International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 3442-3448

Received: 24-03-2019
Accepted: 28-04-2019

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Biodiversity enhancement for sustainable organic farming: A review

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Abstract
Biological diversity is very important for the proper functioning of the ecosystem and for delivering ecosystem services. Maintaining high biodiversity in agro-ecosystems makes agricultural production more sustainable and economically viable. The combination of biodiversity conservation with profitable food production is one of the tasks of modern sustainable agriculture that faces the necessity of reconciling the productive, environmental, and social goals. It has been recognized that biodiversity is key in securing global food supply.
Arora and Kaur (2018) found better growth of earthworms in rice straw, cattle dung and azolla mixture can be due to more acceptability of this mixture to earthworms and/or due to the presence of components that were favourable for their growth. Biodiversity index is significantly higher in organic as compared to other systems (0.86 in Organic Vs 0.66 in conventional system for cabbage and 0.86 in Organic Vs 0.59 in conventional system for red beet). It showed that organic farming has lowest impact on environment (Bavec and Bavec, 2015) [4]. In fruit tree (Khasi Manadarin) based agri-horti system in North East Hill Region, it was observed that inclusion of high value crop (turmeric and ginger) with agricultural crops (groundnut and soybean) gave the highest net return.

Keywords: Biodiversity, enhancement, growth, production, organic farming

Introduction
Biodiversity plays a crucial role in food security, nutrition, and livelihood and in the provision of ecosystem services. Biological diversity encompasses all species of plants, animals, and microorganisms and the ecosystems and ecological processes of which they are parts. In a common parlance, biodiversity may be defined as species richness (plants, animals, and microorganism) in a given habitat. It may be land, in fresh water or sea or as parasites or symbiosis. Biodiversity encompasses diversity of life on all levels: species diversity, genetic diversity as well as habitat and ecosystem diversity. A rich biological diversity is essential for preserving natural processes contributing to man's ability to live, such as natural pest regulation, pollination of fruit biomass by insects, and the decomposition of organic matter into humans. Requisites for a diverse, species rich landscape.
Agricultural policies are increasingly promoting ecological-oriented farming method that preserve biodiversity and conserve natural resources. In historic times, a more diverse landscape unfolded through farming from what was once an undifferentiated landscape dominated by forests. Today as well, regionally adapted and extensive forms of cultivation are essential prerequisites for a diverse species rich landscape.
Till today, 1.75m known species have described and it is estimated to about 12-14m of species. Most of species are found in tropical region of the world

Species	Worldwide	Tropical
Flowering plants	240,000	65%
Ferns	12,000	92%
Fung	120,000	75%

Biodiversity hotspot
Areas which exhibit high species richness as well high species endemism are termed as hot spots of biodiversity. The term was introduced by Norman Meyers in 1988. There are 34 such hotspots of biodiversity on a global level, out of which four are present in India namely,

1. 1. The Himalaya-Western and Eastern Himalaya, form part of Himalayan global biodiversity hotspot
2. The Western Ghats- Part of Western Ghats-Sri Lanka global biodiversity hotspot.
3. Indo-Burma- North-eastern India, except Assam and Andaman group of Islands.
4. Nicobar Islands- Includes Nicobar group of Islands.

Biological diversity can be observed at three levels

Genetic diversity: The variation in the amount of genetic information within and among individuals of a population, a species, an assemblage, or a community.

Species diversity: Number and type of different species found in an area. Biodiversity at the species level, often combining aspects of species richness, their relative abundance, and their dissimilarity (Millennium Ecosystem Assessment 2005) [9].

Ecosystem diversity

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Varity of habitats, living communities, and ecological processes in the living world.

Landscape or eco-regional diversity: Noss (1996) [12], Szaro and Shapiro (1990) [7], Sazro and Salwasser (1991) [8] and Wilson (1998) [20] among many others, have included this fourth forms of biodiversity. It is a mosaic of heterogeneous land forms, vegetation types and land use (Urban *et al*. 1987) [19]. Ecosystems and their components interact with each other to form an even higher level of diversity.

N.E. India: A treasure of biodiversity

The following points depict the picture of the biological diversity in the North-east India:

- Out of 136 species of bamboos found in India, 63 species in 22 genera are found in NE India. Assam has at least 38 species of bamboos.
- Out of 22 spp. of freshwater Tortoise and Turtles, 19 spp. found in Assam.
- Out of 1170 species of birds 958 species are found in Assam.
- Assam harbors at least 150 species of ornamental fish out of 300 species in N.E. India.
- Assam harbors 3017 species of flowering plant out of 7,500 species found in N.E. India
- Half of the total, about 17 species of citrus
- Out North East's 825 species of Assam has 192 species of Orchids.
- About 50% of India's 1500 spp. of butterflies reported from Assam and N.E. India
- 28 conifers, 500 mosses, 700 ferns
- 14 species of canes reported from Assam
- Assam harbors 230 species & subspecies of mammals (44 threatened) against 324 species in North East India.

On the other hand India is also very rich in floral diversity and its percent contribution is given in the following table:

Table 1: Percent contribution of floral diversity of India in world

Plant Group	No. of species described		
	India	World estimated	(%) India
Algae	7,244	40,800	17.75
Bryophytes	2,505	14,500	17.27
Pteridophytes	1,267	12,000	10.56
Gymnosperms	74	650	11.38
Angiosperms	17,926	2,50,000	7.17
Total	29,015	3,17,950	7.17

Source: FSI, 2011)

Value of Biodiversity

The value of biodiversity in terms of its commercial utility, ecological services, social and aesthetic value is enormous. We get benefit s from other organisms in innumerable ways. Sometimes we realize and appreciate the value of the organism only after it is lost from this earth. Very small, insignificant, useless looking organism may play a crucial role in the ecological balance of the ecosystem or may be a potential source of some invaluable drug for dreaded diseases like cancer or AIDS. The multiple uses of biodiversity or biodiversity value have been classified by Ministry of Environment and Forest, GOI (2013) [2] as given below:

Food security: A large number of wild plants are consumed by human being as food.

1. About 80,000 edible plant species have been reported from wild. About 90% of present day food crops have been domesticated from wild tropical plants. Wild relatives usually possess better tolerance and hardiness. A large number of wild animals are also our sources of food.
2. Medicines: About 75% of the world's population depends upon plants or plant extract for medicines. The wonder drug penicillin used as an antibiotic is derived from a fungus called penicillium. Likewise we get Tetracycline from a bacterium. Quinine, the cure for malaria is obtained from the bark of Cinchona tree. A large number of animals are supposed to possess anti-cancer properties which are yet to be explored systematically.
3. Economic benefit: Affluent tourists pay good money to see wildlife, and protected areas. Besides, our forests have been used as fuel wood since time immemorial.
4. Environment and ecological benefit: Biodiversity protects from flood and drought. It provide stable ecosystem with adequate trees help to regulate the water cycle by acting as temporal sink.
5. Social value: Biodiversity is related with the social life, custom, religion aspects of the people. Many of the plants species like tulsi, mango, lotus, bael etc. are considered as holy and sacred in our country. The leaves, fruits or flowers of these plants are used in worship or plants itself is worshiped.
6. Soil fertility sustenance: Many microorganisms' activities aerate the soil. Nutrient cycling has also been enhanced by some deep rooted plant.
7. Aesthetic value: Biodiversity has great aesthetic value. No one of us would like to visit vast stretches to barren

land. People from far and wide spend a lot of time and money to visit wilderness areas where they can enjoy the aesthetic value of biodiversity and this type of tourism is known as ecotourism.

8. Ethical value: Value means all life must be preserved. It is based on the concept of live and let live. We may or may not use a species but if a species exist in nature must give us pleasure.

Besides above benefit biodiversity help in Pollination and seed dispersal. Approximately 90% of flowering plants depend on pollination by bees, birds, bats and other pollinators for reproduction. The loss of pollinators and the services they provide would drastically reduce the size of food harvests and threaten non-agricultural species with extinction. Besides pollination, biodiversity provides many other services to agriculture not detailed here, such as natural pest control.

Biodiversity conservation and sustainable development

- Humans use the planet's resources such as forests, oil and minerals. Many of these resources have accumulated or have grown over thousands or even millions of years. The 2010 WWF Living Planet Report estimates that we'll need the equivalent of two planets by 2030 to support human populations if we continue with our current consumption patterns. To understand sustainable development, think about its three pillars: "economic wealth", "social equity" and "environmental health"; or in other words "profit", "people" and "planet". All three are linked to each other.

Economic wealth: Biodiversity also plays an important role in economic sectors that drive development, including agriculture, forestry, fisheries and tourism. More than three billion people rely on marine and coastal biodiversity, and 1.6 billion people rely on forests and non-timber forest products (e.g. the fruits from trees) for their livelihoods. Many people depend directly on the availability of usable land, water, plants and animals to support their families. In fact, ecosystems are the base of all economies.

Environmental health: The health of an ecosystem is closely related to the quality of life of its inhabitants. Biodiversity is a key component of the "environmental health" pillar of sustainable development.

Social equity: Biodiversity provides people with basic ecosystem goods and services. It provides goods such as food, fiber and medicine, and services such as air and water purification, climate regulation, erosion control and nutrient cycling.

How organic agriculture increases biodiversity

- Organic farms have a higher diversity of plants, insects and animals.
- Wildlife can find shelter more easily in the clusters of wild plants usually growing on organically managed land.
- Abundance of native plants comes with benefits for local animals that are perfectly adapted to live alongside them.
- An increase in both species abundance and richness. The variety of species includes native plants, birds, insects and soil organisms for soil fertility.
- Even species in charge of pollination were found at 50% higher abundance than at conventional farms.

On farm biodiversity enhancement

Biodiversity can be enhanced through on farm level or in field level. There are various farm levels farming system for conservation and enhancement of biodiversity. Some of these are as follows:

i) Homestead garden (Bari) system
ii) Agroforestry system
iii) Traditional farming system (Zabo farming)
iv) Azolla application in rice field
v) Integrated farming system
vi) Plantation of bamboo

Homestead garden (Bari) system

- A Homestead garden (Bari) of Assam has played a significant role in biodiversity conservation and management.
- Over 500 species of native and endemic ethno-medicinal flora are found in any ideal homeland Garden.
- Considered as living gene banks of native and endemic species, managed by communities and tribes with their inherent knowledge based idea and techniques (Nath, D., 2010) [11]

Fig 1: Bari System of Assam

Role of agroforestry in conserving biodiversity

Agroforestry has greater role in conservation of biodiversity. These are discussed below:

- It helps to preserve germplasm of sensitive species. *eg. Aquilaria malaccensis* (agar wood), an endangered and red listed species of India, was the most dominant tree in Home garden in Assam
- Intensification of agroforestry reduced exploitation of protected areas,
- Increasing the species diversity of trees in farming systems.

Traditional farming system

Zabo system of farming has the combination of forestry,

horticulture, agriculture, fishery and animal husbandry with well-founded soil and water conservation base.

Components

- Cereals and pulses
- Different seasonal vegetables
- Fruits
- Livestock : Cattle, Buffalo, Goat
- Fishes, snails and Asian snakehead

Application of azolla in paddy field

Dual cropping of azolla with rice significantly suppressed CH_4 emissions by the following ways:

- Enhance soil biological activity
- Encourage the growth of beneficial microorganisms and earthworms
- Suppress certain soil-borne plant diseases and parasites

Integrated Farming System:

Integrated Farming System promotes biodiversity as given below:

- Promote crop diversification
- Enhance crop yield and water productivity
- Improved livelihood and Cropping intensity
- Improved livelihood and Cropping intensity

Coral reef ecosystem management

- Protects coastline from erosion
- Employment to the fisherman
- Tourism
- Provide habitats and shelter for many marine organism

Role of bamboo in biodiversity conservation

- Plays a significant role in biodiversity conservation and contribute to soil and water management.
- The best known in Asia is the giant panda (*Ailuropoda melanoleuca*), the red panda (*Ailurus fulgens*) and the Himalayan black bear (*Selenarctos thibetanus*) are heavily dependent on bamboo.
- The smallest known bat (*Tylonycteris pachypus*, 3.5 cm) roosts between nodes of mature bamboo (*Gigantochloa scortechinii*), which it enters through holes created by beetles.

Threat to Biodiversity Conservation

- Declining natural resource base and exploitation of resources
- Habitat loss
- Poaching
- Fire and overgrazing
- Invasive alien species
- Climate change and desertification
- Pollution
- legal and administrative failure

Thrust area in biodiversity

- The prime thrust area is only conservation
- Earth summit in June 1992 at Rio de Janeiro, Brazil.
- Convention on Biological Diversity (CBD).
- Conservation of biodiversity- "A common concern of human kind"
- Every nation has "sovereign rights" over its biodiversity.
- India became a party to the convention in 1994

Conservation strategy at national level

- Biological Diversity Act, 2002 (Central Act No. 18 of 2003)
- Biological diversity rules, 2004
- Chapter VI sec. 22 to 25 of the Act calls for the establishment of state biodiversity boards by the state governments
- This act and rules provide guidance to union and state governments

Conservation strategy

In-situ Conservation-In nature (Protected area, Traditional farm, Nature reserve or National park) Ex-situ Conservation - Artificial condition (Zoo or Botanical Garden, Seed bank)

Case study: 1

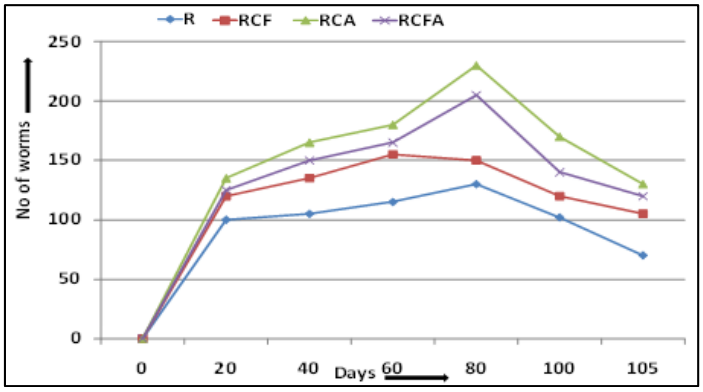

Fig 2: Population buildup of *E. fetida* in various mixtures of rice straw, cattle dung, azolla and fungus

Arora and Kaur (2018) conducted an experiment on Population buildup of *E. fetida* in various mixtures of rice straw, cattle dung, azolla and fungus.

In the study, rice straw (R, control) was mixed with cow dung (C), Azolla (A) and cellulytic fungus *Aspergillus terreus* (F) in different combination viz. RCF, RCA, RCFA and subjected to vermicomposting (Vcom-with Eisenia foetida). It was found that addition of azolla and cattle dung to two parts straw (RCA-666: 314:20g) caused fastest degradation (105 days), gave maximum population buildup of *E. fetida*. The results show that azolla reduces dependence on cattle dung for recycling the carbon rich straw and enhances its agronomic value.

In the study, rate of degradation was faster for mixture of vermicomposting. The RCA and RCFA were the first mixtures ready for harvesting. The difference in feed mixtures could be responsible for variation in the time required for degradation. Faster degradation of the mixtures in the V com group could have been due to combined action of earthworms and microbes. A variety of intestinal microorganism celluloses that enhance biodegradation of organic matter.

The result showed that better growth rate of earthworms in RCA can be due to more acceptability of this mixture as feed by the earthworms and/or due to the presence of components that were favorable for their growth. Peak weight of earthworms on 80th day and decline afterwards in the present study is similar to the results of Shak *et al* (2014) [14]. Who have reported similar trend in weight loss in *E. eugeniae* after 30 days of vermicomposting. The weight loss due to food shortage by the end of vermicomposting has been reported by Suthar (2007) [16].

Case Study: 2

Table 2: Shannon-Weaver diversity Index (H) and frequency of occurrence (O) of weed sp. And influence of earthworm population.

Production system	Weed in white cabbage		Weed in red beet		Earthworm population (no/0.25m^2)
	H	O	H	O	
Control	0.38	14	0.32	13	11.58
Conventional	0.66	18	0.59	17	11.25
Organic	0.86	29	0.81	28	22.41
IFS	0.74	20	0.64	19	13.0

Bevac and Bevac (2015) [4] studied the Shannon-Weaver diversity Index (H) and frequency of occurrence (O) of weed species and influence of earthworm population. Biodiversity index is significantly higher in organic farming as compared to other system.86 in organic vs 0.66 in conventional for cabbage and 0.81 in organic vs 0.59 in conventional for red beet). Similarly, earthworm population was also higher in organic (22.41) as compared to conventional farming (11.25). It showed that organic farming has lower impact in environment.

The emerged weed flora is more affected by agrochemicals input than seed bank which is buffered by the persistence of weed seed in the soil. It might be due to that organic farming system are generally associated with increased biological activity and increased below ground biodiversity. *Arbuscular mycorrhizal* fungi which can provide several benefit to the plant and ecosystem. Organic farming enhances *Arbuscular mycorrhizal* fungi and its ecosystem.

Case Study: 3

Table 3: Performance of fruit tree based agri-horti systems in the NEH region

Tree crop	Field crop	Variety of field crop	Trees ha^{-1}	Net return (Rs. ha^{-1})
Khasi Mandarin	Ground nut	JL-24	400	4541
	Soybean	Alankar	400	19625
	Turmeric	RCT-1	400	30375
	Ginger	Nadia	400	33416
Guava	Ground nut	JL-24	400	3000
	Soybean	Alankar	400	916
	Turmeric	RCT-1	400	2750
	Ginger	Nadia	400	15791
Assam lemon	Ground nut	JL-24	400	3500
	Soybean	Alankar	400	2583
	Turmeric	RCT-1	400	1916
	Ginger	Nadia	400	36625

Mohapatra *et al.* (2009) [10] conducted an experiment for the development of suitable agroforestry system for the region at ICAR Research Complex for NEH Region, Umiam in the year 1987 where various fruit trees were grown with different combinations of agricultural crops. The result showed that up to 7 years of planting we can grows field crops like groundnut, soybean, turmeric and ginger in the inter row spaces. However, after 7 years the yield of groundnut and soybean has declined due to gradual closer of the over stored canopy.

Out of these three fruit tree based system Assam lemon based agri-horti system was more profitable.

Case Study: 4

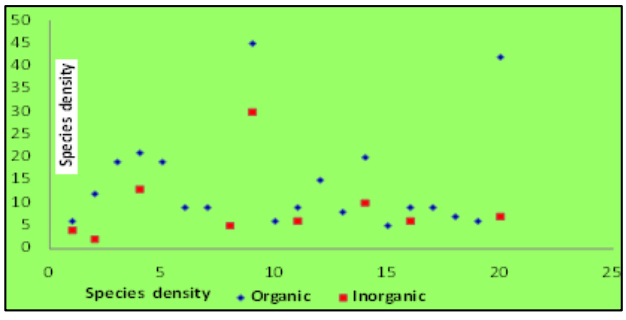

Fig 3: Species density profile for organic and inorganic agricultural sites

Padmavathy and Poyyamoli (2013) [13] studied in kuruvinatham and soriankuppam villages of Bahour community Puducherry during September 2008 to December of 2009. The present study investigated 30 farms-15 organic and 15 inorganic/conventional agricultural fields with varying agro forestry species composition and degree of commercialization.

Over the total study area, 75% (N=30) of the informants were found to possess one or more tree and fruit tree species in their plots. Altogether 20 species that included 15 fruit bearing species and 5 timber tree species were recorded during the study. In organic farming *Cocos nucifera* and *M. paradisiaca* were the dominant species with a density of 45(16.55) and 42 (15%) followed by *M. indica* and *B. flabellier* species with 20(7.3%) individuals, while in Inorganic farming *C. nucifera* (36.4%) and *B. flabellier* (14%) are the dominant species by *Musa paradisiaca* (9.4%) with 8 individuals. All the sites *C. nucifera*, *Musa paradisiacl*, *M. Indica* and *B. flabellier* were the dominant species in both farming system. All these species were found only on the field edges and boundaries.

Case study: 5

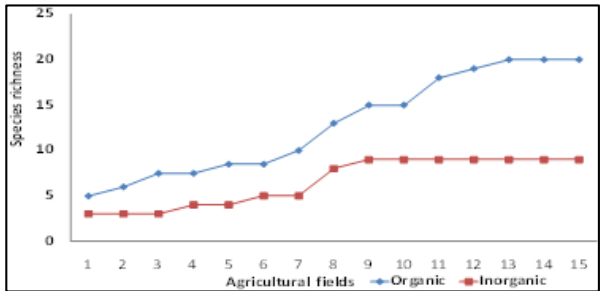

Fig 4: Species richness comparision between Organic and Inorganic Agricultural Sites

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Over the total study area, 75% (N=30) of the informants were found to possess one or more tree and fruit tree species in their plots. Altogether 20 species that included 15 fruit bearing species and 5 timber tree species were recorded during the study. From the above figure it was cleared that species richness and abundance was so slow in Inorganic farming fields (3 and 8) as compared to organic farming sites (5 and 20)

Case study: 6

Table 4: Crop diversity for yield increase and monetary value of different crops

Crop	Plant/m^2	Yield (t/ha)		Crop value (USD/ha)	
		1st yr	2nd yr	1st yr	2nd yr
Sugarcane	9.45	105.58	106.95	2522	2555
Maize	4.00	4.77	4.72	1355	1341
Potato	6.67	31.86	31.27	2058	2020
Maize	5.35	7.17	7.13	2037	2026
Intercropping	7.42	23.71	23.99	2687	2687
Potato	3.71	18.45	18.75	1192	1211
Maize	3.71	5.26	5.24	1495	1489
Wheat	277.36	5.29	5.31	1577	1577
Broad bean	2.69	0.98	0.97	474	469
Intercropping	280.05	6.27	6.28	2045	2045

Chengyun *et al.*(2009) in collaboration with farmers and extension personnel in Yunnan province, tested intercropping of sugarcane- maize, potato-maize, and wheat broad bean either by overlapping growing seasons or by mixing crop species based on differences in their heights. The three crop combinations were compared with their respective monocrops in adjacent plots.

Table 5: Land Equivalent Ratios for crop yields produced by intercropping

Intercropping	1st year	2nd year
Sugarcane/maize	1.63	1.65
Potato/maize	1.31	1.33
Wheat/broad bean	1.34	1.33

The results show that the yields of sugarcane were comparable between monocropped and intercropped plots. The intercropped maize produced an additional 4.77 and 4.72 t/ha in 2006 and 2007, respectively (Table 4). Constituting 64.0 and 63.2% of the production from the respective mono crops, with LER of 1.63 and 1.65 (Table 5). They also intercropped short and tall crops in the same field increasing the spatial utilization of farmland. The maize yields from intercropping were 147% in both years compared with equal areas of the mono crops. The intercropped potato yields in these two years were 115 and 120% compared with equal areas of monocrops (Table 4) resulting in LERs of 1.31 and 1.33.

The result show that intercropping resulted in additional broad bean production 0.98 and 0.97 t/ha in 2004 and 2005, respectively (Table 4) constituting 34.2 and 33.2% of the production from the mono crops, giving LERs of 1.34 and 1.33 in 2004 and 2005 (Table 5)

Such combination of crops took advantages of the differences in their height. Such intercropping resulted in improving growth through a more favorable microclimate. Intercropping short and tall plants may benefit crop growth by increasing light and air diffusion. Besides it boosted yields and reduced disease, produce higher LER and increase farmers income. Through intercropping system we can also enhances the field level crop diversity.

Case study: 7

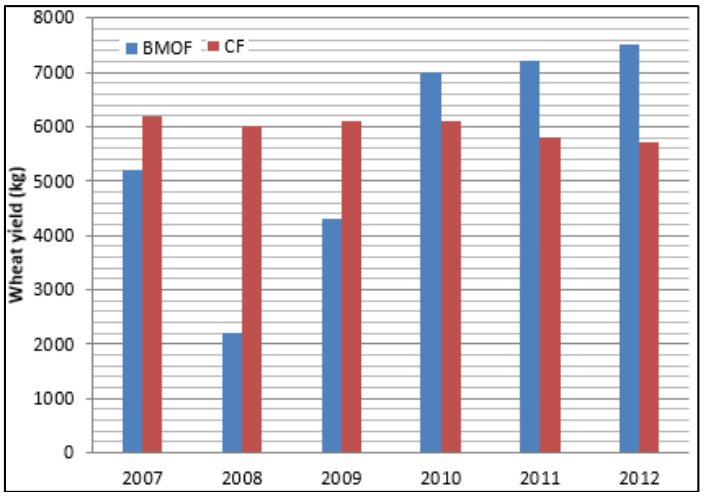

Fig 5: Effect of biodiversity management on organic farming on yield of winter wheat

Haitao *et al.* (2016) [8] conducted this experiment at Hongyi Organic Farm over six years and between Biodiversity Management Organic Farming (BMOF) and Conventional Farming (CF). Linking crop production with livestock to maximal uses of by-products from each production and avoid xenobiotic chemicals, we have achieved beneficial improvement in soil properties, effective pest and weed control, and increased crop yields. After six years they have obtained a gradual but stable increase in crop yields with a 9.6-fold increase in net income.

BMOF have 4 material circles, including 1) feeding cattle with crop residues; 2) using manure produced from earthworm digested composting cattle dung as fertilizer; 3) weed management by mulching farming land with chopped wheat straws and or labor; 4) Pest management through employing solar light traps and natural enemies.

The BMOF has resulted in a consistent increase of crop yields for winter wheat. At the end of six years the yield of winter wheat was 7,394 kg ha^{-1} over CF (5,900 kg ha^{-1}). The increased crop yield of winter wheat of BMOF lands might be

contributed by improved soil quality as well as by effective weed control and insect/pest control. Besides earthworms are well known to benefit soil nutrients via accelerating decomposition and mineralization of nutrient from organic residues. Using wheat straw for weed control reduces the cost of herbicide and residual toxicity to the soil.

Conclusion

Ecosystems are the basis of life and all human activities. Maintaining high biodiversity in agro-ecosystems makes agricultural production more sustainable and economically viable. Agricultural biodiversity ensures pollination of crops, biological crop protection, maintenance of fertility of soils, protection of soils against erosion, nutrient cycling. The benefits of the conservation of the species are important for future generations, because they may serve for medicine, genes useful in breeding and others. The effects of the loss of biodiversity may increase the sensitivity of the ecosystems to various abiotic and biotic stresses.

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