10	5.23[a]	5.36[a]	4.18[a]	3.98[a]

Figures in a row within a season with different letters differ significantly (p=0.05)

A 20-30% less yields of crops in organic farming was reported by Rajendraprasad (2006). Significant reduction in rice yield when 50% chemical fertilizers were substituted with organics was also reported by Yadav et al.(2000). The recession in the crop yields during initial phase of transition from conventional to organic agriculture and recovery in yields after 2-3 years was reported by Sharma and Mohan Singh (2004). Yield loss of organically grown rice is reported to the tune of 24% (Mader *et al*., 2002), though organic farming system showed efficient resource utilization. Although grain yield under organic farming is often lower than under conventional farming, in some cases, increased yields of rice were also reported (Chitra and Janaki 1999). Tanaki *et al.* (2002) studied the growth and yield of rice with organic farming in comparison with conventional farming in Japan and found that the growth and yield of rice increased with continuous organic farming.

Grain quality parameters **:** Physical grain quality parameters like milling%, hulling%, head rice recovery (HRR), L/B ratio; cooking quality parameters like amylose content and elongation ratio were not influenced by the nutrient sources even after 4 years of study. However, in the fifth year, there was an improvement in HRR by 9.5% with organics over inorganics (Tables 6 and 7). Similarly, there was an improvement in elongation ratio by 4.1% with organics over inorganics. Whereas, moderate improvement in nutritional quality parameters such as protein, phosphorus and potassium contents was recorded with organics compared to inorganics and brown rice recorded higher values (by 5-16%) than polished rice (by 1-6%). A significant improvement in nutritional quality (Fe and Mn) with combined application of 2 or more organic sources and with 3 or 4 organic sources in case of Zn and Cu contents in organic farming with Pusa basmati 1 scented rice variety was reported by Singh *et al.* (2007) while sole application of any organic source (Azolla, BGA, FYM and vermi compost) did not increase the nutritional quality. In another experiment on organic farming, Saha *et al*. (2007) studied the grain quality parameters and reported that organic nutrient sources can perform comparatively well as regards chemical and physico-chemical properties and cooking quality of rice, if not better in some parameters than inorganic fertilization.

Field experiments conducted in Annamalai university with rice clearly indicated a positive approach towards organic farming in attaining premium quality produce with higher grain yield. Quality characters *viz.* milling recovery, head rice percentage and protein percentage were significantly higher with organic sources (India agronet, 2001).

Table 6. Grain quality parameters as influenced by treatments (5th year)

	Physical quality								Cooking quality			
Treatments	Hulling (%)		Milling (%)		HRR (%)		L/B ratio		Elongation ratio		Amylose (%)	
	DS	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**
Inorganics	79	77	68	64	28	51	4.26	2.68	2.05	1.69	25.7	24.2
Organics	77	77	66	64	25	56	4.22	2.66	2.09	1.76	26.0	24.0
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.039	0.041	NS	NS

HRR – Head rice recovery; L/B Length/breadth

Table 7. Grain quality (nutritional) parameters as influenced by treatments (5th year)

Treatments	Protein (%)				Phosphorus (g/kg)				Potassium (g/kg)			
	BR		**WR**		**BR**		**WR**		**BR**		**WR**	
	DS	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**	**DS**	**WS**
T2-Inorganics	8.55	8.31	8.16	7.56	1.7	3.2	1.0	1.0	1.7	2.3	1.0	1.0
T3-Organics	8.58	8.71	8.14	7.76	2.0	3.3	1.1	1.2	1.9	2.5	1.1	1.2
CD(0.05)	NS	NS	NS	NS	0.25	0.32	0.08	NS	0.11	0.15	NS	NS

BR- brown rice; WR – white rice

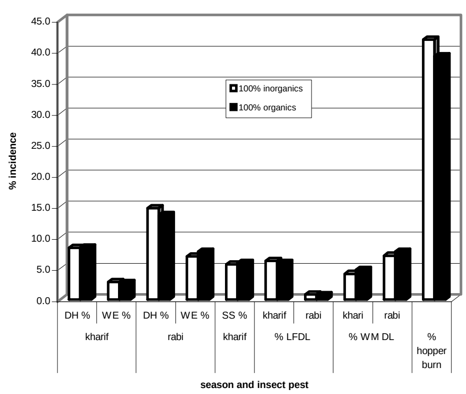
Assessment of quality from taste point of view is difficult, as different persons have different standards depending upon their habits, liking and perception. Based on large number of studies conducted in USA, Britain, Germany and other Eureopean countries, in general, there is no evidence of better taste in organic fruits and vegetables. Whereas, there are enough indications that organically grown products are superior in various essential minerals and vitamins and have lower toxic components such as nitrates and heavy metals (Yadav and Bihari, 2006).

Pest incidence and parasitism: Observations on incidence of pests and natural enemies were recorded and the mean values of 5 years data are reported (Fig. 1 and 2). Stem borer damage ranged from 4.5% to 10.6% (dead hearts) during the vegetative stage and 0.4% to 4.5% (white ears) in the pre-harvest stage in *kharif* season. In the *rabi* season, during vegetative stage, the stem borer incidence ranged from 6.5% to 20.9% (dead hearts) and 2 to 17% (white ears) in the reproductive stage. There was slight difference in the stem borer incidence in the organic and inorganic treatments during *rabi* and *kharif* seasons. The mean dead hearts % was same in orgainic (8.4%) and inorganic (8.3%) treatments. Whereas, the white ears were slightly more in inorganic treatment (2.8%) compared to organics (2.5%) in the *kharif* season. In the *rabi* season dead hearts were less (13.6%) and white ears were more (7.7%) in the organic treatment compared to inorganic treatment where dead hearts and white ears were 14.7 % and 6.9 %, respectively.

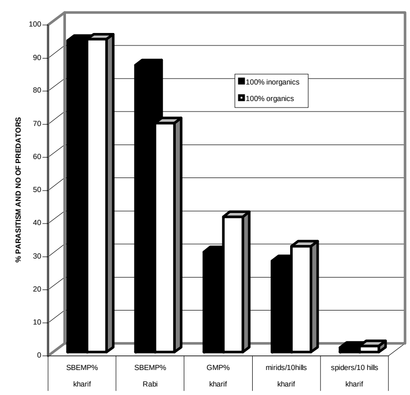
Stem borer egg mass parasitism ranged from 91.2 to 97.6% during *kharif* season and in *rabi* season it was 69.2 to 86.7%. Significant differences were not observed in the parasitism between organic (94.6%) and inorganic treatments (94.1%) in the *kharif* season whereas parasitism was more in inorganics (86.7%) compared to organics (69.2%) in the *rabi* season. The predominant egg parasitoid was *Tetrastichus schoenobii*, among the three parasitoids observed viz., *T. schoenobii*, *Telenomus dignus* and *Trichogramma japonicum*. Gall midge damage ranged from 0.4% to 7.6% (silver shoots) in the *kharif* season and it was not observed during *rabi* season and the damage was on par both in organic (5.9% silver shoots) and inorganic (5.8% silver shoots) systems. Gall midge larval parasitism due to *Platygaster oryzae* ranged from 14.5 to 61.2% and overall mean parasitism was more in the organic treatment (40.9%) compared to inorganics (30.3%). Leaf folder damage ranged from 0.4 to 4.8% and significant differences were not observed between organics (2% and 0.7% in *kharif* and *rabi*, respectively) and inorganics (2.1% in *kharif* and 7% in *rabi*). Mirid bugs and spiders were more in the organic treatment compared to inorganics. In case of BPH, where insects were released artificially in the confined cages (one m^2 area), hopper burn was 42% with inorganics as compared to 39% with organics (Fig. 1). Low incidence of insect pests such as planthoppers and leafhoppers, *Oulema* sp and *Parnara* sp. was observed in organically farmed rice fields which also showed more number of natural enemies such as spiders, mirid bugs and insect pathogenic nematodes (Hidaka 1995; Kajimura et al., 1993 and 1995).

The reason for non-significant differences between organic and inorganic treatments in the present study could be due to the application of recommended dose of nutrients in both systems that prevented the build up of pest pressure to reach ET levels in inorganic system which otherwise happens normally with increased/indiscriminate use of fertilizers and pesticides. No major disease incidence was observed throughout the experiment in both organic and inorganic production systems.

Fig 1. Incidence of insect pests



Incidence of natural enemies



Impact on soil nematode community: Results on the long-term effects of organic and conventional crop management systems on soil nematodes indicated that after a period of five years (ten crop seasons), population and relative abundance of plant parasitic nematodes were significantly low in organic system compared to that in conventional system while the population and relative abundance of microbial feeding nematodes were significantly high in organic system, suggesting a positive effect on soil health (Fig. 3).

Nematodes are the most abundant, diverse and ubiquitous invertebrates present in the soil (Yeates, 1979). Nematodes interact in ecosystems directly as herbivores on plants and indirectly as consumers of microflora and fauna, thus playing a significant role in regulating primary production, predation, decomposition of organic matter and nutrient cycling. Soil nematode community therefore serves as bio-indicator of soil health and ecosystem processes (Bongers and Ferris, 1999).

Several studies demonstrated that the transition from conventional to organic farming increases the abundance of beneficial microbial feeding nematodes while simultaneously reducing the populations of harmful plant parasitic nematodes in organic system compared to the conventional system over a transition period of 3 to 5 years (Briar *et al,* 2007; Ferris *et al.,* 2004). Although various organic amendments showed differential effects on soil properties and nematode communities, all amendments increased the availability of nutrients, microbial biomass and abundance of microbial feeding nematodes (Nahar *et al.,* 2006).

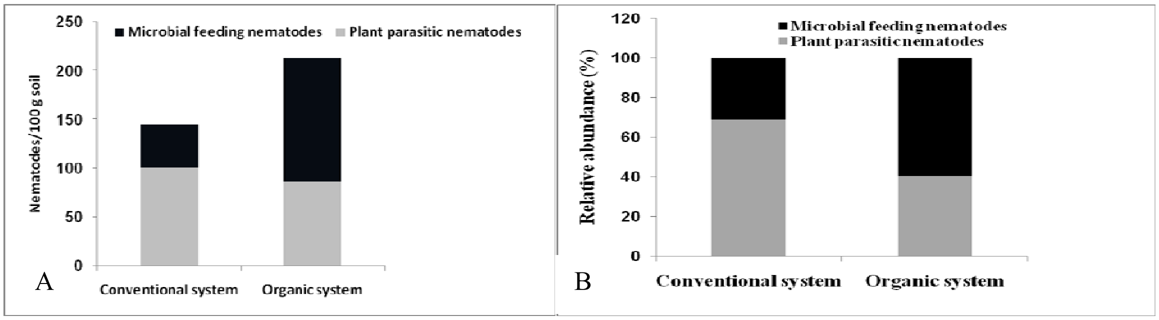


Fig. 3 Population (A) and relative abundance (B) of plant parasitic and microbial feeding nematodes

Impact on soil microbial communities: Observations over five years showed that organic nutrient sources have a stimulating influence on the soil microbial communities as seen by the increase in microbial populations (Fig. 4). Total bacterial, fungal and actinomycetes population were found to increase under organic farming. In addition, the N-fixing microbial populations viz; *Azotobacter, Derxia* and *Azospirillum* and phosphate solubilising bacteria (PSB) were significantly higher with organics (5.72, 4.48, 4.62 and 4.66 log CFU (Colony Forming Unitis)/g soil, respectively) as compared to inorganics with 4.70, 4.04, 4.36 & 4.43 log CFU/g soil, respectively.

Soil microbial communities play an important role in maintaining soil fertility and productivity because they not only regulate transformation processes of elements in soils but also control the build up and break down of organic matter and decomposition of organic residues (Mandal et al, 2007). Microbial characteristics of soils, such as biomass, enzyme activity and diversity, are generally evaluated because of the clear relationships between these factors with soil quality and ecosystem sustainability (Doran and Parkin, 1994). Increased availability of substrates (C and N) required for microbial population build up could be the probable reason for this increase (Bunemann et al., 2006). Higher microbial diversity in organically managed soils was reported by Rao (2005).

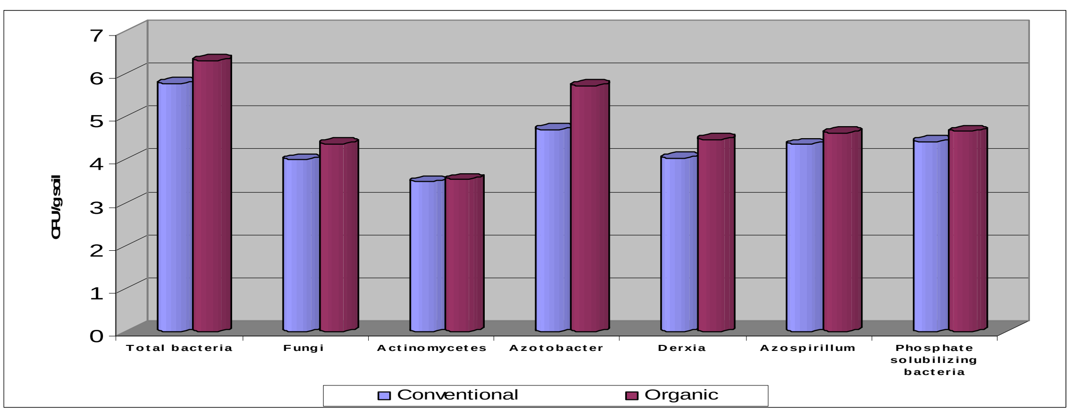


Fig: 4 Microbial populations under conventional and inorganic rice farming

Soil quality parameters: Changes in soil quality parameters were monitored at the end of four years and presented in Table 8. There was a significant improvement in soil physical (bulk density and penetration resistance), fertility (organic carbon and available N,P and K) and biological properties (soil respiration and enzyme activities viz., glucosidase, phosphatase and dehydrogenase) with organics compared to inorganic fertilisers. Compared to inorganics, there was an increase in SOC, available N, P and K by 28, 7, 21, and 21 % with organics, respectively, at the end of four years. Paddy straw being rich in potassium and poultry manure with high phosphorus content are the possible factors responsible for the observed increase in soil P and K values in treatments where these two organic sources were used. A further reason for the SOC increase may be the slow decomposition of applied and native soil organic matter due to prevailing anoxic conditions and formation of difficultly decomposable SOC under rice-rice system (Ponnamperuma, 1984). Increased enzyme activities in soils under organic management than under conventional management due to activities of microorganisms was also reported by Melero *et al.* (2008). Comparable increases in organic carbon, available N, P and K through addition of organic materials was reported by Pathak et al. (1992) and Yadvinder-Singh et al. (2004). Superior soil fertility status on organic farms compared to soils fertilized with chemical fertilizers was reported by Sharma and Mohan Singh (2004).

Enzyme activities in soil were also influenced by different treatments (Table 8). Enzymes catalyse the biochemical reactions involved in nutrient cycling in soils. β - glucosidase, involved in carbon cycling; alkaline phosphatase, that plays a major role in the mineralization of organic phosphorus substrates and dehydrogenase, which is an indicator of total microbial activity were significantly higher with organics compared to inorganics. Increase in extra cellular enzyme activities (alkaline phosphatase, protease, and β-glucosidase) has been reported to be higher in soils under organic management than under conventional management because the addition of organic amendments activates microorganisms to produce enzymes (Melero et al., 2008). Soil respiration rate, another important indicator of soil biological activity was also significantly higher with organics over inorganics. Addition of organic sources provide a stable supply of C and energy for micro-organisms and cause an increase in the microbial biomass pool, thereby increasing soil respiration rate. Several authors have also observed higher respiration rates in organically managed soils than in conventionally managed soils (Carpenter-Boggs et al., 2000) due to additional carbon inputs in organically managed soils. Favourable improvement in soil physical, fertility and biological properties was reported in many organic farming experiments (Carpenter Boggs *et al.* 2000).

Soil quality, as measured by different indices viz., nutrient index (NI), microbial index (MI) and crop index (CI) indicated maximum nutrient (1.10) and microbial (1.19) indices with organics and inorganics recorded 0.97 & 0.95 NI & MI values, respectively (Figure 5). Whereas, the crop index was maximum with inorganics (1.12). The sustainability index (SI) of the soil system, measured from above three indices was maximum with organics (1.63) and inorganics recorded 1.33, which was just above the minimum sustainability index of 1.30.

Table 8. Soil quality parameters after four years under organic and conventional systems

Trts.	Physical		Fertility				Biological			
	B.D Mg/m 3	P.R kg/cm^2	SOC %	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	SR	B-g	A.P	D.H
Inorganics	1.48	11.8	0.78	239	107	469	0.196	140	458	1352
Organic	1.30	7.7	1.00	256	129	567	0.232	162	563	1623
CD (0.05)	**0.07**	**1.45**	**0.09**	**16**	**18**	**45**	**0.024**	**20**	**77**	**32**

B.D- Bulk density; P.R- Penetration resistance; SOC- Soil organic carbon; SR-Soil respiration in mg CO2/24h/g; Bg- Beta glucosidase and AP- Alkaline phosphatase in µg p-nitrophenol/g/h; DH- dehydrogenase in µg Triphenyl formazon/g/24h

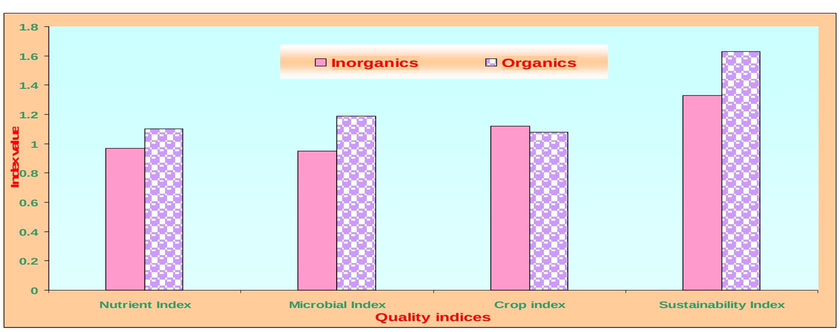


Fig. 5 Soil quality indices in organic and inorganic systems

Pesticide residue analysis: Though overall pesticide consumption in our country is very low compared to that of developed countries, still the menace of residues in our food is much higher under conventional farming. Despite very low consumption, the reasons for higher pesticide residues are: indiscriminate use; non-observance of waiting period; use of sub-standard pesticides; continuance of DDT and other persistent pesticides in health programmes; pesticide use in storage and transit and treatment of fruits and vegetables with pesticides. There are frequent reports of rejection of consignments of Indian agricultural export by the US and EU countries on the ground of sanitary and phytosanitary measures.

Reducing dietary exposure to pesticide residues is an important goal of public health and environmental officials, farmers and other segments of the food industry, and consumers. Though not much study has been made in this direction, organic agriculture, with its strictures against the use of synthetic chemical inputs, seems to offer a low-residue alternative to conventionally-grown produce.

Pesticide residue analysis was done in grain, straw and soil samples (Table 9). Most of the residues were below detectable limits (BDL) in grain, brown rice and white rice with an exception in a few samples where BHC (CHC compound), dimethioate and chlorpyriphos (OP compounds), butachlor (herbicide) were detected. But, all these residues were below toxic levels. Very low levels of residues are coming mainly as drift from conventional farming and from the persistent chemicals used long before 20-25 years.

- Chlorinated hydrocarbons (CHC) or organo chlorine (OCs) and organo phosphate (OPs) group residues are detected in plant and soil samples. CHC residues are more than OP residues in general in plant and soil. Among CHCs, BHC residues are detected in more number of samples than endosulfan and DDT with higher residue levels in straw than in grain.
- Whole grain and brown rice detected more residues and polished rice has negligible and BDL values as most of them will be removed during processing.
- Among OPs, Chlorpyriphos is the only OP compound used in the experiment that was detected in plant and soil samples. OP residue levels are also slightly higher in straw than in grain. OPs are in BDL in polished rice
- Herbicide residues were detected in a few grain and straw samples and were in BDL in soils.
- No clearcut differences were noticed in pesticide residue accumulation between organic and inorganic production systems.

In the present study, the residues of recommended pesticides used in conventional system were not detected in grain and straw at harvest since all these new molecules are easily biodegradable and are not persistent. However, some of the pesticide residues pre-existing in soil (eg: BHC and DDT) were detected in grain, straw and soil at harvest both in organic and conventional systems indicating their long term persistence in soil. Presence of organochlorine pesticide residue in wheat and rice samples was reported by Rekha et al. (2006) in two out of ten organic farms**,** which were converted from conventional to organic practices few years ago.

Brian et al. (2002) obtained data on pesticide residues in organically grown foods, foods produced with IPM, and conventionally grown foods of over 94,000 samples and reported that organically grown foods have fewer and generally lower pesticide residues than conventionally grown foods. Organic foods typically contain pesticide residues only one-third as often as conventionally grown foods. However, organic foods are not pesticide free. Most of the residues in organic foods can readily be explained as the unavoidable results of environmental contamination by past pesticide use, or by "drift" (sprays blown in from adjacent non-organic farms).

Economics of the study: Rice produced in transition years cannot be sold as organic and therefore cannot take advantage of potential organic pricing premiums. Pricing premiums for organic commodities are dependent on market demand as well as the amount of production in any given year and are fragile in nature.

Total cost of cultivation, gross returns, net returns and benefit :cost ratio were calculated at the end of first and fourth years of study under inorganic and organic production systems (Table 10). In the first year, net returns were calculated without price premium for the organic rice. Benefit cost ratio was less with organics (1.09:1) compared to inorganics (1.37:1) in the first year which improved with organics (1.85:1) over inorganics (1.52:1) by fourth year..

Atkinson and Betsy Woods (1999) reported that Lowell farms of Texas recorded their organic rice yield at 50-60% of conventional yields but it commanded a price two to three times higher than that of conventionally grown rice. In India also, though the yield levels of rice under conventional type of farming would have been more, the yield per rupee invested could have been more under organic farming (Rajendran, 2002). The economic comparison made during 1991-2001 (without price premium for organic) in organic corn-soybean rotation with conventional corn-soybean system revealed that the net returns for both systems were similar. Over 10 year period, organic corn was 25% more profitable than conventional corn because organic corn yields were only 3% less while costs were 15% less than conventional corn (Yadav and Bihari 2006).

Conclusions

Global demand for organically grown foods is increasing and organic agriculture is growing fast in recent years. As a result, the area under organic farming and the number of countries practicing it are also increasing every year. India is also not an exception with considerable land area under organic farming and most of the north eastern states have been declared as organic by default.

From the present research study at DRR, it can be concluded that organic system of rice production needs more than two years period to stabilize rice productivity and bring about perceptible improvement in soil quality, sustainability indices and economic returns under intensive, irrigated rice-rice system in vertisols of tropical climate.

Hence, using easily available local natural resources, organic farming can be practiced with a view to protect/preserve/safe guard our own natural resources and environment for a fertile soil, healthy crop and quality food and let our future generations enjoy the benefits of non-chemical agriculture. Given the same profitability, organic farming is more advantageous than conventional farming considering its contribution to health, environment, and sustainability.

References

Atkinson and Betsy Woods. 1999. *Acres USA*. April. P.1-9.

Bongers, T., Ferris, H., 1999. Nematode community structure as a bioindicator in environmental monitoring. *Trends in Ecology and Evolution* **14**: 224–228.

Briar, S.S., Grewal, P.S., Somasekhar, N, Stinner, D. and Miller, S.A. 2007. Soil nematode community, organic matter, microbial biomass and nitrogen dynamics in field plots transitioning from conventional to organic management. *Applied Soil Ecology* **37**: 256-266.

Brian P. Baker., Charles M. Benbrook., Edward Groth and Karen Lutz Benbrook. 2002. Pesticide residues in conventional, IPM-grown and organic foods: Insights from three U.S. data sets. *Food Additives and Contaminants* **19**(5): 427-446.

Bunemann, E. K., Schwenke, G. D. and Van Zwieten, L. 2006. Impact of agricultural inputs on soil organisms- a review. *Australian Journal of Soil Research* **44**: 379-406.

Carpenter Boggs, L., Kennedy, A.C. and Reganold, J.P. 2000. Organic and Biodynamic Management: Effects on soil Biology. *Soil Science Society of America Journal* **64**, 1651-1659.

Chitra, L. and Janaki, P. 1999. Combined effect of organic wastes and inorganic nutrients on the nutrient uptake and yield of rice in *kar* and *pishanam* seasons. *Oryza* **36:** 327-330.

Doran, J.W. and Parkin, T.B. 1994. Defining and assessing soil quality. p. 3-21. In: J.W. Doran et al., (ed.) *Defining Soil Quality for a Sustainable Environment*. SSSA Spec. Publ. No. 35, Soil Sci. Soc. Am., Inc. and Am. Soc. Agron., Inc., Madison, WI.

Ferris, H., Venette, R.C. and Scow, K.M., 2004. Soil management to enhance bacterivore and fungivore nematode populations and their nitrogen mineralization function. *Applied Soil Ecology* **24:** 19–35.

Hidaka, K. 1997. Community structure and regulatory mechanism of pest populations in rice paddies cultivated under intensive, traditionally organic and lower input organic farming in Japan. *Biological Agriculture and Horticulture* **15** (1-4): 35-49.

India agronet. 2001. Organic farming for sustainable agriculture. www.indiaagronet.com

Kajimura, T., Maeoka, Y., Widiarta, I. N., Sudo, T., Hidaka, K., Nakasuji, F. and Nagai, K. 1993. Effects of organic farming of rice plants on population density of leafhoppers and planthoppers. I. Population density and reproductive rate. *Japanese Journal of Applied Entomology and Zoology* **37**(3): 137-144.

Table 9: Pesticide Residues detected* (ppm)

Residues	Grain		Straw		Brown rice		White rice		Soil	
CHC(OCs)										
	Inorganics	**Organics**	**Inorganics**	**Organics**	**Inorganics**	**Organics**	**Inorganics**	**Organics**	**Inorganics**	**Organics**
BHC	BDL-0.02	BDL-0.02	0.05-0.09	0.01-0.03	0.01-0.011	0.005-0.01	BDL-0.005	BDL-0.001	BDL-0.006	BDL-0.018
Endosulfan	0.025-0.04	BDL-0.005	0.06-0.08	0.05-0.07	BDL-0.05	BDL-0.02	BDL	BDL-0.008	BDL	BDL
DDT	BDL-0.07	BDL-0.01	0.06-0.07	0.014-0.04	BDL-0.012	BDL-0.01	BDL-0.003	BDL-0.002	BDL-0.009	BDL-0.008
OPs										
Dimethioate	BDL-0.065	BDL-0.056	0.04-0.130	BDL-0.06	0.037-0.039	0.02-0.04	BDL	BDL	BDL-0.024	BDL-0.005
Methyl parathion	BDL-0.013	BDL-0.011	BDL-0.245	BDL-0.08	BDL-04	BDL-0.02	BDL	BDL	BDL	BDL
Fenitrothion	BDL-0.008	BDL-0.001	BDL-0.06	BDL-0.04	BDL-0.09	BDL-0.002	BDL	BDL	BDL	BDL
Malathion	BDL-0.186	BDL-0.08	BDL	BDL	0.073	0.06	BDL	BDL	BDL	BDL
Chlorpyriphos	BDL-0.03	BDL-0.02	0.024	0.023	0.033-0.049	0.02-0.04	BDL	BDL	0.219	BDL-0.01
Herbicide										
Butachlor	BDL-0.002	BDL-0.001	BDL-0.086	BDL-0.009	BDL	BDL	BDL	BDL	BDL	BDL
* Range of 8 values of 4 seasons; BDL- Below detectable limits										

Table 10: Cost of Cultivation and net returns/ha/annum under two systems

Treatments	**Year 1 (2004-05 [*kharif*+*rabi*])**			
	Total cost (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
Inorganics	35,045	48,152	13,107	1.37:1
Organics	38,950	42,640	3,690	1.09: 1
	Year 4 (2008-09 [*kharif*+*rabi*])			
Inorganics	47,945	72,720	24,775	1.52:1
Organics	54,980	1,02,000	47,020	1.85:1

Kajimura, T., Fujisaki, K. and Nakasuji, F. 1995. Effect of organic rice farming on leafhoppers and planthoppers 2. Amino acid content in the rice phloem sap and survival rate of planthoppers. *Applied Entomology and Zoology* **30**(1): 17-22.

Mader, P., Fliessbach, A., Dubois, D, Gunst, L., Fried P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* **296**: 1694-1697.

Mandal Asit., Ashok K. Patra., Dhyan Singh., Anand Swarup and Ebhin Masto, R. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. *Bio resource Technology* **98** (8):3585-3592.

Melero, S., Madejon, E., Herencia, F.J., Ruiz, J.C. 2008. Effect of Implementing Organic Farming on Chemical and Biochemical Properties of an Irrigated Loam Soil. *Agronomy Journal* **100:** 136-144.

Nahar, M.S., Grewal, P.S., Stinner, D., Stinner, B.R., Kleinhenz, M.D., Wszelaki, A. and Doohan, D. 2006. Differential effects of raw and composted manure on nematode community, and its indicative value for soil microbial, physical and chemical properties. *Applied Soil Ecology* **34**: 140–151.

Pathak, H., Kushwala, J. S. and Jain, M. C. 1992. Evaluation of Manurial value of Biogas spent slurry composted with Dry Mango leaves, wheat straw and Rock Phosphate on wheat crop. *Journal of Indian Society of Soil Science* **40**: 752-57.

Ponnamperuma, F. N. 1984. Straw as source of nutrients for wet land rice. In *Organic Matter and Rice* 17-136. Philippines, Manila: International Rice Research Institute.

Rajendraprasad. 2006. Organic farming. *Indian Farming* 55: 4-6.

Rajendran, S. 2002. Paper presented at the "International conference on organic Rice cultivation. 12-15 November, Korea.

Rao, D. L. N. 2005. Soil microbial diversity in chemical and organic farming. Paper presented at "National seminar on organic farming-Current Scenario and future thrust" during April 27-28, 2005 held at ANGR Agricultural University, Hyderabad, India. Pp 61-64.

Rekha., Naik, S.N. and Prasad, R. 2006. Pesticide residue in organic and conventional food-risk analysis. *Journal of chemical health and safety* **13**(6): 12-19.

Saha, S., Pandey, A. K., Gopinath, K. A., Bhattacharaya, R., Kundu, S. and Gupta, H.S. 2007. Nutritional quality of organic rice grown on organic composts. *Agronomy for Sustainable Development* **27:** 223–229.

Sharma, P.D. and Mohan Singh. 2004. Problems and prospects of Organic farming. *Bulletin of the Indian Society of Soil Science* **22:** 14-41.

Singh,Y. V., Singh, B. V., Pabbi, S. and Singh, P K. 2007. Impact of Organic Farming on Yield and Quality of BASMATI Rice and Soil Properties. Beitrag archiviert under http://orgprints.org/view/projects/wissenschaftstagung-2007.html

Tanaki, M., Itani, T. and Nakano, H. 2002. *Japanese Journal of crop Science* **71**(4):439-445.

Wang, Y.C., Fan, J.Q., Tian, X.Z. and Gao, B.Z. 1994. *Entomological Knowledge*. **35**(1): 257-262.

Yadav, A.K. and Bihari, K. 2006. Conventional vs. organic farming-Myths and Realities (Food quality and safety) in Organic agriculture-Philosophy and Science. Regional centre of organic farming. Imphal. pp. 35-49.

Yadav, R.L., Dwivedi, B. S., Kamta Prasad., Tomar, O. K., Shurpali, N. J. and Pandey, P. S. . 2000. Yield trends and changes in soil organic C and available NPK in a long-term rice-wheat system under integrated use of manures and fertilizers. *Field Crops Research* **68:** 219-46.

Yadvinder-Singh., Bijay-Singh., Ladha, J. K., Khind, C.S., Khera, T. S, and Bueno, C. S. 2004. Effects of Residue Decomposition on Productivity and Soil Fertility in Rice-Wheat Rotation. *Soil Science Society of America Journal* **68**: 854-864.

Yeates, G.W. 1979. Soil nematodes in terrestrial ecosystems. *Journal of Nematology* **11**: 213–229.