# Principles of Organic Farming

*Renewing the Earth's Harvest*

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Dr. Poonam Pande
Dr. Jitendra Singh

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## Acknowledgement

We at the NAVDANYA wish to acknowledge the farmers contributions who for centuries have grown and conserved diversity in their fields. In particular, we want to thank all those farmers who, through their participation in our conservation efforts are in effect co-authors of this work and are changing India's farm destiny to one of hope and health.

*The editorial team*

Vandana Shiva
Poonam Pande
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# Foreword

The contemporary crisis of Indian agriculture is evident with the epidemic of farmers' suicides due to unpayable debt and the return of hunger and starvation for the first time since 1942. The shift to ecological farming has become necessary for renewal of the earth's vital resources, for lowering costs of production and for increasing food security. We are publishing 'Principles of Organic Farming' to facilitate the transition to an agriculture which is sustainable, guarantees livelihood security and food security.

The demand for training in organic farming is increasing day by day. Most of the time the literature for training is available for certain specific aspects of organic farming, for example, dealing only on composting methods, or on pest management. The whole spectrum of technical skills and know-how needed for organic farming is not easily available in one place. Therefore, the present effort is to produce a document that describes the dimensions e.g., biodiversity conservation, seed supply, soil fertility maintenance, pest management, water conservation, issues of trade and distribution etc. of organic farming. Besides, environmental and health impact of chemical agricultue vs organic farming is essential for equipping any one interested in giving up toxic chemicals and shifting to ecological, sustainable farming methods.

Thus this manual for training in organic farming provides material for knowhow of organic farming from the seed to the market, from the field to the table. It also combines scientific principles of agro-ecology, soil ecology, and biodiversity conservation with practical tools that all organic farmers need to have.

Earlier publications and training manuals on biodiversity conservation and organic farming provided by Navdanya include:

- Sustaining Diversity
- Cultivating Diversity
- Biodiversity Based Productivity
- Ecological History of Food and Farming
- Trainer's Training Manual for Sustainable Agriculture and Biodiversity Conservation

The Navdanya team involved in organic farming practices over the last fifteen years comprised of practicing farmers and agro-ecologists. Each learning from the other, so that the farmer's knowledge accumulated over centuries combined with the latest insights in ecology to provide a sound and secure foundation for an organic future.

Navdanya is a movement to provide alternatives to industrial agriculture and globalised agriculture. It is also a movement for ecological security and economic security for small and marginal peasants. Navdanya has evolved creative, innovative, practical alternatives to the Green Revolution and Genetic Engineering, which have been reproduced across the country and other parts of the Third World.

Navdanya's solutions to the present crises faced by the farmers and farming across the globe is holistic and systemic. Our approach is holistic because it covers all aspects of production, not just singular input substitution techniques – organic manures in place of chemical fertilizers, plant based pesticides in place of synthetic pesticides. Navdanya's practical experience and training programs span across all production needs of farmers – seeds, soil fertility, pest control, and water conservation. Our practice and programs cover the entire food chain-from farmer's fields to the tables and kitchens of consumers. We support sustainable production with social justice and fairness in distribution and trade.

Navdanya has facilitated the establishment of more than 50 community seed banks and biodiversity conservation centers in different regions of India. Helping more than 200,000 farmers make a transition to organic farming through training by Navdanya and its partners in Uttaranchal, Uttar Pradesh, Bengal, Orissa, Tamil Nadu, Karnataka, Punjab and Rajasthan.

Besides working directly with farmers in Uttaranchal and U.P., Navdanya has helped organizations to set up programmes for promoting biodiversity conservation and organic farming in different states over the past two decades.

***Karnataka***

- Green Foundation
- Prakriti Sanraksha Kendra

***Tamilnadu***

- CIKS

***West Bengal***

- Vrihi

***Orissa***

- PBSSA

***Rajasthan***

- Jagran Jan Vikas Samiti

***Uttar Pradesh***

- Vigyan Siksha Kendra, Manav Sewa Sansthan, Janhit Foundation

***Uttaranchal***

- Navdanya
- Beej Bachao Andolan

***Madhya Pradesh***

- Kisani Bija Abhiyan

***Jammu and Kashmir***

- Ladakh Women's Alliance
- Ladakh Ecology Group

This manual built on fifteen years of the work by the Navdanya team as well as the additional scientific contribution by Dr. Poonam Pande, our soil-ecology specialist and Dr. Jitendra Singh, ecological pest and disease management specialist.

We hope this manual will help spread the organic movement faster and further in India and will be useful resource for a shift from chemical to organic farming for farmers, NGOs, Government and Universities.

In dedication to an organic future,

***Dr. Vandana Shiva***
*Founder and President*
*Navdanya*

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**PART I**

CHAPTER I

# Chemical farming:
# *The suicide economy*

Over the years, India has experienced several revolutions viz., green, yellow, blue, white and brown but the most notable is the green revolution. This revolution was claimed as a success by projecting that it had made the nation self-reliant with surplus food for the ever increasing population. The misplaced glory of Green revolution was on the basis of the use of High Yielding Varieties (HYVs), heavy doses of chemical fertilizers, pesticides, and heavy farm mechanization that led to unprecedented pressure on our natural resource base. In the initial stages, green revolution lead to an increase in the production of mainly two crops wheat and rice, but the cost paid was in terms of destruction of other crops – millets, oilseeds, pulses and over exploitation of precious water resources and fertile soils. The heavy chemical dosage deteriorated the physical, chemical and biological properties of soil, increased soil salinity and pollution of ground water resources. The use of pesticides has been posing serious environmental and health problems. The cultivation of HYVs has resulted in reduction of on-farm green biomass, thereby changing the mode of traditional agriculture resulting in the disappearance of cattle from the farms, reducing biodiversity, reducing biological productivity, reducing nutrient recycling and thus creating a crisis of non-sustainability, both economic and ecological.

## 1.1 Chemical inputs: unnecessary hazards

At present, though the world produces enough food for its population yet we have not been able to address hunger adequately at household level. It is not the result of insufficient food production, but it is of erosion of entitlements either lack of means to pay for, or to grow the food, appropriating land, water and natural resources for the weaker sections of the society. The green revolution, inspite of recklessly exploiting natural resources projected a false yield increase in its initial stages by focusing on monocultures and externalizing ecological and environmental costs. This "yield" resulted from combinations of high yielding varieties of seeds, chemical fertilizers, pesticides and irrigation that were exorbitantly priced — the production which can not be considered sustainable. After the initial subsides were withdrawn, this deadly combination has resulted in pushing farmers into a debt trap that has resulted in the widespread disturbances of the ecological, economic, social and cultural fabric of erstwhile robust and vibrant rural India. The crisis is being deepened with globalization, as opportunistic and greedy corporates, trap farmers deeper into debt with non-renewable seeds and toxic agrochemicals. Globalization has translated into high costs of production and collapsing prices for farm produce, a recipe for a "Suicidal Economy" where thousands of farmers are committing suicide across the country.

### *1.1.1 The impacts of the green revolution*

With the green revolution came the advent of chemical fertilizers replacing organic agriculture. Though it seemed that green revolution resulted in increase of crop yield and production, but actually it was observed that these practices damaged the soil structure irreversibly over the years. When the soil productivity graph declined, the farmers resorted to increase the dosage of chemical fertilizers to sustain farm production. The increased chemical inputs resulted in soil toxicity, disturbed the soil micro-environment and there-by impeded organic matter recycling. The introduction of pesticides led to poisoning of soil, air, water and crops through enhanced bio-concentration of pesticides.

The use of pesticides and fertilizers are the main components of green revolution. Prior to the green revolution, diversity in crops was a key factor in agricultural systems of India. This diversity provided stability and resilience to the systems as well as economic security to the farmers. However green revolution methods, emphasize upon mono-croppings and highly mechanized farming focused on single function of single species, and failed to take, yields of diverse species and diverse functions into account. The reason for advocating mono-cropping was the ease in sowing; weeding, fertilizing, spraying and harvesting a single crop that lead to replacement of traditional practice of growing different types of crops (poly-culture). This resulted in the erosion of genetic diversity base of the agro-ecosystems.

## 1.2 Threats to agro-biodiversity from the green revolution and genetic engineering

### *1.2.1 Destruction of habitat and agro-ecosystems*

The major reason for the destruction of the agrobiodiversity is the conversion of multifunctional, integrated agroecosystems into production units — "factory farms". Trees, hedge-rows, community forests have been destroyed; north west India had more trees on farms than in forests before the green revolution. The destruction of agrobiodiversity have resulted in depriving the marginal farmers getting multiple products from the farms.

### *1.2.2 Monoculture production: promotion of green revolution*

Monoculture is the single biggest factor that has resulted in the loss of biodiversity through out the country. The country has been forced into this practice first due to green revolution policies and now by large multinationals aiming to push their single product in the market to create and capture producers. This has resulted in abandoning of the species of mixed cropping which ensured sustainability through the mutually beneficial relationships between species eg. cereals and nitrogen fixing pulses and household food security. In many parts people are growing crops that are not suitable to the agroclimatic zone, e.g. in many arid regions, in Maharastra and Gujarat sugarcane monoculture has been promoted by World Bank loan conditionalities, leading to non-sustainable use of already scarce ground water resources.

### *1.2.3 Narrowing the variety base*

Not only has the crop diversity been reduced drastically, the numerous varieties of an individual crop have drastically narrowed. Thousands of rice varieties have been replaced by a handful of dwarf varieties. A Chinese study has recently shown that increasing rice diversity reduces pests and diseases occurrence and increase in productivity per unit area. Further, the native varieties are not necessarily always low yielding. At times varieties like "Basmati" in rice and "Sharbati" in wheat bring farmers double/triple the income because of its quality.

### *1.2.4 The new threat of genetically engineered seeds*

*Bacillus thuringiensis* (Bt) cotton was the first genetically engineered crop cleared for commercial planting in 2002. However, the yields were only 10% of the promised yields and losses ran upto Rs. 25,000 per ha due to high seed costs and high chemical use. In 2003, the Government's Genetic Engineering Approval Committee (GEAC) did not clear genetically engineered Bt. Cotton for new areas in northern India.

The Indian experience with genetic engineering was not translated into either higher yields or higher incomes. The failure of the GE promise makes the need to conserve farmers varieties even more imperative.

The use of pesticides that are not only lethal for the target organism but also to a whole variety of other strands of the delicate food system. This has resulted in the creation of super pests and super weeds. The super pests have developed immunity to the pesticides. The super weeds are not killed by herbicides, the GE canolla plant in Canada is one horrific example of this process.

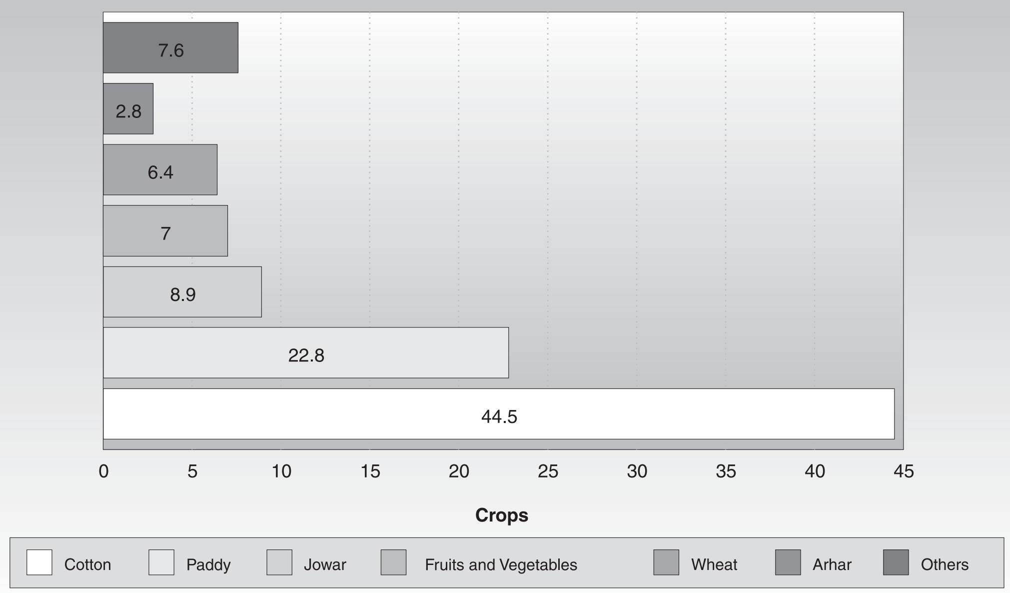
## 1.3 Chemical agriculture

The bane of modern day farming system is the incessant and indiscriminate use of chemicals. These chemicals are not only polluting the grains and the food we eat, they are responsible for the widespread decline in the fertility status of the soil. The use of chemicals is resulting in wiping of the indigenous population of the organism such as mycorrhizal fungi, actinomycetes and thus disturbs the nutrient cycling of the soil eco-system. The harm of chemicals by the process of bio-magnification and bio-concentration has lead to the accumulation of these chemicals both in the tissues of the crop and also of the humans who are ultimately the primary consumers.

## 1.4 Pesticides

About 80,000 tons of pesticides are used in agriculture in India annually (Srinivasan, 1997), mostly in cotton and rice. While cotton is planted on about 5% of the total cultivable area (on about 8 million hectares out of a total of 170 million), it accounts for about 45% of pesticide application (Dhaliwal and Pathak, 1993). Rice accounts for another 23%. (Fig 1.1)

**Fig. 1.1 Crop wise consumption of pesticides in India**




***Dudani and Sengupta, 1991.***

The intensive use of pesticides in agriculture is a cause of serious concern because many of the pest are developing resistance to pesticides and the presence of pesticide residues in agricultural and dairy products. Pesticide resistance in agriculture was first noticed in India in 1963 when a number of serious pests were reported to have become resistant to DDT and HCH (two of the most commonly used pesticides during the 1960s and 1970s). Since then the number of pests with pesticide resistance has increased. The most serious problem of resistance is witnessed in cotton, for which American bollworm is a serious pest. The bollworm has developed resistance to almost all pesticides in a number of regions, and is particularly serious in parts of Punjab, Haryana, Andhra Pradesh, Karnataka and Maharashtra.

Other important pests of cotton, white fly and jassid, have also developed pesticide resistance in some localities. Growing pesticide resistance has meant that a large proportion of agricultural production is lost to pests. According to some estimates, these losses across the crops amount between 20-30% of the total production. The losses are particularly serious in cotton in the year 1997 and 1998 cotton production in Punjab declined by about 50% causing a number of cotton farmers to commit suicide.

Pesticide resistance has mainly been caused by excessive and indiscriminate use of pesticides (Jayaraj, 1989).

The pesticides used in farms are broad-spectrum i.e. they don't distinguish between the harmful and the useful insects in farm. The application results in the annihilation of both the harmful pests and useful predators as well. Generally the life cycle of the pests is short while rate of reproduction is high. Therefore, these pests develop resistance by bringing changes in their genetic make up in a short period of time. On the other hand, the life cycle of the predators is compartively longer and the reproduction is low and hence it takes much longer time for them to develop resistance to pesticides. Continuous use of pesticides kills and wipes out all the beneficiary insects from the farm field. In the absence of predators and abundance of food, the resistant pest populations, thrives.

### *1.4.1 Case study*

The wide spread use of DDT to control mosquitoes, fruit flies and crop pests is common. A single genetic mutation protects fruit flies from the lethal effects of DDT. Surprisingly, every resistant fly had precisely the same genetic change. The researchers could not find mutation in any fly strains collected in the 1930's prior to the use of DDT. Once the resistance is developed it is difficult to eliminate resistance to an insecticide even if you stopped using it. *(Source: The Tribune, March, 2003)*

According to Pimentel, 1995 only 0.1% of pesticides actually reaches the target pests and the rest go to non- target sectors. It has also been estimated that despite heavy pesticide use pests are now causing damage to some 30% of the crops as against pre-pesticide era of 5-10% damage. Thus, indirectly pesticides have increased the number of resistant pests and resulted in enormous crop damage. According to the estimates there are 5-10 million insect species in an ecosystem and only 0.03% of these cause damage directly or indirectly to the crops. As per estimates while in 1920 there were some 40 damaging insects against paddy these had increased to 200 in the period from 1992 to 2000. For pulses it was 10 in 1920 while 240 in 1995. In case of sugarcane the figure for 1920 was 20 which has risen up to 220 in 1992 while for cotton these


were 30 in 1920 and 150 in 1992, for wheat these were 10 and 120 for the year 1920 and 1992 respectively.

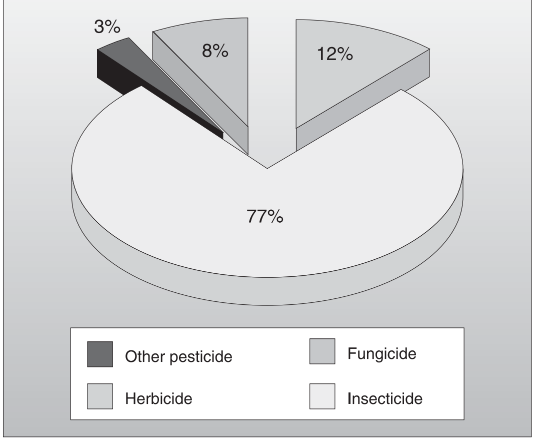


**Fig. 1.2 % Consumption of different groups of pesticides in India**

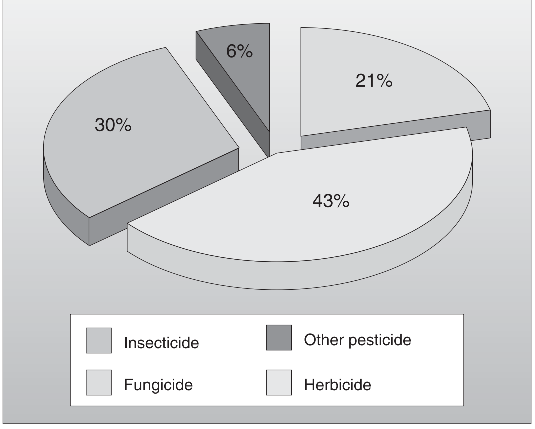


**Fig. 1.3 % Consumption of different groups of pesticides in the World**

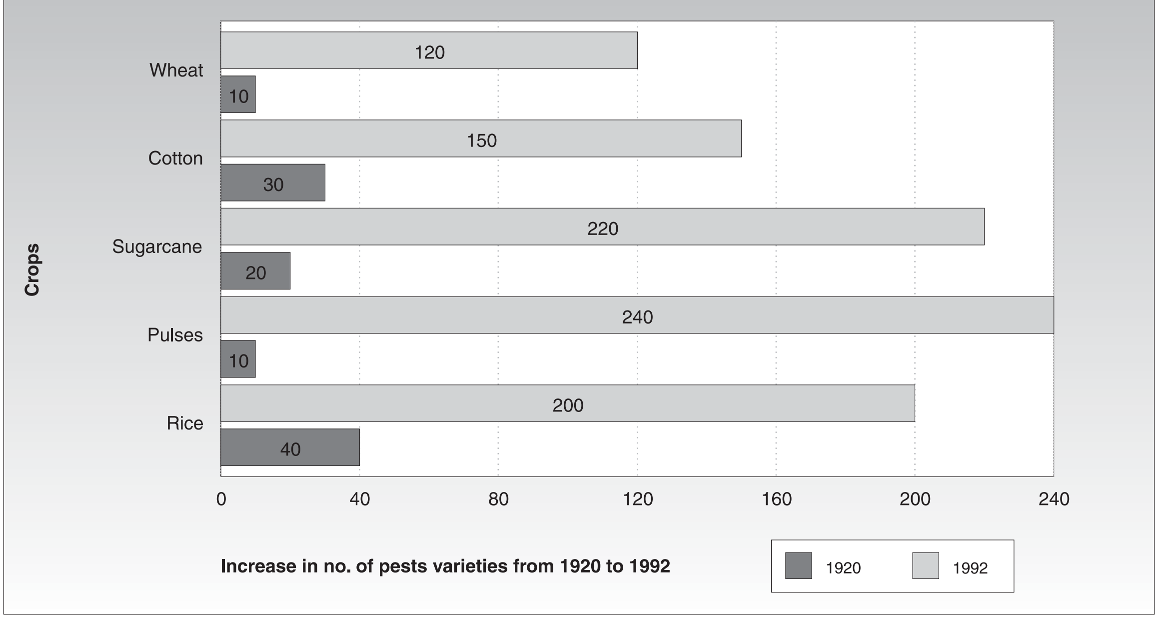


**Fig. 1.4 Pesticides aiding in increasing pests varieties by mutation**

**List of pesticides banned**

(as on 17.06.02)

**Table 1.1: List of pesticides registered for use in the country under section 9(3) of the Insecticides Act, 1968 (June 2002)**

| *S.No.* | *Name* | *WHO Class* |
|---|---|---|
| 1. | 2-4-Dichlorophenoxy acetic acid | II |
| 2. | Acephate | III |
| 3. | Acetamiprid | |
| 4. | Alachlor | III |
| 5. | Aldicarb | Ia |
| 6. | Allethrin | III |
| 7. | Alphacypermethrin | O |
| 8. | Alphanapthyl acetic acid | |
| 9. | Aluminium phosphide | |
| 10. | Anilophos | II |
| 11. | Atrazine | U |
| 12. | Aureofungin | |
| 13. | Azadirachtin (neem products) | |
| 14. | Bacillus thuringiensis | |
| 15. | Barium carbonate | III |
| 16. | Benomyl | U |
| 17. | Benthiocarb (thiobencarb) | II |
| 18. | Bitertanol | U |
| 19. | Bromadiolone | Ia |
| 20. | Butachlor | U |
| 21. | Captafol | Ia |
| 22. | Captan | U |
| 23. | Carbaryl | II |
| 24. | Carbendazim | U |
| 25. | Carbofuron | Ib |
| 26. | Carbosulfan | II |
| 27. | Carboxin | U |
| 28. | Cartap hydrochloride | U |
| 29. | Chlorimuron ethyl | U |
| 30. | Chlormequat chloride | III |
| 31. | Chlorobenzilate | III |
| 32. | Chlorofenvinphos | Ib |
| 33. | Chlorothalonil | U |
| 34. | Chlorpyriphos | II |
| 35. | Cinmethylene | U |
| 36. | Copper hydroxide | III |
| 37. | Copper oxychloride | III |
| 38. | Copper sulphate | II |
| 39. | Coumachlor | U |
| 40. | Coumatetralyl | Ib |
| 41. | Cuprous oxide | II |
| 42. | Cyfluthrin | II |
| 43. | Cyhalofop-butyl | U |
| 44. | Cymoxanil | III |
| 45. | Cypermethrin | II |
| 46. | Cyphenothrin | II |
| 47. | Dalapon | U |
| 48. | Dazomet | III |
| 49. | Decamethrin (deltamethrin) | II |
| 50. | Diazinon | II |
| 51. | DDT | II |
| 52. | Dichloropropene and dichloropropane mixture (DD mixture) | F |
| 53. | Dichlofop methyl | III |
| 54. | Dichlorvos (DDVP) | Ib |
| 55. | Dicotol | III |
| 56. | Dieldrin | |
| 57. | Difenoconazole | III |
| 58. | Diflubenzuron | U |
| 59. | Dimethoate | II |
| 60. | Dinocap | III |
| 61. | Diathianon | III |
| 62. | Diuron | U |
| 63. | Dodine | III |
| 64. | D-trans allethrin | |
| 65. | Edifenphos | Ib |
| 66. | Endosulfan | II |
| 67. | Ethephon | U |
| 68. | Ethion | II |
| 69. | Ethofenprox (etofenprox) | U |
| 70. | Ethoxysulfuron | |
| 71. | Ethyline dibromide (EDB) | F |

| S.No. | Name | WHO Class |
|---|---|---|
| 72. | Ethyline dibromide and carbon tetrachloride mixture (EDCT mixture) | |
| 73. | Fenarimol | U |
| 74. | Fenazaquin | II |
| 75. | Fenitrohion | II |
| 76. | Fenobucarb | II |
| 77. | Fenoxaprop-p-ethyl | U |
| 78. | Fenopropathrin | II |
| 79. | Fenthion | II |
| 80. | Fenvalerate | II |
| 81. | Ferbam | U |
| 82. | Fipronil | II |
| 83. | Fluchloratin | III |
| 84. | Flufenoxyuron | U |
| 85. | Fluvalinate | U |
| 86. | Formothion | II |
| 87. | Fosetyl-Al | U |
| 88. | Gibberellic acid | U |
| 89. | Glufosinate ammonium | III |
| 90. | Glyphosate | U |
| 91. | Hexaconazole | U |
| 92. | Hydrogen cynamide | F |
| 93. | Imazethapyr | U |
| 94. | Imidacloprid | II |
| 95. | Indoxacarb | U |
| 96. | Iprodine | |
| 97. | Isoprothiolane | III |
| 98. | Isoproturon | III |
| 99. | Kasugamycin | U |
| 100. | Kitazin (probenfos) | III |
| 101. | Lambdacyhalothrin | II |
| 102. | Lime sulphur | F |
| 103. | Lindane | II |
| 104. | Linuron | U |
| 105. | Malathion | III |
| 106. | Maleic hydrazide (MH) | U |
| 107. | Mancozeb | U |
| 108. | Metafaxyl | III |
| 109. | Metaldehyde | II |
| 110 | Metasulfuron methyl | |
| 111. | Methabenzthiazuron | U |
| 112. | Methomyl | Ib |
| 113. | Methoxyl ethyl mercury chloride (MEMC) | U |
| 114. | Methyl bromide | F |
| 115. | Methyl chlorophenoxy acetic acid (MCPA) | III |
| 116. | Methyl parathion | Ia |
| 117. | Metolachlor | III |
| 118. | Metoxuron | U |
| 119. | Metabuzin | U |
| 120. | Monocrotophos | Ib |
| 121. | Myclobutanil | III |
| 122. | Nickel chloride | F |
| 123. | Oxadiargyl | |
| 124. | Oxadiazon | U |
| 125. | Oxycarboxin | U |
| 126. | Oxydermeton-methyl | Ib |
| 127. | Oxyfluorten | U |
| 128. | Paclobutrazole | III |
| 129. | Paradichlorobenzene (PDCB) | III |
| 130. | Paraquat dichloride | II |
| 131. | Penconazole | U |
| 132. | Pendimethalin | III |
| 133. | Permethrin | II |
| 134. | Phenthoate | II |
| 135. | Phorate | Ia |
| 136. | Phosalone | II |
| 137. | Phosphamidon | Ia |
| 138. | Propanil propanil | |
| 139. | Prallethrin | II |
| 140. | Pretilachlor | U |
| 141. | Primiphos-methyl | III |
| 142. | Profenophos | II |
| 143. | Propanil | III |
| 144. | Propetamphos | Ib |
| 145. | Propiconazole | II |
| 146. | Propineb | U |
| 147. | Propoxur | II |
| 148. | Pyrethrins (pyrethrum) | II |
| 149. | Quinalphos | II |
| 150. | Simazine | U |
| 151. | Sirmate | |

| S.No. | Name | WHO Class |
|---|---|---|
| 152. | Sodium cyanide | Ib |
| 153. | Spinosad | U |
| 154. | Streptomycin+ tetracycline | |
| 155. | Sulfosulfuron | |
| 156. | Sulphur | U |
| 157. | Tebuconazole | U |
| 158. | Temephos | U |
| 159. | Thiodicarb | II |
| 160. | Thiomethoxin | |
| 161. | Thiometon | Ib |
| 162. | Thiophanate methyl | U |
| 163. | Thiram | III |
| 164. | Transfluthrin | U |
| 165. | Triadimefon | III |
| 166. | Triallate | III |
| 167. | Triazophos | Ib |
| 168. | Trichloro acetic acid | II |
| 169. | Trichlorofon | III |
| 170. | Tricyclazole | II |
| 171. | Tridemorph | II |
| 172. | Trifluralin | U |
| 173. | Validamycin | U |
| 174. | Warfarin | Ib |
| 175. | Zinc phosphide | Ib |
| 176. | Zineb | U |
| 177. | Ziram | III |

Pesticides Banned for manufacture, import and use

- Aldicarb
- Aldrin
- Benzene hexachloride
- Calcium cyanide
- Chlorbezilate
- Chlordane
- Copperacetoarsenate
- Dibromochloropropane (DBCP)
- Dieldrin
- Endrin
- Ethyl mercurychloride
- Ethyl parathion
- Ethylene dibromide (DBCP) use banned w.e.f. 17 .7.03
- Heptachlor
- Maleic hydrazide (banned w.e.f. 17.7.2003)
- Menazon
- Nitrofen
- Paraquat dimethyl sulphate
- Pentachlor nitrobenzene PCNB
- Pentachlorophenol (PCP)

- Sodium methane arsenate (MSMA)
- Tetradifon
- Toxafen
- Trichloroacetic acid (banned w.e.f. 17.7.03)

**List of pesticide formulations banned**

- Carbofuran 50% G
- Methomyl 12.5% L
- Methomyl 24% L
- Phosphaamidon 85% SL

***Pesticides/Pesticide formulations banned for use but their manufacture is allowed for export***

- Captafol 80% (use banned w.e.f. 17.7.03)
- Nicotin sulphate
- Phenyl mercury acetate

**List of restricted pesticides**

- Aluminium phosphide
- DDT
- Lindane
- Methylamide
- Methyl parathion
- Sodium cyanide
- Thiram

(as on 17.06.02)

According to the 1991 census, about 67% of the entire economically active workforce - i.e. about 180 million people - was engaged in agriculture (*Source: Employment Information: Indian Labour Statistics 1994. Chandigarh: Labour Bureau, Ministry of Labour, 1996*). Thus, a large segment of the Indian population is exposed occupationally and/or environmentally to some types of pesticides hazards. The evidences accumulated over the last few decades indicate that the use of such chemicals in agriculture has much greater health risks than was originally believed. For farmers awareness to the trade and common names of the chemical pesticides following table has given.

## List of trade and common name of pesticides

**Acaricides**

| Trade name | Common name |
|---|---|
| Abamex | Abamectin 1.8% EC |
| Dictator-57 | Propargite 57% EC |
| Dictator-plus | Propargite 21.2% + tetradifon 7.5 EC |
| Dinomite | Pyridaben 20% WP |
| Profezon-25 | Buprofezin 25% WP |
| Vapcomic | Abamectin 1.8 % EC |
| Vapcothion | Dicofol 25% + tetradifon 8% EC |
| Vapcothion-22 | Dicofol 16% + tetradifon 6% EC |
| Vapcozin-20 | Amitraz 20% EC |

**FUNGICIDES**

| | |
|---|---|
| Adifon | Triadimefon 25% WP |
| Benomyl-50 | |
| (benovap) | Benomyl 50% WP |
| Canvil | Hexaconazole 5% SC |
| Chloronil | Chlorothalonil 75% WP |
| Coproxide | Copper hydroxide 77% WP |
| Criptan | Captan 50% WP |
| Curtine-v | Cymoxanil 4% + mancozeb 46.5% WP |
| Cycuron-25 | Pencycuron - 25% WP |
| Foldan | Folpet 50% WP |
| Mancothane | Mancozeb 80% WP |
| Mantox | Mancozeb 20%+ copper oxychloride 21.5% |
| Mantox – forte | Mancozeb 20% + (copper oxychloride + copper sulfate+copper carbonate) 21.5% *Stimulant additive: (iron sulfate) 6% WP* |
| Mazal | Imazalil 21.2% EC |
| Master | Prochloraz - 25% WP |
| Prolex | Procymidone 50%WP |
| Rover | Iprodione 50% WP |
| Seedguard | Oxine copper 10% WP |
| Seedguard-40 | Oxine copper 40% WP |
| Tachigazole | Hymexazol 30% SL |
| Titanol vapco | Bitertanol 25% WP |
| Vacomil mz-72 | Matalaxyl 8% + mancozeb 64% WP |
| Vacomil-5 | Metalaxyl 5% G |
| Vacomil 35 | Metalaxyl 35% WP |
| Vacomil-plus 50 | Metalaxyl 15% + copper oxychloride 35% WP |
| Valete | Fosetyl-aluminium 80% WP |
| Vapcotop 70 | Thiophanate-methyl 70% WP |
| Vydan | Triadimenol 25% EC |

**HERBICIDES**

| | |
|---|---|
| Blast | Bentazone 44.1 SL |
| Esterdefore | 2,4-d isooctyl ester 62% EC |
| Ground-up gland-up | |
| Glytex | Glyphosate ipa 48% bio-activator 17% SL |
| Hadaf | Oxyfluorfen 24% EC |
| Hawk | Ioxynil octanoate 25% EC |
| Herbiflurin | Trifluralin 48% EC |
| Herbikill | Paraquat 20% SL |
| Herbstar | Oxadiazon 25%EC |
| Oscar | Tribenuron-methyl 75% WP |
| Propanil - 36 | Propanil 36% EC |
| Vapcor | Metribuzin 70% WP |

**INSECTICIDES**

| | |
|---|---|
| Abamex | Abamectin 1.8% EC |
| Acephate - 50 | Acephate 50% WP |
| Agrinate-24 | Methomyl 24% SL |
| Agrinate-90 | Methomyl 90% SP |
| Boxer | etofenprox 30% EC |
| Bright | Carbosulfan 25% EC |
| Carbaryl-10 | Carbaryl 10% DP |
| Carbaryl-s 85 | Carbaryl 85% WP |
| Cartap | Cartap 50% SP |
| Chlorofet | Chlorpyrifos 48% EC |
| Commando-5 | Imidacloprid 5% GR |
| Commando | Imidacloprid 20% SL |
| Commando-35 | Imidacloprid 35% SC |
| Commando-70 | Imidacloprid 70% WP |
| Cypermethrin-5 | Cypermethrin 5% EC |
| Cypermethrin-10 | Cypermethrin10% EC |
| Cypermethrin-20 | Cypermethrin 20% EC |
| Dacorn-98 | Dazomet 98% G |
| Davonil-35 | Endosulfan 35% EC |
| De de vap | Dichlorvos 50% EC |
| Deltarin-2.5 | Deltamethrin 2.5% EC |
| Deltarin-2.8 | Deltamethrin 2.8% EC |

| | |
|---|---|
| Diazinon-5 (vazinon) | Diazinon 5% G |
| Diazinon-10 (vazinon) | Diazinon 10% G |
| Diazinon-40 (vazinon) | Diazinon 40% EC |
| Diazinon-60 (vazinon) | Diazinon 60% EC |
| Fast | Esfenvalerate 5% EC |
| Fenatode | Fenamiphos 10% G |
| Fenikill | Fenvalerate 5% + fenitrothion 25% EC |
| Fenikill-99.5 | Fenvalerate 0.5% + fenitrothion 99% ulv |
| Patron | Diflubenzuron 25% WP |
| Permethrin 10 | Permethrin 10% EC |
| Phoenix | Lambda-cyhalothrin 5% EC |
| Profezon | Buprofezin-25 WP |
| Senthion-50 | Fenitrothion 50% EC |
| Senthion-s 100 | Fenitrothion 100% ULV |
| Supertak-5 | Alpha-cypermethrin 5% EC |
| Supertak-10 | Alpha -cypermethrin 10% EC |
| Trivap | Cyromazine 75% WP |
| Ultracidin | Methidathion 40% EC |
| Vapcocidin-20 | Fenvalerate 20% EC |
| Vapcomore | Acetamiprid 20% SP |
| Vapcodan | Carbofuran 10% G |
| Vapcotol | Fenpropathrin 10% EC |
| Vap-malathion-50 | Malathion 50% EC |
| Vap-malathion-57 | Malathion 57% EC |

**OILS**

| | |
|---|---|
| Samarol | Mineral oil 96% EC |
| Winterol-s | Mineral oil 96% EC |

**PUBLIC HEALTH INSECTICIDES**

| | |
|---|---|
| Cypothrin | Cypermethrin 40% EC |
| Delete | Deltamethrin 2.5% EC |
| Diazinon-60 | Diazinon 60% EC |
| Dustrin | Malathion 5% DP |
| Goldben | Methomyl 1% + z-9 tricosene 0.05% |
| Killer | Cypermethrin 10% EW |
| Magic | Alpha-cypermethrin 10% EC |
| Persect-0.5 | Permethrin 0.5% DP |
| Persect-25 | Permethrin 25% WP |
| Phinco-t22 | Permethrin 9.75% + tetramethrin 1.5% + piperonyl butoxide 11.25% |
| Shamel | Fenitrothion 50% EC |
| Sniper-10 | Cypermethrin 10% EC |
| Superkill-32 | Cypermethrin 12% + tetramethrin 4% + piperonyl butoxide 16% EC |
| Terminator | Deltamethrin 2.5% WP |
| Tornado | Lambda-cyhalothrin 2.5% EC |
| Tornado-forte | Lambda-cyhalothrin 1% + tetramethrin 4% + piperonyl butoxide 5% EC |
| Vapcocidin-20,10 | Fenvalerate 20%,10% EC |
| Vector | Propoxur 20% EC |

**RODENTICIDES**

| | |
|---|---|
| Lafar | Bromadiolon 0.005% (wax block) |
| Nofar-1 | Brodifacoum 0.005% (pellet) |
| Nofar-2 | Brodifacoum 0.005% (wax block) |

**MISCELLANEOUS**

| | |
|---|---|
| Lafar | Bromadiolon 0.005% (wax block) |
| Nofar-1 | Brodifacoum 0.005% (pellet) |
| Nofar-2 | Brodifacoum 0.005% (wax block) |

## 1.5 Chemical fertilizers

Chemical fertilizers are inorganic chemical preparations added in soil to supplement nutrient deficiency. Chemical fertilizers increase the yield, but with its constant application result in damage to the soil environment, causing immobility of many essential soil nutrients resulting in kanker pan in the terrestrial ecosystem and eutrophication in the aquatic system. The exhausts from chemical factories producing them are heavily loaded with oxides of sulphur and nitrogen, which may results in to acid rains.

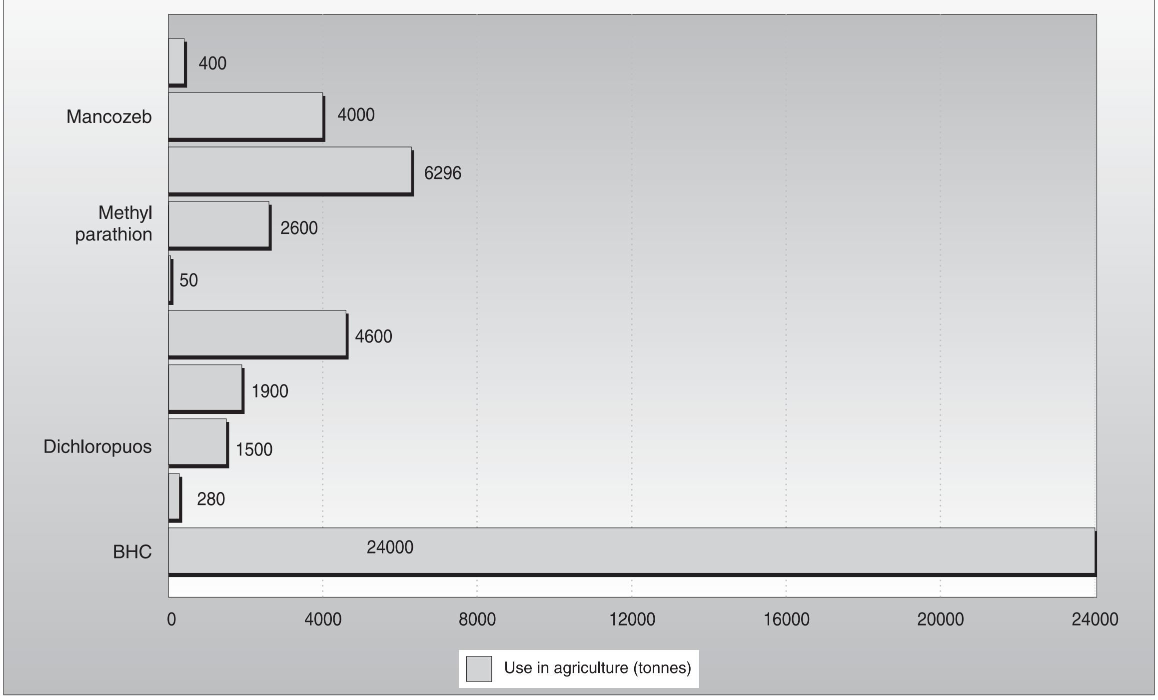
**Table 1.2 Pesticides used on different crops**

| *Crop* | *Pesticide* |
|---|---|
| Rice | HCH, carbofuran, butachlor, triazophos, quinalphos and chloropyriphos |
| Maize | Atrazine, carbofuran and endosulphan |
| Wheat | Aldrin, chlorpyriphos and endosulphan |
| Sorghum | Carbofuran |
| Pearl millet | Metalaxyl |
| Mustard | Lindane, chlorpyriphos and quinalphos |
| Groundnut | Lindane, quinalphos, chlorthalonil and mancozeb |
| Sesamum | Lindane, chlorpyriphos and quinalphos |
| Cotton | Endosulphan, fenvalerate, cypermethrin and deltamethrin. |
| Pea | Fenvalerate and lindane |
| Tomato | Monocrotophos, dimetheoate, endosulfan, fenvalerate, cypermethrin and deltamethrin |
| Cauliflower | Endosulphan, monocrotophos and fenvelerate |
| Okra | Monocrotophos, endosulphan, triazophos and fenvelerate |
| Brinjal | Monocrotophos, endosulphan, triazophos and fenvelerate |
| Chillies | Lindane, quinalphos, dicofol and mancozeb |
| Cabbage | Carbaryl, endosulfan, fenvelerate, cypermethrin and deltamethrin |
| French beans | Monocrotophos and quinalphos |
| Green peas | Carbaryl and phosphamidon |
| Chickpea | Fenvelerate and lindane |
| Pigeonpea | Fenvelerate and lindane |
| Green gram | Fenvelerate, chlorpyriphos, quinlphos, chlorthalonil, mancozeb and lindane |
| Black gram | Fenvelerate, chlorpyriphos, quinlphos, chlorthalonil, mancozeb and lindane |
| Sugarcane | Quinalphos, carbaryl, sevidol, carbofuran and phorate |
| Pepper | Quinalphos and dimethoate |
| Cardamom | Fenthion, monocrotophos and quinalphos |
| Sunflower | Lindane, chlorpyriphos and quinalphos. |
| Safflower | Lindane, chlorpyriphos and quinalphos. |

*Source: Indian Council of Agriculture Research*

On the contrary, in traditional farming practices the soil is enriched periodically by addition of organic manure, such as cow dung, bone meal, and crop residues. In this system the soil supports a healthy population of earthworms, bacteria, fungi, actinomycetes, protozoa, millipedes, insects, spiders and a host of other creatures that are essential for sustaining the health of the soil and improving the mobility of the soil nutrients from the soil to the plant root system.

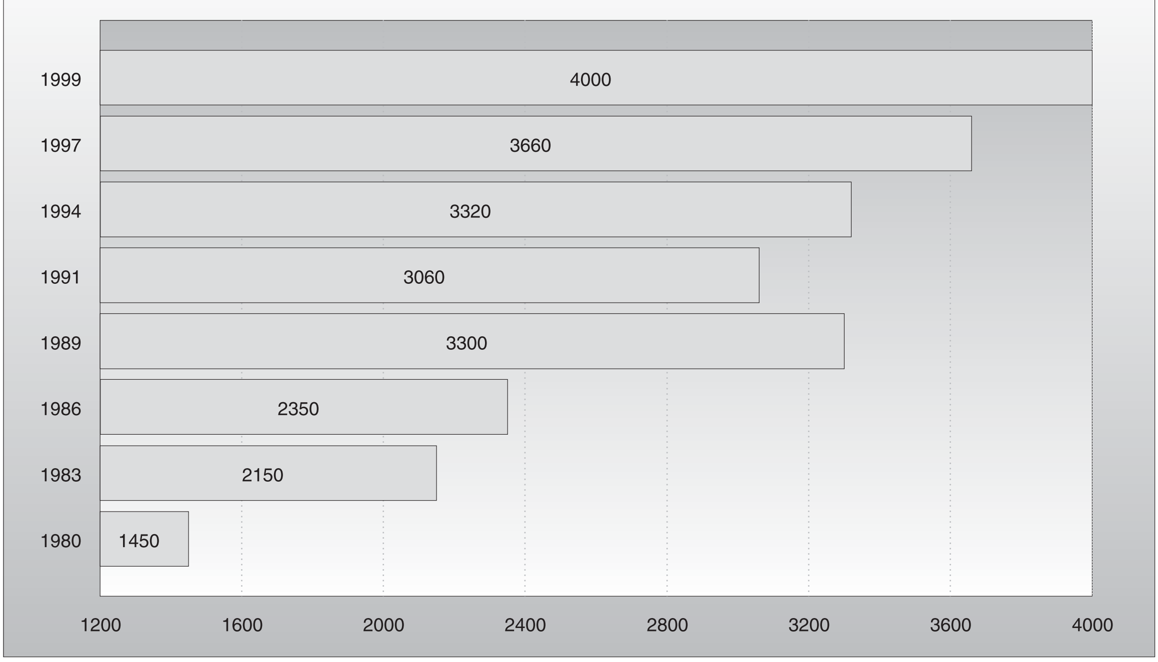
Fig. 1.5 Pesticides banned in the west, but used in India 1994-95 (tonnes)




### *1.5.1 Fertilizer consumption*

In the last three decades, Indian consumption of chemical fertilizers in terms of nitrogen, phosphorus, and potassium has grown at 9.5 percent annually, making India the fourth largest consumer of fertilisers in the world. The production of nitrogenous and

Fig. 1.6 Retail price of urea (Rs./tonnes)



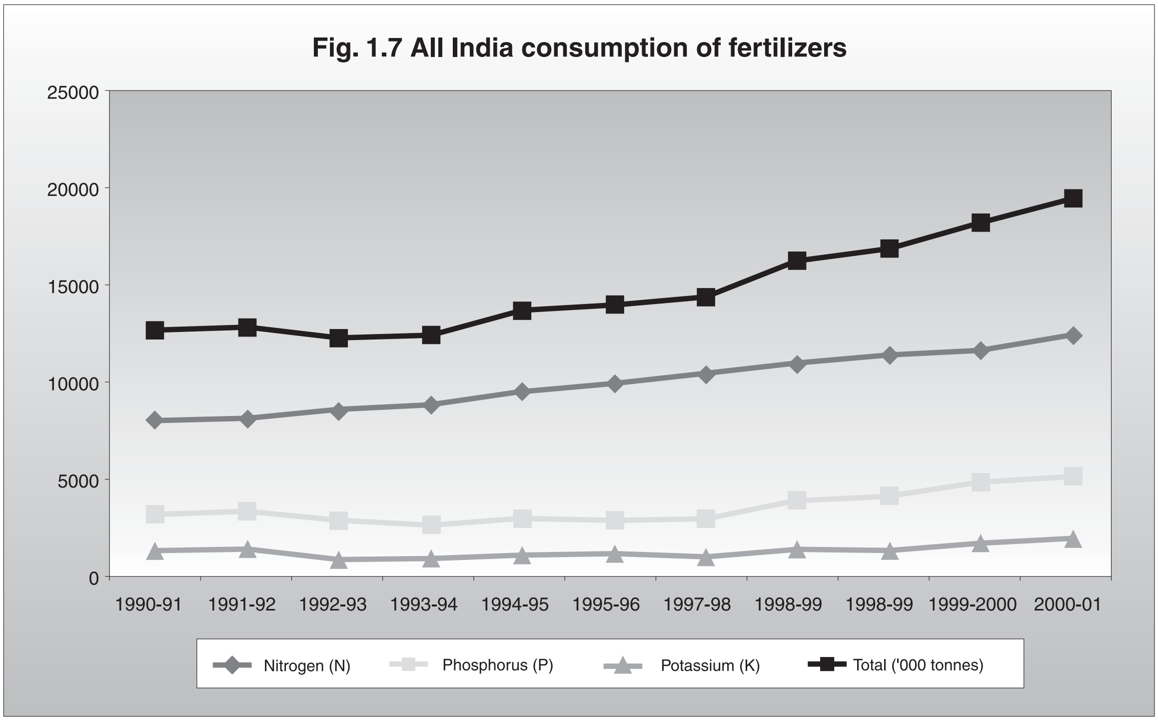
phosphatic fertilizers in 1995-96 was 9.8 mt and 2.89 mt respectively. By 2000 AD the nitrogenous fertilizer requirement shot upto about 12.75 mt with a production of 12.45 mt resulting in demand supply gap of 0.3-1.9 mt (Aggarwal 1996). Indian consumption of fertilizers in terms of nutrients (N, P and K) from 1990 to 2001 is shown in Table 1.3.

**Table 1.3 All-India consumption of fertilizers in terms of nutrients (N, P and K) from 1990 to 2001**

| *Year* | *N* | *P* | *K* | *Total (MT)* |
|---|---|---|---|---|
| 1990-91 | 7997.2 | 3221.0 | 1328.0 | 12546.2 |
| 1991-92 | 8046.3 | 3321.2 | 1360.5 | 12728.0 |
| 1992-93 | 8426.8 | 2843.8 | 883.9 | 12154.5 |
| 1993-94 | 8788.3 | 2669.3 | 908.4 | 12366.0 |
| 1994-95 | 9507.1 | 2931.7 | 1124.7 | 13563.5 |
| 1995-96 | 9822.8 | 2897.5 | 1155.8 | 13876.1 |
| 1996-97 | 10301.8 | 2976.8 | 1029.6 | 14308.1 |
| 1997-98 | 10901.8 | 3913.6 | 1372.5 | 16187.8 |
| 1998-99 | 11353.8 | 4112.2 | 1331.5 | 16797.5 |
| 1999-2000 | 11592.7 | 4798.3 | 1678.7 | 18069.7 |
| 2000-01* | 12336.0 | 5114.0 | 1918.0 | 19368.0 |

*: Target

*Sources: Department of Fertilizers, Department of Agriculture and Cooperation, New Delhi*



CHAPTER II

# Chemical farming:
# *Damage to the environment*

The present agriculture system is largely dependent on inputs such as fertilizers, insecticides, weedicides, fungicides and growth promoting hormones etc. Most of them however, pollute the environment and are hazardous to health of human beings and farm animals. The impacts are not limited to crop and the farm soil but has affected the surrounding natural ecosystems in the landscape impacting the following constituents like:

- Soil
- Ground water and surface water
- Biodiversity
- Food chain
- Pollinators etc.

The continuous use of pesticides has resulted in pollution of our soil, water, atmosphere and general health of the people. Pesticides are poisonous chemicals that cannot distinguish harmful pests from useful insects. They act alike on all life forms-any living thing that comes in contact either dies immediately or after a period of intense suffering. Farmers too, are increasingly exposed to the adverse impact of chemical farming and suffer from mild ailments to respiratory disorders and in some cases contracted cancer and infertility by over-exposure.

***How do pesticides harm the environment?***

- They harm living organisms in addition to the targeted pests.
- They travel in the food chain to bio-accumulate in higher organisms called biomaginification.
- Some persist in soil, air, surface water and ground water for a long time and thus, contaminate our natural resources.

## 2.1 Impact on soil

Important environmental issues related to the use of nitrogenous and phosphatic fertilizers are the increase in phosphate, nitrate, and heavy metal content in soil. It has been observed that certain inorganic elements accumulate in soil due to increased application in the form of fertilisers. Over a period, they become locked by forming bonds with other elements in soil and are thus, not available in nutrient form the the plants. This process is called immobilization of the nutrients in a terrestrial agro-ecosystem. Phosphorus is the best example to illustrate the process. Diammonium phosphate (DAP) is applied as a fertilizer in the farms to provide phosphorus and nitrogen to plants that is vital for plant's metabolic processes. Over a period, phosphorus is immobilized as phosphate and is strongly adsorbed in the soil surface. Another important implication of over use of phosphatic fertilizer is the accumulation of heavy metal content of soil as metals like mercury, cadmium, vanadium, nickel etc. are part of rock phosphate.

## 2.2 Impact on surface water and ground water:

The detrimental effects of intensive agriculture on ground and surface water are largely due to soil erosion associated with mechanised ploughing and loss of organic matter which help in soil aggregation and to nitrate and pesticide pollution. The main threats to water quality posed by chemical agriculture are: high inorganic fertilization levels in combination with high stocking rates, the excessive application of mineral N-fertilizers, the lack of a protective soil cover, narrow crop rotations and frequent tillage, high levels of available nitrogen after harvest, and contamination of water by application of synthetic pesticides.

As organic agriculture uses no synthetic pesticides, there is no risk of ground and surface water pollution due to pesticides. As regards nitrate leaching, Table 2.1 summarizes results on rates of nitrate leaching in Germany and the Netherlands. It shows that under western European conditions nitrate leaching rates per hectare are significantly lower in organic agriculture than in conventional agriculture systems.

The reasons for the lower nitrate leaching rates in organic agriculture are the ban on mineral N-fertilizers and lower livestock densities. These constraints set up by the organic agriculture standards lead to nitrogen on organic farms, nitrogen being

**Table 2.1 Nitrate leaching rates per hectare from organic agriculture compared to conventional agriculture systems**

| *Reduction of nitrate leaching rates in organic agriculture compared to conventional agriculture* | *Authors* |
|---|---|
| > 50% | Smilde (1989) |
| > 50% | Vereijken (1990) |
| 57% | Paffrath (1993) |
| 40% (sand) / 0% (loam) | Blume *et al.*, (1993) |
| 50% | Reitmayr (1995) |
| 40% | Berg *et al.*, (1997) |
| 64% | Haas (1997) |

*Source: Stolze et al., 2000*

- in economic terms - a quantitatively scarce factor. The economic consequences of nitrogen being scarce on organic farms are quite impressive: the opportunity costs (cost of producing on-farm) of 1 kg nitrogen on organic farms can amount to seven to sixteen times the cost of mineral N-fertilizers. So it is not surprising that in contrast to conventional farms where manure and slurry are often a waste problem, organic farmers are forced to develop efficient nitrogen management strategies like intercropping, catch cropping, optimal ploughing in of legume crops or limiting the use of liquid manure to avoid nitrogen losses.

The increase in use of nitrogenous and phosphatic fertilizers has resulted in serious impact on environment by increased nitrate contents in surface and ground water, which has been a cause of major concern in both developed and developing countries. High nitrate problem is noticed in many parts of India (Tripathi 1986). Nitrate level in some parts of Haryana and Punjab is at alarming level due to excessive use of fertilizers. A summary of some of the investigations made by previous authors on nitrate, phosphate and fluoride contents of ground water in some of the states is given in Table 2.2.

**Table 2.2 Concentration of pesticide residues in ground water**

| *Reference* | *Findings* |
|---|---|
| Kakkar 1981 | High nitrate concentration in ground water of Haryana |
| Handa 1985 | Nitrate level in dug well 100 – 300 mg/L Potassium> 100 mg/L, $PO_4$ 1.0 – 3.65 mg/L(Chhata, Mathura and Moradabad, U.P.)Dug well of Agra: Nitrate level -1302 mg/L Assam, West Bengal, Orissa, Kerala – 100 mg/L |
| Gupta 1991 | Out of 1080 samples, average nitrate level was recorded to 271 mg/L. Fluoride was also on higher side. |
| Gupta *et al.,* 1993 | Fluoride in ground water of 77 villages minimum 2.28 mg/L maximum – 22 mg/L |
| Andamuthu and Subbaram 1994 | Out of 129 well water 36.45 % samples exceeded the limit of nitrate concentration. Average nitrate level was found to be 41.7 mg/L at Bhayani, Tamilnadu |
| Nawlakhe *et al*., 1994 | Nitrate 0 – 246 mg/L, Fluoride 0.2 – 5.2 mg/L at Palamu, Bihar |
| Prasad *et al*., 1994 | Nitrate 0.1 to 200 mg/L, Fluoride 0.3 to 1.8 mg/L in North Bihar |
| Rao *et al.,* 1994 | Fluoride 0 – 12.5 mg/L in ground water of Unnao (U.P.) and Shivpuri (M.P.) |
| Singh *et al*., 1994 | $NO_3$ 4 – 4400 mg/L In Rajgarh Tehsil, Churu District of Rajasthan |
| Joshi *et al*., 1995 | Nitrate level 1.2 – 164 mg/L in bore wells , 1.3 to 150 mg/L in dug wells. Rural area of Nagpur |

### *2.2.1 Pesticides in aquatic ecosystem*

The uncontrolled use of pesticides has led to the contamination of many of our hydrologic systems. Pesticide contamination of ground water is an issue of national concern because ground water is used as a source of drinking water. There are two main places where pesticide contamination of water occurs:

**Ground water:** Non-degraded pesticides seep into ground water of which all of the rural population relies for drinking.

**Surface water:** A place that can be a river or stream for the run-off of the agricultural field can contaminate the water bodies

A study conducted by Center for Science and Environment (CSE) in 2003 revealed that, raw water samples collected from ground water had high concentration of pesticidal residues such as organochlorines viz. endosulphan and dialdrin, and organophosphorus pesticides viz. dimethoate and methyl parathion. CSE's findings also drew the attention once again to the high amount of pesticides indiscriminately used for agricultural practices. When pesticides do get into groundwater, the contamination can last for many years and spread over a large area before their denaturation and dilution.

### *2.2.2 Pesticide residues in bottled water*

Centre for Science and Environment (CSE) has conducted study on pesticide residues in bottled water. The results showed that pesticide residues were found in all the samples. The pesticide residues found were of the deadliest kind. Among them organochlorine, gamma-hexachlorocyclohexane (g-HCH, or lindane) and DDT were the most prevalent.

24 out of the 34 samples had DDT residues in them. Minimum concentration 0.0001 mg/l was recorded in Minscot; highest 0.0037 mg/l in Volga, which is 37 times above the European Economic Community's (EEC) limit for an individual pesticide.

29 out of the 34 samples were Malathion positive. Concentration levels ranged from 0.0004 mg/l in Aquafina to as much as 0.04 mg/l in Bisleri.

Chlorpyriphos was detected in 28 out of 34 samples. For instance, in No. 1 Mc Dowell – I (0.037 mg/l), it was 370 times more than the EEC's permissible limit for a particular pesticide. Bisleri (109 times), Kinley of Coca-Cola (109 times) and Aquafina of Pepsi were 23 times higher than the EEC's permissible limit for an individual pesticide. The test of the CSE laboratory clearly revealed that each sample contained multiple residues of pesticides.

A major challenge facing modern agriculture, therefore, is to control pests and protect crop yields by application of bio-pesticides and thus, shunning the hazardous chemical pesticides that contaminates our soil environment surface and ground water resources. This can be achieved only by practicing organic farming practices that relies on natural traditional ways for fighting the harmful pests.

## 2.3 Impact of pesticides on biodiversity

Biodiversity refers to all species of plants, animals and microorganisms in a unit of land including the ecosystems and ecological processes of which they are a part of (Odum, 1971). Biological diversity includes both the number and frequency of

*Navdanya's Agrobiodiversity Farm*

ecosystems, species or genes in a given unit. It includes genetic base, species diversity in a farming system and ecosystem diversity of a landscape (e.g. cropland, grassland, woodland) (Odum 1971; OTA, 1987). A powerful human threat to species diversity is the release of toxic chemicals and pesticides, herbicides into our land and water resources (i.e. catchment areas of lakes and rivers). The indiscriminate use of hazardous plant chemicals has resulted in reduction in biodiversity of natural predators of the harmful pests, outbreak of secondary pests, emergence of mutant varieties of harmful pests, development of resistance to pesticides and contamination of food and the poisoning of ecosystem. It has been observed that in chemical control, the decline in the predator's composition in rice ecosystem by 3.5 times and in cotton by 12 times clearly indicates the ill effects of pesticides.

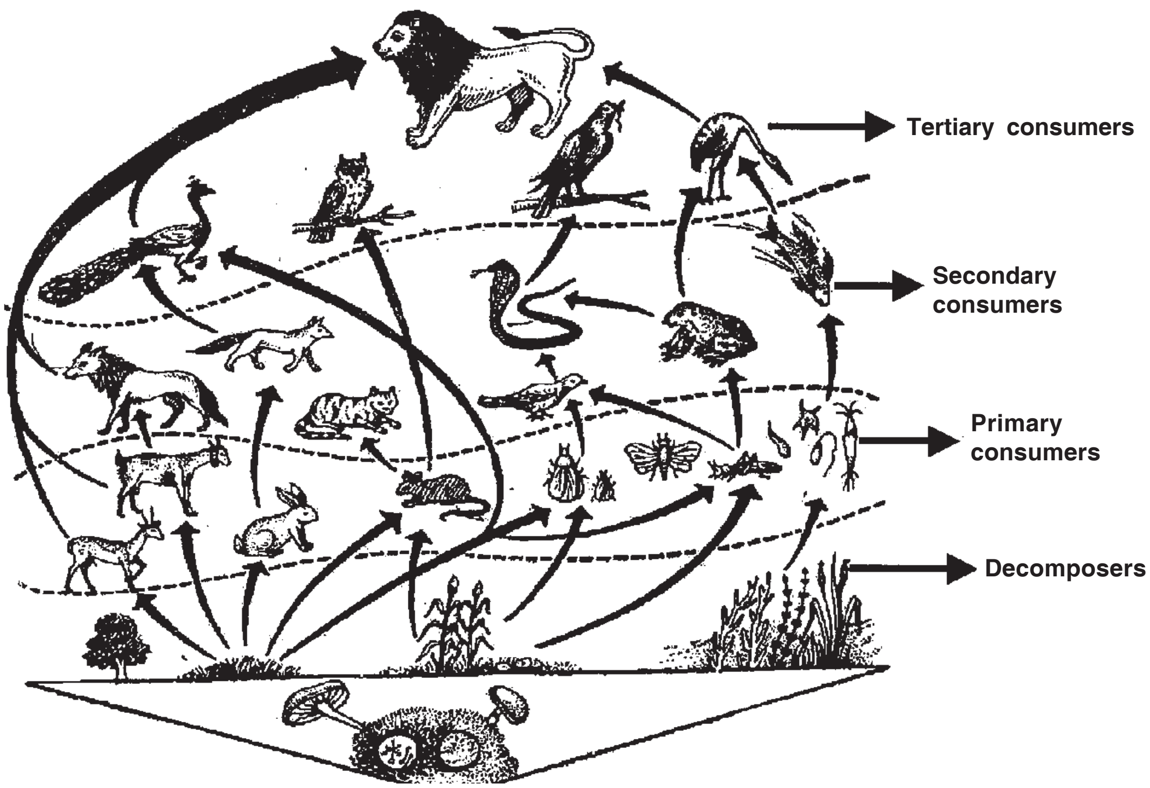
Navdanya in its constant effort for rejuvenation of the biodiversity in agro-ecosystems has initiated an agro-ecological farm. This farm aims to promote the low input sustainable agriculture both for protecting the ecological processes and for reducing the cost of cultivation of the farmer. Biodiversity as per Navdanya is the only viable and potent option for chemical farming that poisons the soil and body of the farmer.

## 2.4 Effect on food chain

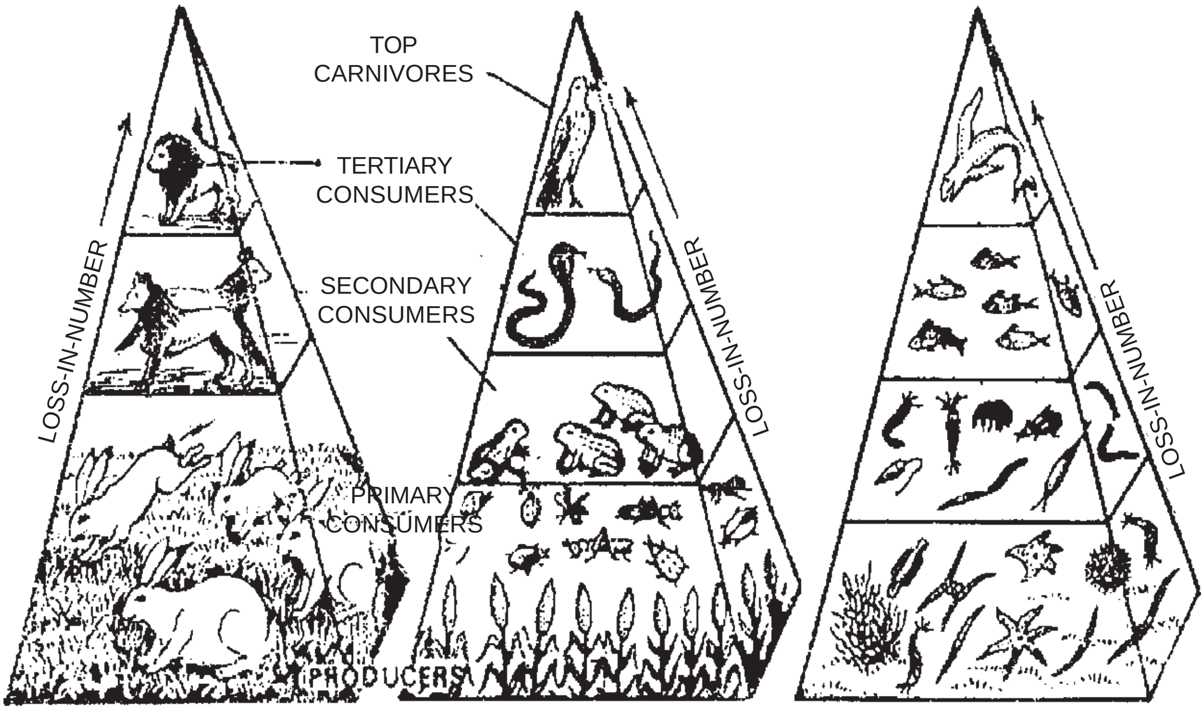
Artificial chemicals have an adverse effect on organism. Broadly, this usually involves pesticide and insecticide application. There are direct and indirect ways in which organisms are affected, as they become targets of pesticide application. Secondary effects on organisms result from loss of prey that is due to the eradication of some organism from the food chain. Chemicals have also adversely affected birds and mammals (wildlife) as their food and water sources are contaminated by pesticide residue. Pesticides concentrate by process of bioaccumulation wherein, chemicals in each trophic chain get accumulated in the body of organisms when they consume a host of smaller organisms of their food chain.

### *2.4.1 Food chain*

All living organisms are dependent on plants, either directly or indirectly, for their survival. Plants use the energy of sun to produce food. They are therefore called producer. The plant–eating animals (herbivores) feed on plants and depends directly on them for existence and growth. These are called primary consumers. The meat-eating animals (carnivores) feed and depend on the herbivores for their survival. They are called secondary consumers. Thus, each organism is dependent and connected to another. This is called the food chain and each level is called a trophic structure. In nature an imbalance at one level affects the entire food chain and web. Thus every organism has a status in ecosystem, this status is known as ecological niche as shown below in the figure. The predator (an organism which feeds on the pest) and prey populations are so interdependent that an increase or decrease in either population causes drastic changes in the population of the other. The use of agro-chemicals in agriculture has altered both pest and predator populations and this has affected productivity drastically.




Food web of the aquatic grass land and forest ecosystems




Upright ecological pyramids of (A). Grassland ecosystem (B). Cropland ecosystem (C). Pond water ecosystem

**Energy pyramid: the complex food chain**

**Biomagnification and bioconcentration** An insect feeding on plants sprayed with pesticides might be eaten by another insect, which might then be eaten by a bird with the result that the magnification of pesticides in the body of an organism takes place which is defined as biomagnification. Traces of pesticides too small to kill the targeted pest can accumulate to levels high enough to harm species further up on the food chain, which is termed as biological concentration of pesticidal residues in an organism.

Many pesticides do break down rapidly in the environment, but some like DDT and dieldrin remain toxic for 20 years or longer, continuing to kill insects and harm other organisms by accumulating in the body.

## 2.5 Destruction of pollinators

Many species of insect such as bees, butterflies, beetles and flies are important to our survival as pollinator species, yet their contributions are often forgotten or taken for granted. Often such species annoy us and we liberally squish, swat, and spray them. However, farmers and other commercial growers recognize the importance of insect pollinators to the success of their crops and often pay for the pollination services that these species perform free of charge, providing us with many of the fruits and vegetables that we enjoy. Let us examine the role of pollinator in every day life.

Pollinators are important part of any ecosystem. Reports show that butterflies and honeybees are declining due to excessive use of pesticides in an agro-ecosystem. It is well known that the bees and butterfly play an important role in agriculture by the process of pollination. Pollination is the process wherein, the bees and butterfly help in cross fertilization of the pollens in the adjoining field and widen the genetic base of the crop. This helps in significant improvement of yields or quality of seeds and fruits and, setting of seed itself through pollination. Pollinators need protection from excessive exposure to pesticides and other chemicals that can poison them or impair their reproduction. These chemicals can also eliminate nectar sources for pollinators, destroy larval host plants for moths and butterflies, and deplete nesting materials for bees.

### *2.5.1 Pollination biology and its importance in biodiversity conservation*

Pollination biology deals with the study of pollinating insects; the birds, bees and butterflies among the other pollinating fauna. Many are large and colourful, others are small and drab, but all contribute to the perpetuation of natural communities. Many of them play important roles in agriculture. Insect populations fluctuate considerably from year to year, in response to climate and other environmental variables. They are also threatened by certain human activities, and concern is growing over the future health of pollinator populations. Our goal is to examine fluctuations over time, and our methods will entail multiple observations repeated at fixed locations.

### *2.5.2 Ecological significance*

Nearly a quarter of a million identified species of flowering plants feed over three quarters of a million insect species. Conservative estimates predict ten times as many unidentified insect species contained mostly within the tropics. One reason for the great proliferation of plants and insects (for comparison, birds are represented by approximately 6,200 species and reptiles by approximately 5,800 species) has been the development of specialized pollinator relationships in which flowers have evolved to attract pollinators using bright coloration and fragrance. The pollinators then unknowingly pollinate the flower while attempting to reach the nectar food source provided by the flower. No other natural phenomenon illustrates more vividly the principle that conservation measures must be directed at ecological processes, and not just individual species.

### *2.5.3 Economic significance*

Approximately 73% of the world's cultivated crops, such as cashews, squash, mangos, cocoa, cranberries and blueberries, are pollinated by some variety of bees, 19% by flies, 6.5% by bats, 5% by wasps, 5% by beetles, 4% by birds, and 4% by butterflies and moths. For a example, a significant portion of New York's economy includes apple orchards and vineyards which are dependent upon combinations of wild and cultivated bees. The consequences of a population decline in pollinators is a serious cause for concern. It is estimated that the services of native pollinators are worth $4.1 billion dollars a year to U.S. agriculture. In other words, one out of every three bites or swallows you take was made possible by a pollinator.

### *2.5.4 Current threats*

Evidence is overwhelming that both wild and domesticated pollinators are declining around the world. Some have already suffered total extinction, and others are at risk from a variety of threats:

- **Habitat reduction.** The loss and fragmentation of natural habitats have disrupted native populations of many plants and pollinators. Every time that wild lands are converted to shopping malls or housing, for example, many pollinators lose their homes.
- **Pesticides.** In an attempt to eliminate herbivorous crop pests, growers have been spraying complex mixtures of pesticides that kill not only the pests, but also the native pollinator populations.
- **New parasites of honeybees.** Tracheal mites now infect the respiratory system of adult honeybees throughout North America. Another destructive pest, the Varroa mite is a recently discovered external parasite that now affects bee colonies in over 30 states. During the course of a season here in New York, so many bees are injured and killed that many hives cannot build up enough resources to survive through the winter.
- **Fungal, protozoan, and bacterial diseases of honey bees.** The usual set of problem diseases that affect any highly social animal continue to infest many domestic honeybee colonies, adding to the expense and difficulty of maintaining healthy populations.

**Bats - a forgotten aid to agriculture?**

Bats often receive bad press. Considered pests and the carriers of disease almost half of the 1000 known species of bats are considered threatened or near threatened. However, their role in agriculture is often overlooked. Many species are highly beneficial as pollinators, seed dispersers and insect controllers. Important tropical plants such as bananas, bread fruits, mangoes, cashews, dates and figs rely on bats for pollination and seed dispersal, and in the United States a single colony of 150 big brown bats can protect crops from 18 million or more root worms each summer. Guano is prized by organic farmers and gardeners for its properties as a plant fertilizer, soil builder, soil cleanser, fungicide, nematicide and compost activator. Guano contains about 10 percent nitrogen, 3 percent phosphorous and 1 percent potassium, together with all the minor trace elements necessary for a plant's overall health.

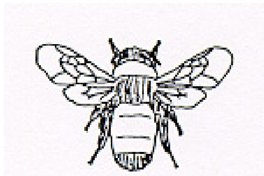
Bats are highly threatened by a range of problems including habitat loss, conflict with humans and pesticide use. Although the link between bat population decline and agricultural land management has not been clearly demonstrated, organic agriculture can play an important role in bat conservation by providing habitat and food sources while at the same time benefiting from the services that these often forgotten mammals provide.

### *2.5.5 Identification of the pollinators in the field*

Plants depend on the work of pollinators for survival, one of the world's most vital processes linking both plants and animals. Pollinators may include several different orders of insects including *Hymenoptera* (bees, ants, wasps), *Lepidoptera* (butterflies and moths), *Coleoptera* (beetles), and *Diptera* (flies), and also many different animal species including primarily bats and hummingbirds. Currently, 82 species of mammalian pollinators, including bats, 103 species of avian pollinators and one reptile are considered threatened or extinct according to IUCN criteria, the total ratio of threatened vertebrate pollinators to the total numbers of vertebrates in their genera being extremely high. The interactive process of pollination involves a pollinator gathering nectar produced by colorful flowering plants that attract the pollinator's attention. While the pollinator is landing on the flower gathering nectar, it is unknowingly transferring pollen from the stamen (male part of the plant) to the pistil (female part of the plant) assuring reproduction. Reproduction in plants may occur as self-pollination or cross-pollination within the species.

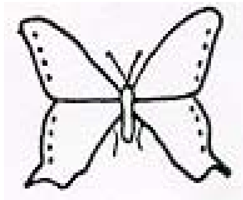
#### *2.5.5.1 Identification*

##### *2.5.5.1.1 Hymenoptera:* bees, ants, wasps



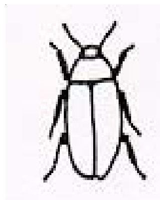
Many of the most familiar insects belong to this order containing over 108,000 species worldwide. Adults are hard bodied, active insects, usually possessing 2 pairs of membranous wings that generally have large cells and few veins. All adults have chewing mouth parts and in some bees and wasps, mouth parts are modified into tongue-like structures for drinking liquids. Most species have a constriction or waist called the pedicel between the base of the abdomen and the thorax. Females of most species have a well developed ovipositor which in wasps and some bees and ants is modified into a stinger. Most species are solitary, but ants and some bees and wasps have a complex social organization with sterile female workers and fertile males and females. This order of insects is economically important as pollinators of various cash crops and wild plants. The most dedicated pollinators from this group are the bees, which are specialized for feeding at flowers and gathering honey and pollen. More than 3,500 species were found in North America alone. Bees are generally 4-25 mm long and may be black, brown, or banded with white, yellow, or orange. In many species, the tongue is long and pointed, adapted for probing into flowers. All bees are covered with branched or feathery hair, but some have more hair than others. When a bee visits a flower, pollen sticks to the hair. Most female bees have a pollen collecting apparatus, males do not collect pollen and therefore lack this structure. In most species, the pollen is combed into a special pollen basket or brush, which is usually located on the hind leg. Most bees are solitary with each female constructing a nesting tunnel underground or in a plant stem or wood, in which it then stocks the brood cells with pollen and nectar for the larvae. However, honey bees and bumble bees are social, they live in colonies consisting of a fertile Queen, sterile female workers and males, or drones. Most bees can sting, but only the social species do so readily in defense of the colony.

***2.5.5.1.2 Lepidoptera:* butterflies, moths**



Known for their brightly colored wings, butterflies and moths constitute approximately 125,000 known species worldwide. These insects have 4 membranous wings covered with delicate pigmented or prismatic scales that rub off easily. The mouth parts of most adults form a long, coiled tube, or proboscis, used for drinking liquids such as nectar or fermenting tree sap. In some species the adults do not feed and the proboscis is reduced or absent. A few primitive moths have jaws and feed on pollen. Although they are all quite uniform in structure, butterflies and moths vary greatly in wing span, ranging from 3-270 mm. Butterflies fly only during the day and tend to be brightly colored with knobbed antennae. Most hold the wings together vertically over the thorax when at rest. The majorities of moths are night fliers and are coloured in generally somber hues, but some moths fly by day and have brighter colours. Moths have various types of antennae. Unlike butterflies, moths hold the wings roof-like over the body, or flat against a support when at rest. While some species of butterflies and moths are considered agricultural pests, most are harmless and are actually beneficial in their role as pollinators of flowers and as sources for commercial silk.

***2.5.5.1.3 Coleoptera:* beetles**



The largest order in the animal kingdom, *Coleoptera* contains a third of all known insects, approximately 300,000 species worldwide. Beetles range from large tropical insects approximately 130 mm in length, to smaller species less than 1 mm. Some crawl on land, others fly or live in water. Beetles can be easily recognized by the tough, armour-like fore wings called the elytra, that cover the membranous hind wings used for flying. When the insect is at rest, the elytra usually meet in a neat line down the middle of the back. They are often brightly colored or patterned. There are many types of beetle antennae, most being thread-like or clubbed in various ways, usually containing 10-11 segments. Most beetles have large compound eyes. Although almost all beetles fly, they do so apparently only to get to low vegetation or other natural features of their habitat. Chewing mouthparts with well-developed mandibles enable beetles to eat a broad range of materials. Many beetles are predators, others are scavengers, and a few are parasites. Beetles are known to eat leaves, bark, dung, wool, and other fabrics. Some species are considered pests since they attack plants and stored foods, while others are important for pollination and also as predators of other plant pests.

***2.5.5.1.4 Diptera:* flies**

This order contains over 86,000 known species. Prevalent in all habitats, flies are easily distinguished from other insects because they have only 1 pair of normal wings. The second pair, just behind the first, is represented by two knobbed organs, the halteres, thought to stabilize the body during flight. Many flies have a membranous lobe, or calypter, at the base of each wing overlying the haltere, its presence is an aid in recognizing particular families. Most flies have large compound eyes and mouthparts modified for piercing, lapping, or sucking fluids. The antennae range from short 3 segmented organs to long, thread-like structures. They are feathery in midges and mosquitoes and clubbed in mydas flies. Some blood sucking flies are carriers of diseases such as malaria and yellow fever. Others which feed on unsanitary substances, carry bacteria that cause diseases such as typhoid and dysentery. Some flies are agricultural pests while others are considered valuable as pollinators of flowers, scavengers, and sources of food for wildlife, including parasitic and predatory flies which help to control other insect pests.

Wild insect pollinators such as small solitary bees are even more vulnerable than honey bees to organophosphate pesticides that have largely replaced organochlorines like DDT. Moreover, many crops that would benefit in quality and quantity from pollination that is more thorough are not sufficiently pollinated because of heavy pesticide applications. Cotton harvests, for example, could increase by as much as 20% if the flowers were fully pollinated by bees, which could result in increase in farm income. However, using bees to enhance cotton production has proven impossible on a large scale where there has been continued intensive use of insecticides. When aircraft applies pesticides through aerial spraying, as much as 50% to 75% of the chemicals sprayed can miss their target, leading to inadvertent exposure and dissemination of non target organisms such as pollinators.

### *2.5.5.2 Monarch butterfly: a case study*

A classic case of danger of pesticides and the genetically engineered crop is the threat posed to non-target insect population and the wildlife. This is seen as a danger and onslaught on biodiversity conservation. A recent study conducted at the Cornell University in New York was recently published in the science journal Nature and

**Some pesticides highly toxic to bees**

Aldrin
Bendiocarb
Carbaryl
Chlorpyrifos
Diazinon
Dichlorvos
Dieldrin
Dimethoate
Endosulfan
EPN
Fenitrothion
Fenthion
Heptachlor
Malathion
Methomyl
Mevinphos
Monocrotophos
Parathion
Pirimiphos-ethyl
Phosmet

***Sources***: *Basic Guide to Pesticides, Shirley Briggs, 1992.*

University in New York was recently published in the science journal Nature and suggests that pollen from Bt corn may have toxic effects on larvae of the monarch butterfly. The caterpillar, or larval stage, of this insect feeds on milkweed. Because some milkweed grows next to corn in the Midwest, there is the potential that Bt corn pollen may drift onto milkweed and affect monarch larvae.

Monarch butterfly *(Danaus plexippus)*

The study reported that in a period of 4 days, 44 percent of the monarch larvae died that fed on the Bt-pollen-coated leaves. No caterpillars died that ate leaves dusted with regular corn pollen or the control leaves. Second, leaf consumption by the larvae was much less on the Bt-pollen-dusted leaves. Third, larvae that survived on Bt-pollen-dusted leaves were less than half the size of larvae that fed on leaves with no pollen.

This shows that the introduction of the Bt crop has resulted in the destruction of the normal physiological process of the butterfly and thus is a threat to the survival of the pollinator.

#### *2.5.5.3 The threat to extinction of pollinators by use of pesticides: A case study in Australia*

Agriculture Western Australia has cautioned farmers to take all precautions to minimise harm to commercial bees when insecticides are used on crops. The warning comes after more than 100 beehives involved in canola crop pollination northeast of Goomalling were accidentally damaged through spray drift from aerial spraying. Foraging honeybees in a large canola crop were killed when dimethoate-based spray was used to knock down aphids in nearby barley crop.

It was an unfortunate occurrence which has illustrated the hazard for bees from crop spraying at this time of the year when there are up to 4,000 beehives involved in canola crop pollination. Dimethoate is a toxic chemical to honey bees. It has a long residual time (72 hours), and can wipe out all the bees in a crop. This, in turn, affects the incomes of beekeepers, which need to move their hives to several sites throughout the year to gather nectar for honey production.

*Monarch-Caterpillar*

CHAPTER III

# Chemical farming:
# *Damage to health and nutrition*

## 3.1 Impact of chemical farming on health

The major cause of ill effects of chemical inputs in the agro-ecosystems are best summed in the two processes of bio-magnification and bio-concentration that are widely prevalent in the food web and food chain both in the aquatic and terrestrial systems. All chemical pesticides are potentially dangerous. Several health related problems have been reported because of improper, excessive and continued use of agrochemicals. Some of the most common ailments are as follows:

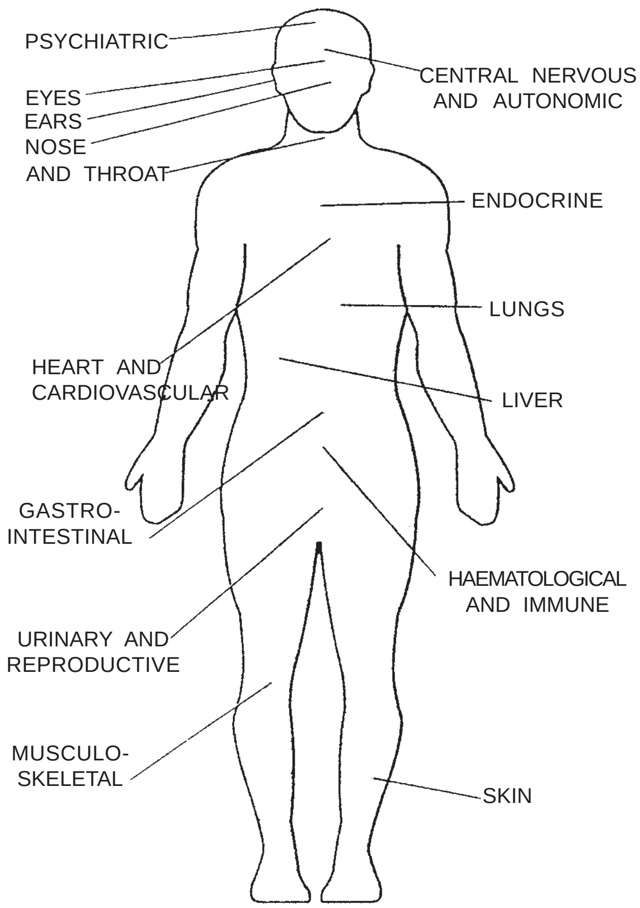
- Slow poisoning
- Skin disorders
- Damage to reproductive system
- Cancer
- Sterility
- Respiratory disorders
- Damage to nervous system
- Asthma

Pesticides in developed countries are sprayed on a variety of crops (e.g. rice, maize, and soybean) and non-food crops (e.g. cotton and tobacco) of which large amounts are exported to developing countries. Consumption of food with high levels of chemical pesticide residues causes acute poisonings while the chronic effects of consuming lower levels of pesticides over a long period though are still not fully known. Studies on farmers and their families repeatedly show that they are the high risk groups in terms of exposure to toxic pesticides as they lack protective clothing, have leaking spray equipment, mix and apply pesticides with bare hands, and storage of pesticides with food. Navdanya in its study on the "*Impact of Pesticides on Women in Agriculture*", 2002 revealed that women were exposed to high levels of pesticides that at times led to nauseating feeling and respiratory ailments.

Pesticide residues on foodstuffs are a life-threatening problem. This situation has been recognized in the developed countries. They have systems to monitor this problem by having established programmes, which undertake regular testing of food samples for residues. Most developing countries are unable to set up programmes to regularly monitor pesticide residues on food. In India, hundreds of people die from pesticide poisoning each year. A plantation company in India has been spraying a deadly pesticide since 1976 in cashew plantations. This has adversely affected the health of cashew plantation workers and those living near plantations (Center for Science and Environment, 2002 and India Today magazine, 2002).

### *3.1.1 How do pesticides harm people?*

- Pesticides enter the body through the lungs, digestive system or skin. Depending on the concentration of pesticide, health effects can be immediate (acute) or they can occur after years of low-level exposure
- Symptoms of acute poisoning can include headaches, blurred vision, and nausea and vomiting, changes in heart rate, muscle weakness, respiratory paralysis, mental confusion, convulsions, coma and death
- Chronic low-level pesticide exposure can lead to cancer, nervous system disorders, liver and kidney damage, and respiratory problems etc. as shown in figure.
- Pesticides can affect reproduction by malformation of foetus, causing miscarriage, stillbirth or birth defects, or by altering genetic material so that a mutation is carried on to the next generation.




## Pesticides are toxic, because:

- They have chemicals that denature the enzyme system of humans
- The chemicals have known to effect the central nervous system of body
- The chemicals denature hormone system and cause reproductive disorders
- Chronic low-level exposure to pesticides causes bioaccumulation in body fat which later on act as center to produce toxins that interfere with natural body functions.

#### 3.1.1.1 *Impacts of some of the pesticides on human health*

- **Chemical family: Organophosphates**

**Action on Human System:** Degrade acetylcholinesterase (an enzyme) in the tissues.
**Internal Exposure:** Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating.
**External Exposure:** Minimal rashes but readily absorbed through the skin.
**Chronic Exposure:** Loss of appetite, weakness, weight loss, and general feeling of sickness.
**Type of Pesticide:** Insecticides, acaricides.

- **Chemical family: Carbamates**

**Action on Human System:** Reversible changes in acetylcholinesterase enzyme of tissues.
**Internal Exposure:** Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating.
**External Exposure:** Minimal rashes but readily absorbed through the skin.
**Chronic Exposure:** Loss of appetite, weakness, weight loss, and general feeling of sickness.
**Type of Pesticide:** Insecticides, acaricides.

- **Chemical family: Organochlorines (chlorinated hydrocarbons)**

**Action on Human System:** Disrupt function of nervous system, mainly the brain.
**Internal Exposure:** Headache, dizziness, weakness, shaking, nausea, excitability, disorientation.
**External Exposure:** Minimal rashes but readily absorbed through the skin.
**Chronic Exposure:** Some buildup in the fat tissues. May cause nervousness, weakness, and shaking.
**Type of Pesticide:** Insecticides and acaricides (HCB is a fungicide).

- **Chemical family: Chlorophenoxy pesticides**

**Action on Human System:** Irritant to lung, stomach and intestinal linings. Injure liver, kidney, and nervous system.
**Internal Exposure:** Prompt vomiting, burning sensation in stomach, diarrhea, and muscle twitching.
**External Exposure:** Moderately irritating to eyes, skin, and lungs. Chronic Exposure: do not remain in body; passed out within hours or days.
**Type of Pesticide:** Herbicides.

- **Chemical family: Paraquat and diquat**

**Action on Human System:** Injure skin, nails, cornea, liver, kidney, linings of stomach and intestine, and respiratory system.

**Table 3.1: Symptoms of acute and chronic pesticide poisoning**

| *Acute* | *Chronic* |
|---|---|
| **Central nervous system** | |
| Exhaustion, weakness, paralysis, acute headache, nausea, vomiting, tremor, peripheral neuropathy, fever, blurred vision, sweating, contracted pupils, salivation | Incoordination, fits, unsteadiness, numbness, tingling, acute depression, symptoms that mimic recognized neurological diseases. |
| **Eyes, ears, nose and throat** | |
| Burning, irritating and watering mucous membranes of eyes, ears, nose and throat | Conjunctivitis, sore throat and eye damage. |
| **Heart and cardiovascular** | |
| Slow pulse, cardiac arrhythmias, heart block | Chest pains, circulatory failure heart muscular damage. |
| **Lungs** | |
| Shortness of breath, bronchospasms, excess secretion, cyanosis, respiratory depression. | Asthma, burning and irritation, lung damage. |
| **Urinary and reproductive system** | |
| Dysuria, frequency of urination, uncontrol-lable incontinence, spontaneous abortion | Kidney damage, sterility, foetus malformation. |
| **Musculo-skeletal system** | |
| Muscle cramps, tremor, paralysis, muscular twitching. | Muscular tenderness, low muscle strength, muscle cramps. |
| **Skin and sensory organs** | |
| Burning, itching. | Persistent dermatitis, especially of hands, eczema. |
| **Gastro-intestinal tract** | |
| Excessive thirst, nausea, vomiting, abdominal pains and cramps, diarrhea, loss of sphincter control. | Odd taste in mouth, weigh loss, bleeding internally. |
| **Liver** | |
| Necrosis, some hepatic malfunction | Disruption of enzyme systems, low tolerance to chemicals and alcohol, chemical hepatitis, Jaundice. |
| **Endocrine system** | |
| | Suppression of adrenal cortex, hyperthyroidism. Hyperglycemia, suppression of endocrine function. |
| **Psychological changes** | |
| Irritability, loss of memory and concentration, anxiety | Chronic fatigue, personality change, emotional problems, lassitude, depression, reduced drive, insomnia. |

Source: Pesticides News, March 1996.

**Internal Exposure:** Burning pain, nausea, vomiting, and diarrhea. External Exposure: Irritates and injures skin and nails.
**Type of Pesticide:** Herbicides.

- **Chemical family: Pyrethrins and pyrethroids**

**Action on Human System:** Very low human toxicity.
**Internal Exposure:** Slight toxic reaction.
**External Exposure:** Swelling of mouth and throat, irritating to nose, throat, eyes.
**Type of Pesticide:** Insecticides, acaricides.
The acute and chronic symptoms of pesticides are as follows:

## 3.2 Organic farming increases nutrition while chemical farming robs us of it

The green revolution despite its projected success in augmenting wheat and rice output is responsible for distortions in pattern of food production. These distortions have come into being due to the emphasis of green revolution to grow a single crop (monocropping). The monocultures of crop and the paddy - wheat cycle have seen to wipe out the rich traditional practice of the cultivating variety of crops that provided both nutritional and economic security to the farmer. The green revolution's two major distortions are the increasing disappearance of traditional foods and loss of nutritional food from our dishes.

Under the pressure of the spread of monocultures of crops, which are traded on worlds markets, highly nutritious crops adapted to local ecosystems and local cultural systems have disappeared. These are often called "lesser known" or "under exploited crops" because from the perspective of centralized systems of agricultural development, they are not known and not yet "exploited". However, local communities have known the value and characteristics of these crops for very long and have utilized them fully for meeting their nutritional and cultural needs. One of the area of focus of the Navdanya is to prevent the extinction of some of these high value crops cultivated on a small scale by reintroducing them in farming systems to both increase nutrition and farmers incomes while conserving resources. Some of them are as follows:

### *3.2.1 Resource conserving nutritious crops*

- **Finger millet (ragi or madua):**

**Botanical name:** ***Eleusine corcana***

*Finger millet (Ragi)*

Finger millet has traditionally been the most important crop growing in many parts of India. The new hybrid crops and the associated agricultural developmental work have displaced this millet in the last few decades. It is a grain of high nutritive value. The protein of this millet is as nutritionally rich as in the case of milk. It is considered an especially suitable food for diabetic patients. Its malting properties make it special among millets.

***Nutrients per 100 gm of Ragi:***

| | |
|---|---|
| Protein | 7.3 gm |
| Calcium | 44 mg |
| Energy | 328 kcl |
| Phosphorus | 283 mg |
| Iron | 6.4 mg |
| Carotene | 42 mg |

- **Foxtail millet (Kauni):**

**Botanical name:** ***Setaria italica***

Foxtail millet is an intermediate drought crop, which gives very high yields. It can grow at elevations upto 6000 ft. It is often sown as alternate crop with sorghum when rainfall is deficient.

***Nutrients per 100 gm of grain:***

| | |
|---|---|
| Protein | 12.3 gm |
| Calcium | 37 mg |
| Energy | 290 kcl |
| Phosphorus | 290 mg |
| Iron | 12.9 mg |
| Carotene | 32 mg |

*Banyard millet (Jhangora)*

- **Banyard millet (Jhangora):**

**Botanical name:** ***Echinochloa frumentaceum***

This is one of the fastest growing millets and can be harvested in approximately four months. The plant has a vigorous growth and has wide adaptations in terms of soil and moisture requirements. It is grown for both grain and fodder and is an important forage crop.

***Nutrients per 100 gm of grain:***

| | |
|---|---|
| Protein | 6.2 gm |
| Calcium | 20 mg |
| Energy | 307 kcl |
| Phosphorus | 280 mg |
| Iron | 2.9 mg |
| Carotene | - |

*Buckwheat (Ogal)*

- **Buckwheat (Ogal, phaphra)**

**Botanical name:** ***Fagopyrum esculentum***

Buckwheat is a pseudocereal, and is grown usually in the Himalayan high altitudes. When tender, the plant is used as a green vegetable. The grain is one of the 'phalahar' or foods that can be consumed during fasts. It is available in the plains as 'kotu'.

*Amaranth (Ramdana)*

- **Amaranth (marsha, ramdana)**

**Botanical name:** ***Amaranthus frumentaceous***

The Amaranth is also called 'ramdana'or god's grain. Amaranth is the world's most nutritious grain. Its seeds, which come in black, brown, red, gold and white can be popped, ground, baked and cooked. 50 to 80% of the amaranth plant is edible. Due to its high dry matter content, an equivalent amount of fresh amaranth provides 2-3 times the amount of nutrients found in other vegetables. It has nearly twice as much protein as other cereals, and contains more dietary fibre than wheat, corn, rice or soybeans and is a richer source of calcium, iron and vitamin A.

### *3.2.2 Pulses*

Pulse/legumes production has shown no significant gains, with the result that the per capita availability of pulses has sharply declined; and the prices of pulses have escalated to levels beyond the reach of poor. This has resulted in a sharp decline in the protein availability in diets of the poor. Pulse production has declined rapidly with the spread of wheat and paddy monoculture and is bound to decline further with the policy emphasis on cash cropping and export–oriented agriculture.

**Some of the pulses grown organically at Navdanya farm are as follows:**

- **Blackgram (urad):**

**Botanical name:** ***Phaseolus mungo***

Blackgram is usually grown pure. The large seed variety of blackgram is considered better than the small seeded. It is drought resistant and forms a valuable food resource if millets fail. The proteins in blackgram are comparable more to proteins from animal sources and thus this pulse is considered to be substitute for meat.

*Blackgram (Urad)*

- **Greengram (moong):**

**Botanical name:** ***Phaseolus radiatus***

Greengram can be cultivated in both the early and the late monsoon, with varieties especially suitable to each season. Greengram has the least tendency to cause flatulence among the pulses, is easily digestible and is considered to be an ideal food for ill. The flour is often used as a substitute for soap, especially for children.

*Greengram (Moong)*

- **Rice bean (navrangi):**

**Botanical name: *Vigna umbellate***

Rice bean is a creeper with very lush growth and provides good ground cover. It has bright yellow fowers. The bean comes in nine colours, which gives it its vernacular name 'navrangi'. It is consumed as a pulse.

- **Cowpea (lobiya):**

**Botanical name: *Vigna unguiculata***

- **Horsegram (gahath):**

**Botanical name: *Dolichos biflorus***

- **Lentil (masoor):**

**Botanical name: *Lens esculenta***

*Cowpea (Lobiya)*

*Horsegram (Gahath)*

The lentil is highly nutritious, but is considered to be heating. The meal of lentils, without their coat is of great richness. The bitterness in the lentil may be removed by soaking it for sometime in water with a little baking soda.

### *3.2.3 Vegetables and fruits*

Navdanya in its pioneering study on the food starvation and its genesis in modern India have identified the multinational responsible for the misery and widespread malnutrition of the masses. In its publication *Corporate Hijack of Food*, it describes how the World Bank and WTO are pushing the poor to starvation for its anti people policies. The change in the eating habits of masses and the deviation of traditional foods to that of *junk* or the *fast food* are resulting in nutrient deficiencies that were never heard of before.

*Lentil (Masoor)*

This outstanding deficiency in Indian diets today is due to the low intake of vegetables and fruits by change in eating habits of people. The problem of iron deficiency in our country today, is as much due to deficiency of iron as to deficiency of vitamin C (which can also be supplied by green leafy vegetables).

Analysis of samples of fruits and vegetables sold in Delhi revealed disturbingly high levels of heavy metal contamination of arsenic, cadmium and mercury that are carcinogenic in nature. The reason that can be attributed is the high level of pollution of the sludge from which these seasonal vegetables are irrigated with.

In another study by Campden Research Station (Analytical Survey of the Nutritional Composition of Organically Grown Fruit and Vegetables) revealed that there are differences in nutritional status between organic and non-organic produce. The data are presented in the following table:

**Table 3.2: Differences in nutritional status between organic and non-organic produce**

| | ***Nutrients in Organic food per 100 g*** | ***Nutrients in chemically produced food per 100 g*** |
|---|---|---|
| ***Apples*** | | |
| Sugars (total) | 8.8g | 9.5g |
| Vitamin C | 21.6mg | 19.3mg |
| ***Apples after dehydration*** | | |
| Sugars (total) | 63.4g | 70.0g |
| *Tomatoes* | | |
| Vitamin C | 21.8mg | 18.0mg |
| Vitamin A | 4.7mg | 3.5mg |
| ***Tomatoes after dehydration*** | | |
| Vitamin C | 349mg | 288mg |
| Vitamin A | 7.3mg | 5.5mg |
| ***Carrots*** | | |
| Glucose | 0.9g | 1.3g |
| Potassium | 269mg | 217mg |
| ***Carrots after dehydration*** | | |
| Sugars (total) | 42.8g | 52.8g |
| Potatoes | | |
| Sugars (total) | 0.7g | 0.8g |
| Vitamin C | 13.5mg | 17.8mg |
| Potassium | 329mg | 370mg |
| Zinc | 310µg | 260µg |
| ***Potatoes after dehydration*** | | |
| Sucrose | 1.0g | 2.4g |
| Fructose | 1.2g | 0.7g |
| Glucose | 2.0g | 1.2g |
| Iron | 5.7mg | 4.7mg |
| Calcium | 64.0mg | 56.4mg |
| Zinc | 1810µg | 1350µg |

*Source: Campden Research Station (Analytical Survey of the Nutritional Composition of Organically Grown Fruit and Vegetables)*

Pesticide like DDT stay in the soil for a long time, pollute our water, accumulate in our food. Various studies done in Bombay, Hyderabad, Pantnagar and Ludhiana showed clearly that pesticides residue (DDT/BHC) are found in rice, pulses and wheat /flour (VHAI).

Modern agricultural practices have adversely affected the quality of our food supply. Growing foods with methods designed to increase production or to facilitate transportation and storage (such as the development of sturdy, square tomatoes) is often detrimental to their nutritional value. Nutritional value is rarely considered when developers modify the genetic and phenotypic make up of plants. The soil productivity has been degraded through modern chemical farming practices. Most chemical fertilizers do not cater to all of the minerals needed for optimum plant growth. Organic foods have been shown to have a higher nutritional value than conventionally grown foods. They are also free of residues of pesticides, herbicides, fungicides and other additives during food processing and preservation.

According to Sultan Ismail, (2002), organic foods are more nutritious than chemical ones. The data are presented in the following table:

**Table 3.3 : Availability of protein, carbohydrates and lipids in organic and chemical crops (maximum availability of nutrients mg/100 gm dry weight)**

| *Crop* | *Input* | *Protein* | *Carbohydrate* | *Lipids* |
|---|---|---|---|---|
| Okra | Chemical | 0.94 | 4.00 | 0.80 |
| | Organic | 1.30 | 6.20 | 1.15 |
| Peanut | Chemical | 1.10 | 5.70 | 1.20 |
| | Organic | 1.34 | 6.90 | 2.00 |

Foods are often picked before they are ripe and allowed to ripen in transit, at the market or during home storage. The artificial ripening is also done by adding growth hormones and chemicals in large quantity that adversely affects the physiology of the food (grains, fruits and vegetables). They do not acquire their whole set of minerals and vitamins, which on natural course of ripening are present during the later stages of growth. Food products kept for longer duration as in transit or in market make them stale and deteriorate their nutritional status of the food. Fruits and vegetables lose significant amounts of vitamin C within 3 days in cold storage, and even more at room temperature. Dried fruits can also lose vitamins A, C and E if exposed to oxygen and light. Thus the stored foods are of low nutritional value, and their lower nutrient content increases the need of taking supplements.

You can overcome some of these problems if you grow your own food or buy organically grown fruits and vegetables (which are generally fresher because they cannot be stored as long). Commercial fruits and vegetables are frequently sprayed with toxic chemicals. Many of these substances are harmful, and they accumulate in body fat, with deleterious health effects over the years. A good example is DDT, which is still present in human fat tissue and in mother's milk, although its use was banned years ago.

Many of the pesticides prohibited in the United States have been freely sold to third world countries, which then export foods to the US. Controls on the use of pesticides and other chemicals are not strict in many of these countries. The workers who apply these chemicals contract diseases.

According to an international report from Journal of Applied Nutrition, 1993, the organically grown food averaged 63% higher in calcium, 78% higher in chromium, 73% higher in iron, 118% higher in magnesium, 178% higher in molybdenum, 91% higher in phosphorus, 125% higher in potassium and 60% higher in zinc. The organically raised food averaged 29% lower in mercury than chemically grown food.

Recently a Delhi based NGO "Srishiti" has filed a civil writ petition against Ministry of Agriculture, Ministry of Chemicals, Fertilizers and Petrochemicals, Ministry of Health and Family Welfare, Ministry of Environment and Forests and Ministry of Food and Consumer Affairs, Govt. of India for firstly, a ban on the pesticides and insecticides in India which have already been banned in the other countries, secondly for prescription of maximum residue levels (MRLs) of the registered pesticides according to the international standards. According to "Srishti", wheat, milk, fish, tea, edible oils and practically all other foods in India are heavily contaminated with the most dangerous pesticides. Other relevant studies show similar results.

ICMR (Indian Council of Medical Research) 1993, conducted a seven years study called the "Surveillance Contaminants in India" which reported high levels of pesticides residue in food. In 1999, a study conducted by AICRP (All India Co-ordinated Research Projects on Pesticide Residue), showed 60% food commodities contaminated with pesticides of which 14% were over the MRL. According to their study, vegetables and fruit samples collected from 16 states in India, showed that in the states of Tamil Nadu, Uttar Pradesh, Kerala and MP, 90 to 100% of the samples were contaminated with pesticides. Samples of groundnut, sesame, soybean and vegetable oils were contaminated with HCH and DDT. The study showed that milk and milk products were also highly contaminated with carcinogenic beta-HCH. Study conducted in the year 2000 by CERC, Ahemdabad found that most of the wheat flour brands were contaminated with pesticides. The research conducted in Punjab, Haryana, Delhi and Mumbai revealed widespread contamination not only of the wheat flour but also of the grain samples.

Chapter IV

# Chemical farming fuelling suicide among farmers

## Economic non-viability of chemical farming leads to suicidal economy

Chemical farming depends on costly external inputs such as seeds, fertilizers, pesticides etc. In the initial stages of the green revolution, these inputs were subsidized. Under the impact of globalization and trade liberalization, subsidies have been removed. In the meantime there is a need for increased use of chemical fertilizers because agrochemicals behave like ecological narcotics — the more you use, the more you need. Increasing costs make chemical farming a losing proposition for farmers and eventually a negative economy, with costs of production becoming higher than the price farmers get from there crops, pushing farmers into debt and suicides.

How does agricultural industrialization and production for the export market lead to uprooting a market which leads to the uprooting and destruction of small farmers while benefiting the large farms? According to Shiva (2001), agricultural industrialization and exports increases single commodity harvests. Navdanya's publication ***Yoked to Death-*** *Globalization and Corporate Control of Agriculture* describes how a single multinational company owns the entire supply chain right from the seeds the farmer procures, to the pesticides he needs to save his crop, to the money he loans for carrying the costly operation that is called chemical farming and then to find depots to store and the companies to transport his produce. He eventually becomes a puppet in the hands of the multinationals. With all farmers growing the same commodity over large areas, the prices farmers receive from their crops come down, while the costs of inputs, which are imported, are always rocketing high. As a result, farmers' profit margins get drastically narrowed. As costs of production increase, farmers experience a cost-price squeeze. In this process, only the multinationals are benefited.

The costs of chemical farming are high. Most of the pesticides available in the market are very expensive and out of reach of poor farmer. Pesticide companies spread false information about efficacy of their pesticides forcing the poor farmers to buy their product. The poor farmer is forced to take loan from rich money lenders to buy pesticides. Pesticide manufacturers and dealers are concerned about selling their products and therefore do not give information on how much to apply and how frequently. In most cases, either too little or too much is applied. Application of less than the prescribed dose does not kill the pests while application of too much destroys the plants as well. In either case, the farmer is the loser. The mass suicide by farmers in Andhra Pradesh, Karnataka, Punjab and Maharashtra bears testimony to this fact trap. Navdanya's publication *"Seeds of Suicide"* has shown how chemical agriculture is pushing the farmer into a debt trap due to the increase in pesticides and fertilisers. Farmers are selling kidneys or commiting suicide by consuming the very pesticide for which they had taken the debt.

The impact of trade liberalisation and globalisation has been felt in each and every state. Farmers from states like Punjab, Karnataka, Maharashtra and Andhra Pradesh bear the maximum burden in terms of high social and ecological costs for globalisation. They are being forced to sacrifice their lives and livelihoods, as they are unable to withstand the onslaught of the price structure. In a publication *Corporate hijack of agriculture* Shiva *et al.,* (2001) cites how trade liberalization and market access rules of WTO are anti farmer and are instrumental in snatching the livelihood of the farmers by unfair trade practices. Growing indebtedness and increasing crop failure are the main reasons for the farmers that lead them to commit suicide. The suicide by farmers highlights these high social and ecological costs of the globalisation of non-sustainable agriculture. While the benefits of globalisation to the seeds companies and corporations which own chemical manufacturing units through expanding markets, the cost and risks are solely being born by the small farmers and landless peasant.

The epidemic of farmer's suicide is the real barometer of the stress under which Indian agriculture and Indian farmers have been put by globalization. It is due to this unbearable stress that the farmers have committed suicide across the length and breadth of rural India. The suicides by farmers highlights these high social and ecological costs of the globalization of non-sustainable agriculture which are not restricted to the cotton growing areas of these states but have been experienced in all commercially grown and chemically farmed crop in all regions.

The two most significant ways through which the risks of crop failures have been increased by globalization are the introduction of ecologically vulnerable hybrid seeds and the increased dependence on agri-chemical input such as pesticide, which are necessary to be used with pest prone hybrids.

A detailed study in 2000 by Navdanya has summed up its finding in the publication ***Seeds of Suicide*** (Shiva et. al., 2000) wherein, it has been stressed that when a farmer is sucked into chemical farming he starts to loose control of his production initially, followed by losing his land and other assets and finally loses his own life in this costly bargain.

The privatization of the seed sector under trade liberalisation has led to a shift in cropping patterns from polyculture to monoculture and a shift from open pollinated varieties to hybrids. The case of Warangal district of Andhra Pradesh is noteworthy. The shift from mixed cropping to monocropping is stark. The change has been very rapid, converting Warangal from a mixed farming system base wherein millets, pulses and oilseeds were grown to a center where now monoculture of hybrid cotton is widespread. Similar reports have been recorded from districts of Punjab, Karnataka and Maharashtra. Shifting from chemical to organic agriculture and from monocultures to biodiversity has become an economic necessity, not just an ecological imperative.

If farming has to be sustained and farmers have to survive, chemical free organic agriculture is the only way out.

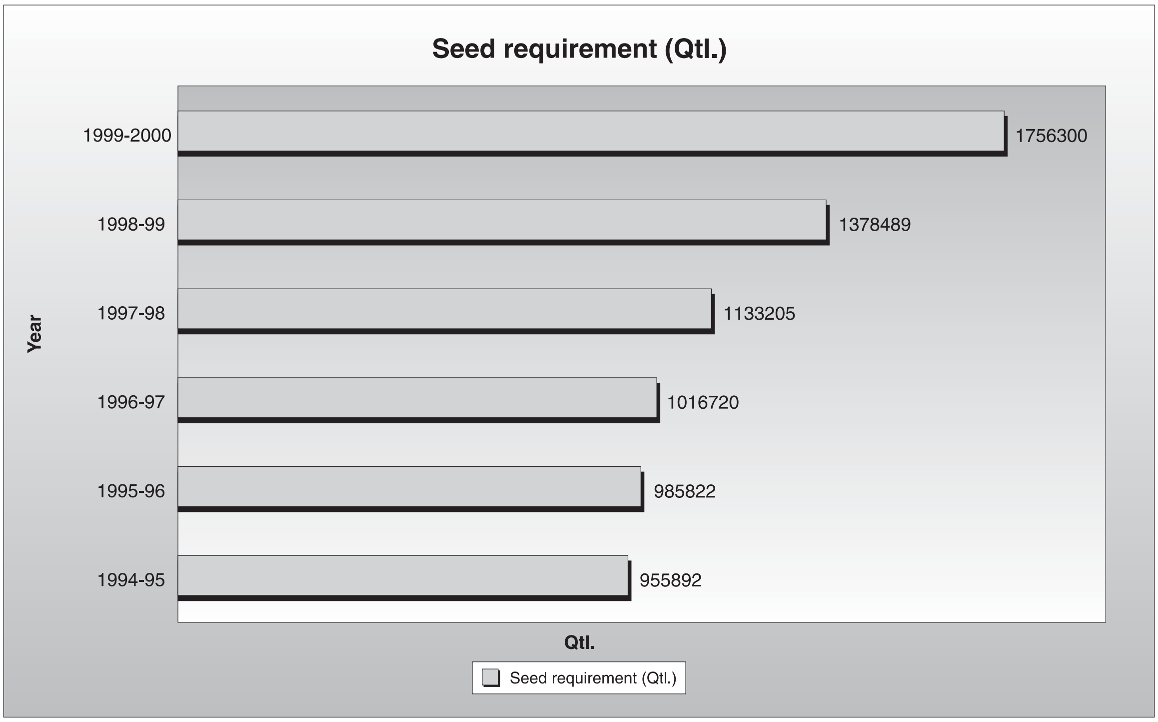
**More than 16,000 farmers have committed suicide in Andhra Pradesh alone from 1995 to 1997 (Observer, 1999).**

**As many as 82 farmers from Vidarbha and Marathwada regions of Maharashtra had committed suicide during the year 1998 after being overburdened by debts (The Hindu, New Delhi, 21.07.1998).**

**About 80 cases of suicides by farmers and agricultural labourers reported from five villages of Sangrur district of Punjab (The Hindu, New Delhi, 21.04.1998).**

**In Punjab 3,000 suicides are committed annually**

**Table 4.1: Requirement of seeds in Andhra Pradesh**




The ever growing interest and the accumulating debts in Rentichintala Mandal of Andhra Pradesh has led to distress sale of kidneys by many farmers. The farmer are caught in lose-lose situation and there is no way out either for getting rid of the debts or getting humiliated at the hands of "aarthies" and money lenders. After the incident of kidney sale by farmers came to the knowledge of everyone, the life of these farmers has become even worse. There is no support either from the government or from the village itself. In 1999-2000 suicides by farmers continued in Punjab due to the acute indebtness, exploitation of commission agents and crop failures.

**PART II**

CHAPTER V

# The organic way of farming: *A living economy*

## 5.1 Organic farming in the broader context of sustainable agriculture

Organic farming is a production system, based on renewal of ecological processes and strengthening of ecological functions of farm ecosystem to produce safe and healthy food sustainability. Organic farming avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests".

In contrast to modern systems, organic agriculture represents a deliberate attempt to make the best use of local natural resources. The aim of organic agriculture, also known as ecological or biological agriculture, is to create integrated, humane, environmentally and economically viable agriculture systems in which maximum reliance is placed on locally or farm-derived renewable resources, and the management of ecological and biological processes. The use of external inputs, whether inorganic or organic, is reduced as far as possible. Recent years have seen a dramatic increase in adoption of organic agriculture in industrialized countries.

The important thing for most organic farmers is that it represents a system of agriculture rather than simply a set of technologies. The primary aim is to find ways to grow food in harmony with nature. The term organic is "best thought of as referring not to the type of inputs used, but to the concept of the farm as an organism, in which the component parts the soil minerals, organic matter, micro-organisms, insects, plants, animals and stable whole" (Lampkin and Padel, 1994).

Most farmers in developing countries are poor and marginalized from input and product markets.

Organic Farming is based on sound agro-ecological principles

## 5.2 Principles of organic farming

Organic Farming is based on principles of agro-ecology. These include:

***On a general level***

- Improvement and maintenance of agro-ecosystem based on conservation of soil, water and biodiversity
- Preventing exploitation and pollution of natural resources
- Reduction in consumption of non-renewable energy
- Production of nutritious and high quality products
- Conservation of indigenous knowledge and traditional farming systems
- Protection of freedom and independence of farmers with respect to seed sovernity and other inputs and markets
- Diversity
- Decentralisation

***On a practical level***

- Conservation of soil
- Maintenance of soil fertility
- Natural nutrient mobilisation
- Pest management through biological pest control
- Increase in biodiversity genetic base
- No use of synthetic and agrochemicals
- Prohibition of Genetic Engineering and related products
- Usage of farm manures and crop residues
- Biologically active soil life

**Ecosystem diversity**

According to the World Resources Institute, an ecosystem is made up of the organisms of a particular habitat, such as a farm or forest, together with the physical landscape in which they live. Although little research has been carried out comparing agro-ecosystem diversity in different farming regimes, many of the principles of organic agriculture are likely to have a positive impact on ecosystem diversity (IFOAM, 2002) "maintain a significant portion of farms to facilitate biodiversity and nature conservation", including (among other) wildlife refuge habitats and wildlife corridors that provide linkages and connectivity to native habitat.

Organic agriculture has a high and possibly decisive potential for reversing the dramatic decline of biodiversity.

***Essential characteristics of Organic Farming***

- Sustainable use of local resources
- Ensuring basic biological functions of soil-water-nutrient-humus-continuum
- Maintenance of diversity of plants

- Maintenance of nutrient cycle within the farm
- Stability due to diversification
- Optimum input output ratio

## 5.3 Organic agriculture nurtures soil biodiversity

Scientific research has demonstrated that organic agriculture significantly increases the density and species of soil's life. Suitable conditions for soil fauna and flora as well as soil forming and conditioning and nutrient cycling are encouraged by organic practices such as: manipulation of crop rotations and strip-cropping; green manuring and organic fertilization (animal manure, compost, crop residues); minimum tillage; and of course, avoidance of pesticides and herbicides use.

Benefits of organic management on soil biological activity are summarized below

- **Abundant arthropods and earthworms.** Organic management increases the abundance and species richness of beneficial arthropods living above ground and earthworms, and thus improves the growth conditions of crops. More abundant predators help to control harmful organisms (pests). In organic systems the density and abundance of arthropods, as compared to conventional systems, has up to 70-120% more spiders. The biomass of earthworms in organic systems is 30-40% higher than in conventional systems, their density even 50-80% higher. Compared to the mineral fertilizer system, this difference is even more pronounced.
- **High occurrence of symbionts.** Organic crops profit from root symbioses and are better able to exploit the soil. On average, mycorrhizal colonization of roots is highest in crops of unfertilized systems, followed by organic systems. Conventional crops have colonization levels that are 30% lower. Even when all soils are inoculated with active micorrhizae, colonization is enhanced in organic soil.
- **High occurrence of micro-organisms.** Earthworms work hand in hand with fungi, bacteria, and numerous other microorganisms in soil. In organically managed soils, the activity of these organisms is higher. Micro-organisms in organic soils not only mineralize more actively, but also contribute to the build up of stable soil organic matter (there is less untouched straw material in organic than in conventional soils). Thus, nutrients are recycled faster and soil structure is improved. The amount of microbial biomass and decomposition is connected: at high microbial biomass levels, little light fraction material remains undecomposed and vices versa.
- **Microbial carbon.** The total mass of microorganisms in organic systems is 20-40% higher than in the conventional system with manure and 60-85% than in the conventional system without manure. The ratio of microbial carbon to total soil organic carbon is higher in organic system as compared to conventional systems. Organic management promotes microbial carbon (and thus, soil carbon sequestration potential).

- **Enzymes.** Microbes have activities with important functions in the soil system: soil enzymes indicate these functions. The total activity of microorganisms can be estimated by measuring the activity of a living cell-associated enzyme such as dehydrogenase. This enzyme plays a major role in the respiratory pathway. Proteases in soil, where most organic N is protein, cleave protein compounds. Phosphatases cleave organic phosphorus compounds and thus provide a link between the plant and the stock of organic phosphorus in the soil. Enzyme activity in organic soils is markedly higher than in conventional soils. Microbial biomass and enzyme activities are closely related to soil acidity and soil organic matter content.
- **Wild flora**. Large organic fields (over 15 ha) featured flora six times more abundant than conventional fields, including endangered varieties. In organic grassland, the average number of herb species was found to be 25 percent more than in conventional grassland, including some species in decline.

In most cases, organic agriculture conserves better than conventional agriculture the site-typical plant community of floral species of arable land. A survey comparing organic with conventional fields showed that in the organic system the share of the fields with endangered floral species was 79 percent as opposed to 81 percent 27 years earlier, showing that the share had almost not changed. In the conventional fields the rate had dropped from 61 percent to 29 percent (Frieben, 1997).

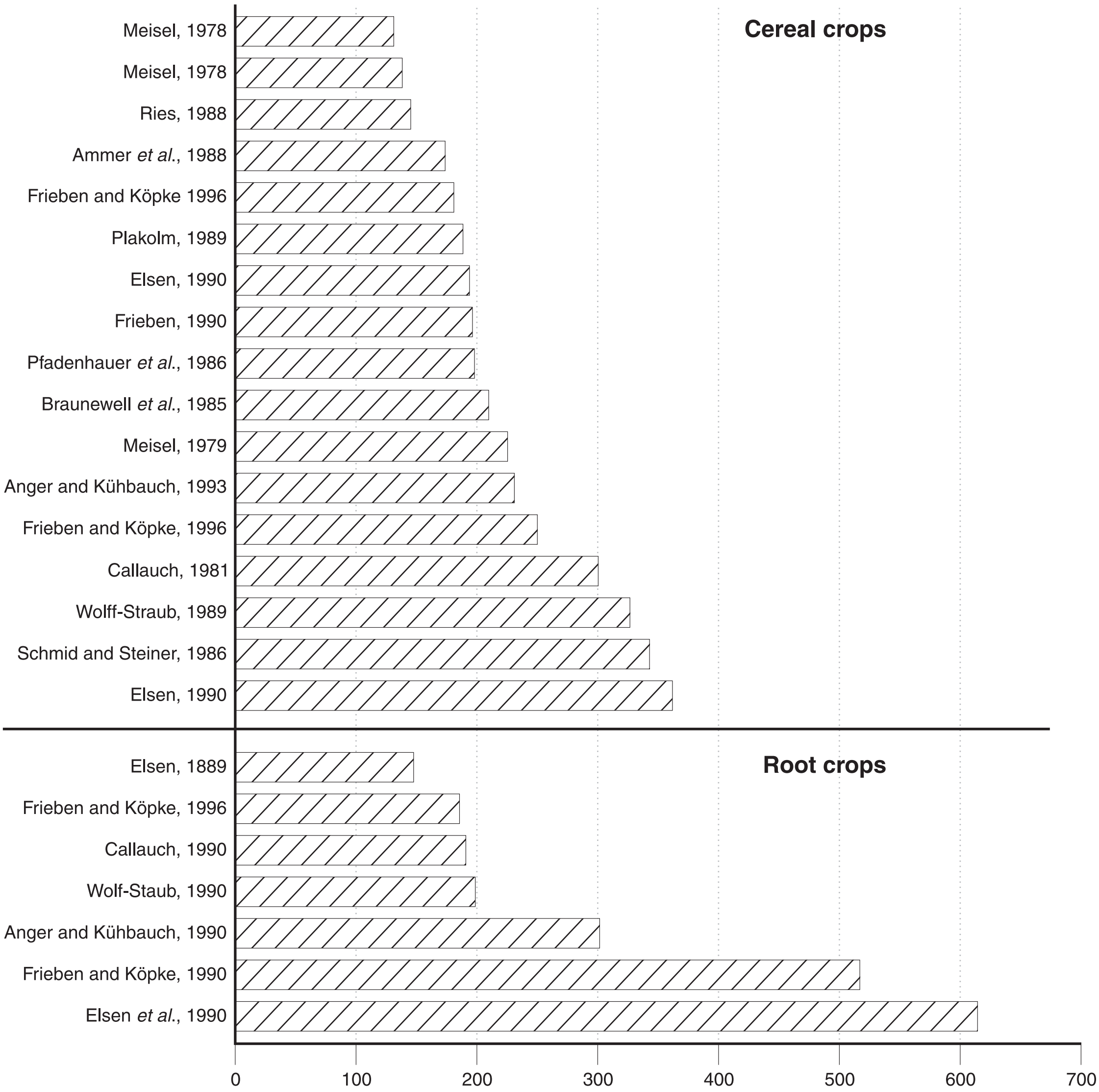
The higher floral diversity and abundance in organic arable fields is generally due to the ban on synthetic N-fertilizers and herbicides. The limited availability and

**Table 5.1: Effects of organic and conventional agriculture on fauna**

| *Animal group* | *Abundance - number of individuals* | | | *Species diversity - number of species* | | |
|---|---|---|---|---|---|---|
| | *Better performance in organic agriculture* | *No significant difference between organic and conventional agriculture* | *Better performance in conventional agriculture* | *Better performance in organic agriculture* | *No significant difference between organic and conventional agriculture* | *Better performance in conventional agriculture* |
| Earthworms | 17 | 1 | 0 | 4 | 3 | 0 |
| Arthropods | | | | | | |
| • Carabids | 13 | 2 | 0 | 6 | 2 | 0 |
| • Spiders | 6 | 1 | 0 | 0 | 0 | 0 |
| • Myriapods | 4 | 0 | 0 | 1 | 1 | 0 |
| • Bugs | 2 | 1 | 0 | 1 | 1 | 0 |
| • Mites | 2 | 0 | 1 | 1 | 1 | 0 |
| Birds | 5 | 0 | 0 | 2 | 0 | 0 |
| Total cases of all animal groups | 49 | 5 | 1 | 15 | 8 | 0 |

*Source: Pfiffner et al., 2001*

**Figure 5.1: Studies comparing species numbers of arable weed flora in organic and conventional arable fields in Central Europe**




The number of species found in organic fields in shown in percent compared to the conventional variants (Conventional = 100%)
*Source: Frieben, 1997, modified by Köpke, 1999*

input of nitrogen, the application of mechanical and thermal weed control and more diverse crop rotations and a higher crop diversity lead to more favourable conditions for many wild plant species.

In organic grassland, the average number of species were found to be around 25 percent higher in organic than in conventional grassland.

- **Faunal diversity** Organic agriculture displays in most cases a higher faunal biodiversity than conventional agriculture. Apart from the better food resources in organic fields, the key factors are more fauna-compatible plant protection management, organic fertilization, the more diversified crop rotation and the more structured landscapes with semi-natural habitats and field margins.

The effects of organic agriculture on faunal biodivesity have been studied particularly for soil fauna and for birds. A review of 44 research studies in Europe and the United States of America (on farm and pilot trials) on the effects of farming systems on beneficial invertebrates and birds consistently shows a better performance of the organic system (See table 8). Of the faunal groups analysed (i.e. earthworms, arthropods and birds) in 49 out of 55 investigations organic agriculture performed better in terms of abundance.

## 5.4 Energy use

Energy consumption in agriculture includes the direct consumption of fossil energy (e.g. fuel and oil), as well as indirect energy consumption (e.g. from the production of synthetic fertilizers and pesticides). Nevertheless, limited fossil energy resources and the climatic relevance of its use require efficient energy use, even in agriculture. Relevant parameters for evaluating energy use in agriculture are energy consumption and energy efficiency.

Considering both, direct and indirect energy consumption, scientific calculations on energy consumption per hectare indicate that organic farms use less energy than conventional farms; several researchers (Haas & Kopke, 1994a) calculated the energy consumption of organic farms to amount 64 percent of the on conventional farms. Other recent research [Zarea *et al.,* 2000 (in Iran); Fliessbach *et al*., 2001 (in Switzerland)] confirms the figures mentioned above at lower levels, with energy consumption on organic farms amounting to 45 percent or 30 to 50 percent of conventional farms, respectively.

Table 5.2 below shows figures on energy consumption (GJ) both per hectare and per unit of output (t) for different crops, comparing organic and conventional agriculture systems in Germany, Italy, Sweden and Switzerland. The determining factor for energy consumption of a specific crop is cropping management, which includes tillage intensity, manuring and weed control. On a per hectare scale, all authors determined lower energy consumption on organic farms.

A second parameter appropriate for evaluating energy use is energy efficiency. It provides information about the ratio of energy input and output. Comparing rotations of different production systems in Iran, Zarea *et al.,* (2002) found the energy efficiency of organic agriculture to be 81 percent better compared to high-input conventional agriculture. In a similar investigation in Poland Kus & Stalenga, (2000) calculated a 35 percent higher energy efficiency of organic compared to conventional agriculture. Under Mediterranean conditions in Italy, a 25 percent higher efficiency in organic wheat and an 81 percent higher efficiency in organic vineyard production systems were found (Ciani and Boggia, 1993 Ciani, 1995).

**Table 5.2: Calculations of energy consumption of different products**

| *Product* | *Energy use GJ /ha* | | | *Energy use GJ/t* | | |
|---|---|---|---|---|---|---|
| | *Conventional* | *Organic* | *as % of conventional* | *Conventional* | *Organic* | *as % of Conventional* |
| **Winter wheat** | | | | | | |
| Alföldi *et al.*, (1995) | 18.3 | 10.8 | -41 | 4.21 | 2.84 | -33 |
| Haas and Köpke (1994) | 17.2 | 6.1 | -65 | 2.70 | 1.52 | -43 |
| Reitmayr (1995 | 16.5 | 8.2 | -51 | 2.38 | 1.89 | -21 |
| **Potatoes** | | | | | | |
| Alföldi *et al.*, (1995) | 38.2 | 27.5 | -28 | 0.07 | 0.08 | +7 |
| Haas and Köpke (1994) | 24.0 | 13.1 | -46 | 0.08 | 0.07 | -18 |
| Reitmayr (1995) | 19.7 | 14.3 | -27 | 0.05 | 0.07 | +29 |
| **Citrus** | | | | | | |
| Barbera and La Mantia (1995) | 43.3 | 24.9 | -43 | 1.24 | 0.83 | -33 |
| **Olive** | | | | | | |
| Barbera and La Mantia (1995) | 23.8 | 10.4 | -56 | 23.8 | 13.0 | -45 |
| **Apple** | | | | | | |
| Geier *et al.*, (2001) | 37.35 | 33.8 | -9.5 | 1.73 | 2.13 | +23 |
| **Milk** | | | | | | |
| Cederberg and Mattsson (1998) | 22.2 | 17.2 | -23 | 2.85 | 2.41 | -15 |
| Wetterich and Haas (1999) | 19.1 | 5.9 | -69 | 2.65 | 1.21 | -54 |

*Source: Stolze et al., 2000*

Even though the ban on synthetic pesticides might lead to higher fuel consumption on organic farms due to increased mechanical weed control (Hass and Kopke, 1994), in developed countries research results presented below show that with respect to energy consumption, organic agriculture is performing better than conventional agriculture.

Organic agriculture follows the ecosystem theory of closed (or semi-closed) nutrient cycle on the farm. Organic land management allows the development of a relatively rich weed-flora as compared to conventional systems. The presence of versatile flora attracts beneficial herbivores and other air-borne or aboveground organisms. Their presence improves the nourishment of predatory arthropods. When comparing diversity and the demand of energy for microbial maintenance (as indicated by the metabolic quotient), it becomes evident that diverse populations need less energy per unit biomass. A diverse microbial population, as present in the organic field plots, may divert a greater part of the available carbon to microbial growth rather than maintenance. In agricultural practice this may be interpreted as an increased turnover of organic matter with a faster mineralization and delivery of plant nutrients. Finally, more organic matter is diverted to build-up stable soil humus.

The main reasons for this are:

- No input of mineral N-fertilizers which require a high energy consumption for production and transport on organic farms;

- Lower use of highly energy-consumptive foodstuffs (concentrates);
- Lower input of mineral fertilizers (P, K);
- Ban on synthetic pesticides.

With respect to energy consumption, organic agriculture is performing better than conventional agriculture.

## 5.5 Erosion control

Organic soil management improves soil structure by increasing soil activity and thus, reduces erosion risk. Organic matter has a positive effect on the development and stability of soil structure. Silty and loamy soils profit from organic matter by an enhanced aggregate structure. Organic matter is adsorbed to the charged surfaces of clay minerals. The negative charge decreases with increasing particle size. Silt is very susceptible to erosion since it is not charged, but organic matter layers on the silt surface favor aggregates with silt too (Anon, 2000).

CHAPTER VI

# Soil as a living system

## 6.1 Soil

The soil is a living system. It contains millions of living organisms, which create the complex dynamic living processes of the soil.

### Types of soil

There are two sources of soil matter:

*A. Mineral*

- Forms from rock and sediment
- Most soils form from minerals and are called mineral soils

*B. Organic*

- Forms from peat, muck, and plant remains
- May form in swamps or very wet areas

## 6.2 The functions of the soil

Though often overlooked, the soil performs many vital functions for the environment and society. A healthy soil is important for the following:

- Maintenance of the basic resources for food production: soil, clean water and stable climate
- Maintenance of terrestrial and aquatic biodiversity (soil life is the basis of over-ground life; healthy soil minimises agro-chemical pollution and nutrient leaching into watercourses)
- Regulating the flow of water on the planet, including reducing flooding
- Reducing water clean up costs (through reduction in pesticide and nutrient pollution)
- Reducing climate change (soil is a major carbon store and it reduces atmospheric methane, both are major greenhouse gases)

- Reduction in the need for water for irrigation in agriculture
- Improvement in health through an increase in the nutrient content of food and reduction in pesticide residues

## 6.3 Soil ecosystem

Soil ecosystem is a natural unit in which the life cycles of plants, animals and other organisms are linked to each other and to the rest of the non-living environment to form a natural system. Billions of organisms inhabit the upper layers of the soil, where they break down dead organic matter, releasing the nutrients necessary for plant growth.

Soils contain enormous numbers of diverse living organisms assembled in complex and varied communities. Soil biodiversity reflects the variability among living organisms in the soil - ranging from the myriad of invisible microbes, bacteria and fungi to the more familiar macro-fauna such as earthworms and termites. Plant roots can also be considered as soil organisms in view of their symbiotic relationships and interactions with other soil components. These diverse organisms interact with one another and with the various plants and animals in the ecosystem, forming a complex web of biological activity.

Environmental factors, such as temperature, moisture and acidity, as well as anthropogenic actions, in particular, agricultural and forestry management practices, affect to different extents soil biological communities and their functions.

Soil organisms contribute a wide range of essential services to the sustainable functioning of all ecosystems. They act as the primary driving agents of nutrient cycling, regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emissions; modifying soil physical structure and water regimes; enhancing the amount and efficiency of nutrient acquisition by the vegetation; and enhancing plant health. These services are not only critical to the functioning of natural ecosystems but constitute an important resource for sustainable agricultural systems.

## 6.4 Healthy soils from agriculture

Capturing the benefits of soil biological activity for agricultural production requires adhering to the following ecological principles:

- **Supply organic matter.** Each type of soil organism occupies a different niche in the web of life and favours a different substrate and nutrient source. Most soil organisms rely on organic matter for food; thus a rich supply and varied source of organic matter will generally support a wider variety of organisms.
- **Increase plant varieties**. Crops should be mixed and their spatial-temporal distribution varied, to create a greater diversity of niches and resources that stimulate soil biodiversity. For example diverse habitats support complex mixes of soil organisms, and through crop rotation or inter-cropping, it is possible to encourage

the presence of a wider variety of organisms, improve nutrient cycling and natural processes of pest and disease control.

- **Protect the habitat of soil organisms.** The activity of soil biodiversity can be stimulated by improving soil living conditions, such as aeration, temperature, moisture, and nutrient quantity and quality. In this regard, reduced soil tillage and minimized compaction - and refraining chemical use - are of particular note.

The microorganisms include bacteria, actinomycetes, algae and fungi. Macro-organisms include earthworms and arthropods such as insects, mites and millipedes. Each group plays a role in the soil ecosystem and can assist the organic farmer in producing a healthy crop. Micro-organisms can be grouped according to their function: free-living decomposers convert organic matter into nutrients for plants and other micro-organisms, rhizosphere organisms are symbiotically associated with the plant roots and free-living nitrogen fixers.

## 6.5 Decomposers

In an undisturbed soil, leaves and other organic debris accumulate on the surface, where the decomposers break them down. Aerobic bacteria and certain small animals begin the process. Actinomycetes and fungi join these organisms. Mites, springtails, small insects, other arthropods and earthworms assist the process by consuming, mixing and transporting materials. The rate of decomposition is affected by soil temperature, moisture and food availability. The main by-products of the decomposition process are soluble plant nutrients and microbial remains that bind the soil particles together, giving a stable crumb structure. Since biological activity is greatest when the soil is warm, nutrient availability is highest during summer, when crop needs are greatest. The decomposers are most active in the upper layer of the soil, i.e. the top 8 cm (3 in.). Organic farmers incorporate organic matter into the surface layers when conditions are favorable to stimulate decomposition and thereby provide plant nutrients.

## 6.6 Rhizosphere organisms

Plant roots exude a large number of organic substances and continually slough off root caps into the soil. These materials are food for the many microorganisms living in a zone of intense biological activity near the roots called the rhizosphere. Bacteria benefit most from the food supplied in the rhizosphere and may form a continuous film around the root. Roots form the microbial highways of the soil. Other microorganisms liberate nutrients from the clay and humus colloids (a colloid is a mass of fine particles).

## 6.7 Symbiotic organisms in the rhizosphere

The best-known symbiotic relationship occurs between nitrogen-fixing *Rhizobia* bacteria and legumes. The *Rhizobia* inhabit small pea-like lumps (nodules) on the roots, extracting carbohydrates from the plant and providing the plant with soluble nitrogen compounds synthesized from nitrogen gas in the soil atmosphere. Mycorrhizal fungi have similar symbiotic relationships with the roots of many plants. By extending the surface area of the roots by as much as 400 times, the fungi help the plant with the absorption of water and nutrients and with its ability to withstand heat and drought. These symbiotic relationships begin at germination when the young sprout exudes toxins to kill pathogens and hormones to attract beneficial organisms.

- **Earthworms**

The most important group of larger soil animals is the earthworms. Earthworms perform the final task of humification — the conversion of decomposed organic matter to stable humus colloids — and mix the humus with material from the lower soil horizons. The digestive tract of the earthworm has a remarkable capacity to literally alter the chemical and physical nature of soil. Earthworms are major agents in the process of soil creation through the formation of clay-humus complexes and they play a key role in the management of calcium. By inoculating their castings with intestinal flora, earthworms distribute microbial populations throughout the soil. Earthworms can increase the availability of phosphorus from rock phosphate by 15-39 per cent. They act as mini-subsoilers, their burrows increasing soil aeration, drainage and porosity.

- **Arthropods**

Mites are the most abundant of the soil arthropods. Most mites are beneficial, feeding on microorganisms and other small animals. They assist with decomposition by browsing on preferred fungi, thus preventing any one species from becoming dominant, and by transporting the spores through the soil. Springtails perform similar functions. Larger arthropods, slugs and snails burrow through the soil and feed on dead plant material. By maintaining a suitable environment for the hundreds of species of soil creatures, large and small, organic farmers provide their crops with an abundant supply of plant nutrients.

- **Protozoa**

Protozoa comprised of the three groups; (1) flagellates, (2) amoebae (both naked and testate), and (3) ciliated, are important in maintaining plant-available N and mineralization processes (Coleman, 1985) and, as bacterial-feeders, are important in controlling bacterial numbers and community structure in the soil (Foissner 1986). The presence or absence of certain protozoa species is indicative of the presence of certain hazardous wastes and therefore may be highly useful indicator organisms of certain types of environmental impacts (Foissner 1986).

- **Nematodes**

Nematodes are one of the most ecologically diverse groups of animals on earth, existing in nearly every habitat. Nematodes eat bacteria, fungi, algae, yeasts, and diatoms and

**Table 6.1: Functions of the soil fauna**

| | *Nutrient cycling* | *Soil strucure* |
|---|---|---|
| **Microflora** (bacteria + fungi) | Catabolise organic matter. Mineralise and immobilise nutrients. | Produce organic compounds that bind aggregates. Hyphae entangle particles onto aggregates. |
| **Microfauna** | Regulate bacterial and fungal populations. Alter nutrient turnover. | May affect aggregate structure through interactions with microflora. |
| **Mesofauna** | Regulate fungal and microfaunal populations. Alter nutrient turnover. Fragment plant residues. | Produce fecal pellets. Create biopores. Promote humification. |
| **Macrofauna** | Fragment plant residues. Stimulate microbial activity. | Mix organic and mineral particles. Redistribute organic matter and microorganisms. Create biopores. Promote humification. Produce fecal pellets. |

may be predators of several small invertebrate animals, including other nematodes. In addition, they may be parasites of invertebrates, vertebrates (including man) and all above and below ground portions of plants. Nematodes range in length from 82 µm (marine) to 9 m (whale parasite) but most species in soil are between 0.25 and 5.5 mm long.

Nematodes are recognized as a major consumer group in soils, generally grouped into four to five trophic categories based on the nature of their food, the structure of the stoma and esophagus and method of feeding (Yeates, 1972). Plant-feeding nematodes possess stylets with a wide diversity of size and structure and are the most extensively studied group of soil nematodes because of their ability to cause plant disease and reduce crop yield. Fungal-feeding nematodes have slender stylets but are often difficult to categorize and have been included with plant-feeders in many ecological studies. Bacterial feeding nematodes are a diverse group and usually have a simple stoma in the form of a cylindrical or triangular tube, terminating in a teeth (Nicholas, 1975).

Predatory nematodes are usually large species possessing either a large styles or a wide cup-shaped cuticular-lined stoma armed with powerful teeth (Nicholas, 1975). Omnivores are sometimes considered as a fifth trophic category of soil nematodes. These nematodes may fit into one of the categories above but also ingest other food sources. For example, some bacterial feeders may also eat protozoa and/or algae and some stylet-bearing nematodes may pierce and suck algae as well as fungi and/or higher plants. Stages of animal parasitic nematodes, such as hookworms, may also be found in soils but generally are not common in most soil samples.

Nematodes and protozoa function as regulators of mineralization processes in soil (Coleman, 1985). Bacterial and fungal feeding nematodes release a large percentage of N when feeding on their prey groups and are thus responsible for much of the plant available N in the majority of soils (Ingham, *et al.,* 1985). Nematode-feeding also selects certain species of bacteria, fungi and nematodes and thereby influences soil structure, carbon utilization rates, and the types of substrates present in soil (Ingham, 1992). Root-feeding nematodes are among the greatest pests in agricultural systems and, with the loss of many nematicides, are becoming greater concerns. Without doubt, plant establishment, survival and successional processes are influenced by these soil organisms

## 6.8 The soil foodweb: functional food chain

Bacteria and fungi perform one of the major nutrients cycling processes, nutrient retention, in soil (Coleman *et al.,* 1992). The amount of N P S and other nutrients immobilized in bacterial and fungal biomass can be considerable, from several micrograms to milligrams of biomass, comprising a significant portion of the stable nutrient pool (Ingham *et al.,* 1986). When the bacterial or fungal component of the soil declines, more nutrients are lost into the ground and surface water (Coleman *et al.,* 1992). A major means of retaining nutrients may also be arthropod fecal material depending on the ecosystem.

Soil bacteria are important in maintaining normal nutrient immobilization and decomposition processes in all ecosystems (Coleman *et al.,* 1985; Ingham, *et al.,* 1986a, b). Plants are strongly influenced by the presence of bacteria in the rhizosphere, especially with respect to microbial immobilization of nutrient, and mineralization of nutrients from bacterial biomass by predators. Disturbance of these soil processes may result in the un-coupling of mineralization and plant growth, with the resultant loss of nutrients from the system, causing problems for systems into which nutrients move (Ingham and Coleman, 1984).

As climate changes occur, bacterial populations in the soil could be significantly impacted (Coleman *et al.,* 1992). As temperature increases, bacterial numbers could increase, resulting in greater immobilization of nutrients in their biomass, causing greater nitrogen limitation of plant growth. Alternatively, bacteria could be inhibited by increases in carbon dioxide, resulting in decreased decomposition of soil organic matter and plant litter, which ultimately would change soil structure and nutrient cycling. Alterations in the fungal to bacterial biomass ratio strongly impacts vegetative community structure. If a forest soil, usually strongly dominated by fungi, loses the fungal component, reflected by a decrease in the ratio of fungi to bacteria, conifer species may be at risk of death. If the fungal to bacterial biomass ratio decreases past one, re-establishment of conifer species may be impossible.

Mutualist bacteria and fungi can be critically important for plants and animals alike, for example, nitrogen-fixing bacteria on legumes, or rumen bacteria in cows, deer or elk. Without their mutualists, these plants and animals are not capable of competing with other organisms and become locally extinct. While methods are not yet capable of distinguishing between saprophytic and pathogenic species of bacteria and fungi in soil, their total and active biomass, and effects of different disturbances on their distributions, can be estimated. However, work should continue on methods to differentiate bacterial and fungal community composition in soil.

Soil processes are important for maintaining normal nutrient cycling in all ecosystems (Coleman *et al*., 1985; Dindal 1990; Ingham, *et al*., 1986a, b). Plant growth is dependent on the microbial immobilization and soil foodweb interactions to mineralize nutrients. In undisturbed ecosystems, the processes of immobilization and mineralization are tightly coupled to plant growth but following disturbance, this coupling may be lost or reduced. Nutrients may be no longer retained within the system, causing problems for systems into which nutrients move (Ingham and Coleman, 1984; Hendrix *et al*., 1986; Nannipieri *et al*., 1990). Measurement of disrupted processes may allow determination of a problem long before normal cycling processes are altered, before the natural vegetation is lost, or human health problems occur. By monitoring soil organism dynamics, we can perhaps detect detrimental ecosystem changes and possibly prevent further degradation.

Immobilization of nutrients in soil, i.e., retention of carbon, nitrogen, phosphorus, and many micronutrients in the horizons of soil from which plants obtain their nutrients, is a process performed by bacteria and fungi. Without these organisms present and functioning, nutrients are not retained by soil, and the ecosystem undergoes degradation. Thus, to assess the ability of an ecosystem to retain nutrients, the decomposed portion of the ecosystem, i.e., active and total fungal biomass, and active bacterial biomass must be assessed.

The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain. Food chains are not isolated sequences but are interconnected with one other. This interlocking pattern is known as food web.

The structure and function of the soil foodweb has been suggested as a prime indicator of ecosystem health (Coleman, *et al.,* 1992; Klopatek, *et al.,* 1993). Measurement of disrupted soil processes, decreased bacterial or fungal activity, decreased fungal or bacterial biomass, changes in the ratio of fungal to bacterial biomass relative to expected ratios for particular ecosystems, decrease in the number or diversity of protozoa, and a change in nematode numbers, nematode community structure or maturity index, can serve to indicate a problem long before the natural vegetation is lost or human health problems occur (Bongers, 1990; Klopatek *et al.,* 1993).

Soil ecology has just begun to identify the importance of understanding soil foodweb structure and how it can control plant vegetation, and how, in turn, plant community structure affects soil organic matter quality, root exudates and therefore, alters soil foodweb structure. Since this field is relatively new, not all the relationships have been explored, nor is the fine-tuning within ecosystems well understood.

However, some relationships between ecosystem productivity, soil organisms, soil foodweb structure and plant community structure and dynamics are known, and can be extremely important determinants of ecosystem processes (Ingham and Thies, 1995).

Alteration of the soil foodweb structure can result in sites, which cannot be regenerated to conifers, even with 20 years of regeneration efforts (Colinas *et al.,* 1993). Work in intensely disturbed-forested ecosystems suggests that alteration of soil foodweb structure can alter the direction of succession. By managing foodweb structure appropriately, early stages of succession can be prolonged, or deleted (Allen and Allen, 1993). Initial data indicates that replacement of grassland with forest in normal successional sequences requires alteration of soil foodweb structure from a bacterial-dominated foodweb in grasslands to a fungal-dominated foodweb in forest (Ingham, E. *et al.*, 1986 a, b; 1991; Ingham and Thies, 1995).

In addition to responses to disturbance, it is clear that species diversity, community diversity and foodweb complexity increases with increasing successional stage (Moore *et al.,* 1991; Ingham, E. *et al.,* 1989). Indeed, examination of foodweb interactions and ecosystem diversity, instead of community diversity, may result in new ecosystem measures that reflect this increased community diversity and increased connectivity in later successional stages.

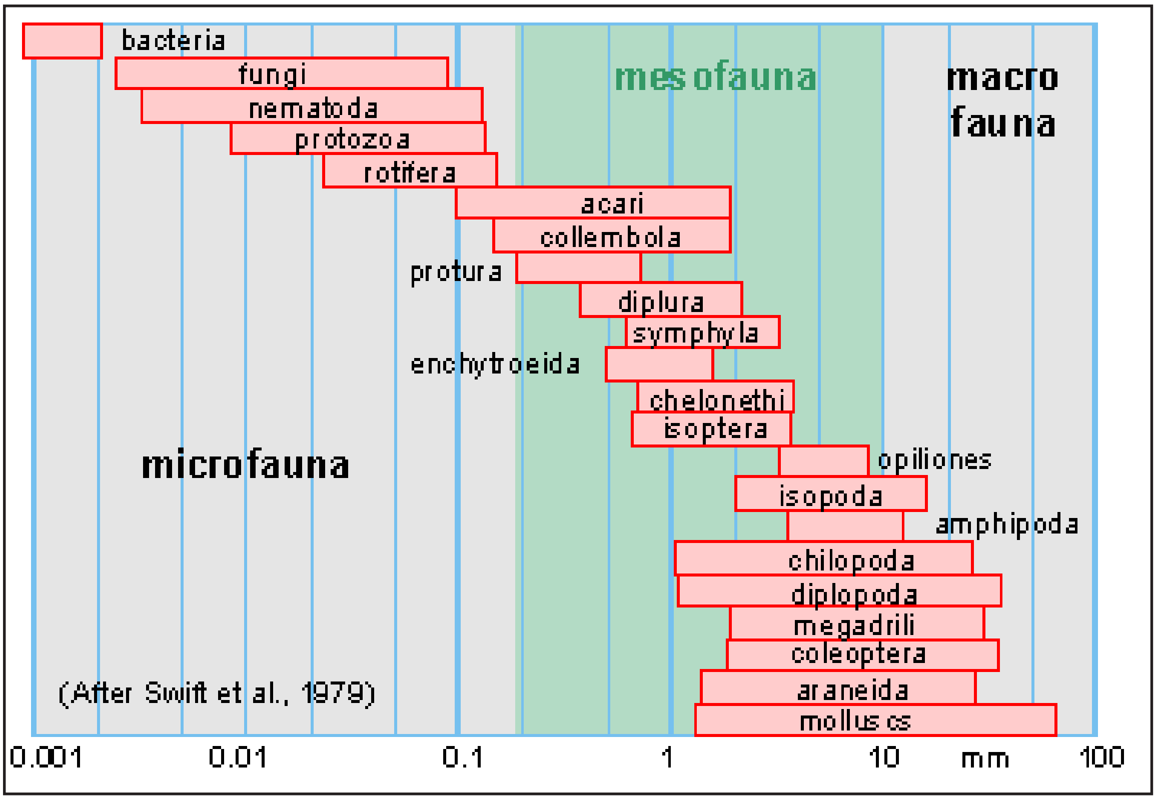
The numbers, biomass, activity and community structure of the organisms, which comprise the soil foodweb, can be used as indicators of ecosystem health because these organisms perform critical processes and functions. Soil decomposers (bacteria, fungi and possibly certain arthropods) are responsible for nutrient retention in soil. If nutrients are not retained within an ecosystem, future productivity of the ecosystem will be reduced as well as cause problems for systems into which those nutrients move, especially aquatic portions of the landscape (Klopatek, *et al.,* 1993).

As ecosystems become more productive, the total amount of nutrients retained within the system increases. As succession occurs, nutrients are increasingly immobilized in forms that are less available for plants and animals, such as phytates, lignins, tannins, humid and fulvic acids (Coleman *et al.,* 1985, 1992). In order for nutrients to become available once again to plants and animals, they must be mineralized by the interaction of decomposers, i.e. bacteria and fungi, and their predators, i.e. protozoa, nematodes, microarthropods, and earthworms (if present).

These predator populations and the rates at which they perform mineralization processes are important to ecosystem stability. The activity of these predator-prey interactions (which determines the rate at which mineralization occurs) are in turn affected, and perhaps controlled by, higher-level predators such as millipedes, centipedes, beetles, spiders, and small mammals.

It is perhaps something of a conundrum that in healthy ecosystems, while nutrient cycling and productivity increases, nutrient loss is minimized. What makes this possible is the increasing complexity of the soil foodweb. As total ecosystem productivity increases, biodiversity below ground, i.e., the structure and function of the soil foodweb, also increases (Moore *et al.,* 1991). The greater the foodweb complexity, i.e., the interaction of decomposers, their predators, and the predators of those predators responsible for nutrient cycling and the retention of nutrients within the soil (Coleman *et al.*, 1985; 1992), the fewer the losses of nutrients from that system, the more tightly nutrients cycle from retained forms to plants, and back again. Without the soil foodweb, plants would not obtain the nutrients necessary for growth, and the above ground foodweb would not long continue (Nannipieri *et al.*, 1990).

Fig. 6.1 Rate of decomposition of soil organisms by body width




Interactions of decomposers with their predator groups (protozoa, nematodes and microarthropods) maintain normal nutrient cycling processes in all ecosystems (Coleman 1985, Coleman *et al.*, 1992). Plant growth is dependent on microbial nutrient immobilization and soil foodweb interactions to mineralize nutrients (Nannipieri *et al.*, 1990). In undisturbed ecosystems, the processes of immobilization and mineralization are tightly coupled to plant growth. Following disturbance, this coupling is lost or reduced (Ingham *et al.*, 1986a, b; Coleman *et al.*, 1992).

Lal and Stewart (1992) reviewed the relationship between system health and soil organic matter, and suggested that soil organism loss correlate with detrimental ecosystem changes. Development of the relationship between soil foodweb structure and function and assessment of potential toxic impact could be extremely useful for assessing ecosystem health.

## 6.9 Soil testing: an integral part of assessing soil fertility dynamics in an organic farming systems

Organic farmers must closely monitor soil fertility to ensure adequate crop nutrition. Both soil testing and plant tissue analysis is methods of evaluating soil nutrient levels. The results help to add or stop application of certain type of nutrients depending upon its presence on farm soil or otherwise.

### *6.9.1 Presence of nutrient in the soil*

***Nitrogen***

Legume crops, such as annual grain legumes like lentils, peas and field beans, and perennial forage legumes such as alfalfa; and legume green manures with sweet clover or lentils provide nitrogen. If sufficient crop material is retained and mixed to soil, these crops act as important source of nitrogen for subsequent crops. Animal manures can be an excellent source of nitrogen and other nutrients, although manures in the raw form can be very high in nitrates and ammonia.

***Phosphorous***

Organic certification standards permit farmers to use only organic or natural rock forms of phosphate. Animal manures are an excellent organic source of phosphorous; however, rock phosphate is essentially unavailable to plants, similar too much of the phosphate is already present in the soil.

***Potassium***

Potassium deficiencies decrease annual crop yields and perennial forage establishment significantly. Perennial forages require larger amounts of potassium than annual crops. When crops are grown for forage and most of the plant material removed, potassium is also removed from the soil and must be replenished. The addition of animal manure from livestock may return sufficient potassium to the soil.

***Sulphur***

Well-drained, sandy and grey-wooded soils are often deficient in sulphur. Cereal grains and flax have a lower sulphur requirement, and thus will be less severely affected by a deficiency than crops such as canola, grain legumes and forage legumes. Gypsum, a natural rock form of sulphur, can be applied to the soil to increase its sulphur content. Various forms of sulphates may be added to the soil, including zinc, iron and potassium sulphates. However, certified organic farmers may not use ammonium sulphate.

### *6.9.2 Soil analysis*

## Soil analysis and its importance

Soil analysis is used to determine the level of nutrients present in soil sample. Soil is the source for most of the essential nutrients required by the crop. Our soil resource

*Plant samples for nutrient analysis*

can be compared to a bank where continued withdrawal with out repayment cannot continue indefinitely. As nutrients are removed by one crop and not replaced for subsequent crop production, yields will decrease accordingly. The results of a soil analysis provide the farmer with an estimate of the amount of nutrients needed to supplement nutrients that are deficient in soil. The basis for all organic farming systems is the sound health of the soil. In addition to maintaining adequate fertility, organic farmers strive for biologically active soil containing microbial populations required for nutrient mobilisation and cycling.

### *The major objectives of soil testing are*

Soil testing is a useful tool for making fertilizer recommendations for various crops and cropping sequences as well as reclamation of problem soil. The major objectives of soil testing are:

- To evaluate soil fertility status for making fertilizer recommendations
- To predict the probable crop response to applied nutrients
- To classify soil into different fertility groups for preparing soil fertility maps
- To identify the type and degree of soil related problems like salinity, alkalinity and acidity etc. and to suggest appropriate reclamation and amelioration measures

### *Soil sampling and processing*

For collecting a representative soil sample the following considerations are taken:

- The sample must truly represent the field that is sampled.

- Variations in slope, colour, texture, crop growth and management practices are important factors that should be taken into account for sampling. Separate samples are required from areas differing in characteristics.
- Large areas may be divided into appropriate number of smaller homogenous units for better representation.

### *Depth of sampling*

The following factors are kept in mind:

- For cereals, vegetables and other seasonal crops the samples should be drawn from 0-15 cm i.e. plough layer
- For deep-rooted crops or longer duration crops like sugarcane, or under dry farming conditions, obtain samples from different depths depending on individual requirement
- For plantation crops or fruit trees, prepare composite sample from soil collected at depths of 0-30,30-60 and 60-100 cm from 4 to 5 pits dug in about 0.5 ha field at the time of planting

### *Precautions in collection and storage of samples*

- Avoid contact of the sample with chemicals, fertilizers or manures
- Do not use bags or boxes previously used for storing fertilizers, salt or any chemical
- Store soil samples preferably in clean cloth or polythene bags
- Use glass, porcelain or polythene jar for long duration storage

### *Labeling of samples*

- A label of thick paper with identification mark and other details should be put inside the sample bag and another label carrying same details tied/pasted outside the bag
- In case the soil sample is wet, the label should be written with lead pencil or a permanent ink marker

*Soil Samples*

### *Processing of soil samples for analysis*

- Air-dry the soil samples in shade
- Crush the soil clods lightly and grind with the help of wooden pestle and mortar
- Pass the entire quantity through 2 mm stainless steel sieve
- Discard the plant residues, gravels and other material retained on the sieve

- Remix the entire quantity of sieved soil thoroughly before analysis
- Analysis of soil by standard procedures for estimation of physico-chemical properties.

In order to validate the hypothesis that organic farming leads to enhanced soil biodiversity and increases the fertility of soil, a study was conducted at Navdanya's agro-ecological farm to assess microbial status of soil vis-a-vis organic farming practices. The study is mentioned in detail;

## 6.10 Scientific field investigation to assess long term effects of orgnic farming

***Experiment*** : Developing soil profile of Navdanya agro-ecological farm by conducting assessment of its microbial population, enzymatic activities and nutrient dynamics.

***Site*** : Navdanya Agro-Ecological Farm, Village Ramgarh, Dehradun

### *6.10.1 Introduction*

In order to fulfill the primary requirements of the agro-ecosystems fertility and to protect the environment, it is necessary to develop and adhere to soil management practices that maintain the quality of soil, which includes conserving the organic matter and developing a soil system wherein soil is biologically active. Agricultural practices and the farming systems, in particular the soil amendments regulate the soil microbial biomass. The soil biomass in turn, affects the mineralization of carbon and nitrogen in the soil, facilitates nutrient cycling and accumulates organic matter. In this era of chemicalisation of agriculture, it has been observed that the soil microbe has been a casualty. It is therefore necessary that long-term field experiments may be carried out for studying the influence of organic amendments on soil characteristics and the soil microbial biomass. At present, only limited consistent information is available concerning the changes in the soil physico-chemical and microbial characteristics, under long-term field conditions, in response to managing a farm only through the organic inputs. There is an urgency to carry out such experiments to determine the impact of inputs to a farm agro-ecosystem.

Agriculture is the primary occupation for millions of Indians. Its age old and time-tested practices have been vitiated in the recent past by adoption of chemical farming replacing traditional organic farming. The shift in agricultural practices was greed driven. The aim was to enhance grain production that would lead to enhanced profit while neglecting the concept of sustainability. This chemicalised farming in common parlance is termed as modern agriculture.

Modern agriculture largely depends on the use of expensive inputs such as chemical fertilizers, pesticides and herbicides. Over the years, when the soil productivity graph declined, the farmers resorted to increase in the dosage of chemical fertilizers that they assumed would enhance crop production. This increased chemical fertilization, instead lead to soil toxicity that resulted in the killing of the beneficial soil micro flora and fauna as the destruction of useful soil microbes. The introduction of pesticides to control the newfound problem of insect pests led to increased poisoning of soil, air, water and crops through bio-concentration.

The prolonged usage of inorganic chemicals in form of fertilizers, herbicides, pesticides and nematicides in farm ecosystems is vitiating the agro-ecosystem on one side and posing threat to human health on the other. The usage of inorganic pesticides is on the rise. The usage of chemical fertilizers has also registered a similar trend. This increase in fertilizers has resulted in deposition of heavy metals like arsenic and cadmium in the soil. It has been observed that certain inorganic elements accumulated in the soil, are locked by forming bonds with other useful elements forming stable complexes in soil. As a result, the plants are starved of nutrients, a phenomenon known as immobilization of nutrients. Phosphorus has the tendency to form stable complexes in the soil and is present in almost all the fertilizers. Thus, when diammonium phosphate (DAP) is applied in the farms over a period, phosphorus is immobilized as Ca, Fe, Al – phosphate and inositol mono or hexa phosphates and is absorbed into the soil complex and is not available to the crop.

Thus, the very purpose of application of fertilizers to enhance soil fertility is defeated and with this process the other essential nutrients too become a casualty. The farmer by practicing modern farming practices unknowingly is moving towards a situation wherein; degradation of farm soil by locking of soil nutrient is resulting in loss of soil fertility. The farmer who is ignorant of this phenomenon and refuses to listen is sucked unwittingly into the vortex of debt.

### *6.10.2 The need*

In a soil system the interactions between soil organisms form a web of life, just like the web that biologists study above ground. Soil biology is understudied, compared to that above ground, yet it is important for the health of agro-ecosystems. If farm soil is healthy, there will be high numbers of microorganisms such as bacteria, fungi, actinomycetes etc. If the soil has received heavy treatments of pesticides, chemical fertilizers, soil fungicides or fumigants that kill these organisms, the tiny creatures die, or the balance between the pathogens and beneficial organisms is upset, allowing the opportunist, disease-causing organisms to become problems.

In addition to responses to disturbance, it is clear that species diversity, community diversity and food web complexity increases with increasing successional stages (Moore *et al.*, 1991; Ingham and Horton, 1987). Indeed, examination of food web interactions and ecosystem diversity, instead of community diversity, by assessing the soil microbial status may result in new ecosystem measures that reflect this increased community diversity and increased nutrient dynamics in later successional stages.

The physico-chemical properties, microbial population and their biomass, enzymatic activity and community structure of the organisms, which comprise the soil food web, can be used as indicators of ecosystem health because these organisms perform critical processes and functions. Soil decomposers (bacteria, fungi and possibly certain arthropods) are responsible for nutrient retention in soil. If nutrients are not retained within an ecosystem, future productivity of the ecosystem will be reduced as well as cause problems for systems into which those nutrients move, especially aquatic portions of the landscape (Klopatek, *et al*., 1993).

As ecosystems become more productive, the total amount of nutrients retained within the system increases. As succession occurs, nutrients are increasingly immobilized in forms that are less available for plants and animals, such as phytates, lignins, tannins, humid and fulvic acids (Coleman *et al.,* 1985, 1992). In order for nutrients to become available once again to plants and animals, they must be mineralized by the interaction of decomposers, i.e. bacteria and fungi, and their predators, i.e. protozoa, nematodes, micro-arthropods, and earthworms.

Time and again the farmers have been warned against the excessive use of chemicals in agro-ecosystems. Ecologists, environmentalists, academicians and researchers had predicted disaster due to the indiscriminate use of fertilizers and pesticides. But actual field data on demonstration plots that could substantiate these claims in field conditions providing an alternative to the farming community are scarce.

To fill this gap Navdanya agro-ecological farm with a rich background of more than a decade of organic farming was identified as a test plot to study the impact of organic farming on the soil health.

### *6.10.3 Assessing parameters for a living soil system*

The soil biomass is an essential component of most of the terrestrial ecosystem because it is regulating the nutrient cycling, and acts as a labile source of plant available nutrients (Jenkinson and Ladd, 1981). It exerts a major influence on other components of the ecosystem, because it controls the flow of energy to the higher trophic levels in the decomposer food web (Wardley, 1995) and is closely linked to the ecosystem primary productivity. Literature survey indicates that the estimation of microbial population dynamics of soil is the true indicator of the status of soil health. The soil is a living component, which has in it a myriad of organisms ranging from micro as bacteria, fungi, algae to macro-organism as ants, earthworms, beetles etc.

It has been observed that microbial biomass can be used as an effective bio-indicator of soil quality. Over large spatial scales such as a farm fields the soil microbial biomass is strongly correlated with the soil C and N and there are circumstances where the measurement and the enumeration of the soil microbes and their type may provide a reliable estimate of the soil quality as a measurement of soil biomass. It has also been observed that the soil microbes respond dramatically to the soil amendments specifically to such chemicals that tend to degenerate the micro-environs of the soil microbes.

The parameters that assess soil health are soil microbial population, biomass, enzymatic activity and community structure that indicate its position in the detritus food web that is indicative of the ecosystem health. A healthy soil may be visualized as a factory in which soil microbes are constantly working in perfect harmony to create and sustain the most important activity- **life**. Organisms work on dead plants and organic matter to decompose it and release the nutrients that can be easily absorbed by the plants. Soil microbes perform these activities with the help of enzymes.

The total activity of micro-organisms can be estimated by measuring the activity of a living cell-associated enzyme such as alkaline phosphatases, acid phosphatases, phytase and dehydrogenase. These enzymes play a crucial role in the respiratory pathway. Phosphatases cleave organic phosphorus compounds and thus provide a link between the plant and the stock of organic phosphorus in the soil. Enzyme activity in organic soils is markedly higher than in conventional soils. Microbial biomass and enzyme activities are closely related to soil acidity and soil organic matter content.

In view of the above-mentioned scenario, a study was taken up to develop a soil profile of Navdanya's agro-ecological farm by conducting assessment of its microbial population, enzymatic activities and nutrient status of farm soil. The study was assigned by Navdanya to the Society for Environmental Reconstruction and Training (SERT) having special interest in the development of environmental friendly sustainable agriculture practices.

### *6.10.4 Objectives*

1. To analyse the soil for its physical parameters such as pH, EC, OM and OC.
2. To analyse the soil for the microbial status including VAM and phosphatase and phytase producing organisms.
3. To monitor the enzymatic activity such as acid phosphatase and alkaline phosphatase dehydrogenase in organic farm.
4. To develop a profile for accrediting Navdanya Organic farms as a demonstration plot for carrying out future studies for organic trials.

### *6.10.5 Location and farming practice of Navdanya's agro-ecological farm*

Navdanya agro-ecological farm is situated 20 km from Dehradun city, in the state of Uttaranchal, India. The climate of the area varies from hot in summers to very cold in winters. Maximum temperature reaches $45^0$C in summers and minimum temperature is $5^0$C. The average annual rainfall is 1800 mm. The farm is managed according to the principles of organic farming. The farm refuse is recycled within the premises of the farm. Mixed cropping is practiced wherein the aim is to increase output per unit of land both in terms of productivity and variety. Monocropping and monoculture is discouraged. Only traditional seed varieties that are saved every year in the farm are grown in a rotational manner. The farm is fertilized by employing composting, vermi-composting, green manuring and mulching.

The farming practices aiming at soil fertility maintenance through the use of legume green manures are integral to Navdanya organic farming concepts for enhancing its soil fertility and productivity status. As no chemical fertilizers in form of external output are applied, the nitrogen requirements for crop production are met either through the application of raw or composted livestock manures or through the use of legume green manures. Rhizobium bacteria on legume roots fix atmospheric nitrogen; legumes incorporated into the soil are used as a source of nitrogen. This agro-ecosystem is a production system working on principles based on renewal of ecological processes and strengthening of ecological functions of farm ecosystems to produce safe and healthy food sustainability.

The farm avoids and excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. The farm relies on crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests.

### *6.10.6 Material and methods*

#### *6.10.6.1 Sampling of soil from Navdanya farm*

Navdanya farm was divided into different sites. In each site the rhizosphere soil samples (soils near the roots) were taken. The soils from the top were scraped off to remove foreign particles. The depth of soil samples was 5- 15 cm. Soil samples were also collected from the adjoining chemicalised farms for comparative study.

The soil samples were homogenized by placing all the soil samples collected from one site on large clean sheets. All stones and plant material as well as coarser roots (> 1 cm diameter) were removed. This was done by passing the soil sample through a sieve with a 0.5 cm diameter mesh.

#### *6.10.6.2 Laboratory investigations*

Laboratory investigations were carried out under two broad aspects. The first aspect concentrated on analysis of important physico-chemical properties and nutrient status of soil while the second one dealt with the microbial studies and enzymatic activities.

#### *6.10.6.3 Physio-chemical characteristics of soils*

Important physico-chemical properties of the soils of each site were determined. These include pH, electrical conductivity (EC), water holding capacity (WHC), soil texture, textural class, soil structure and organic matter.

Chemical properties include total nitrogen, phosphorus and potassium and other major and minor nutrients.

#### *6.10.6.4 Biological properties of soil*

Biological properties determined were :

1. Microbial Biomass: Biomass C, N and P

2. Enzyme activities: dehydrogenase activity, acid phosphatase, alkaline phosphatase and phytase.

#### *6.10.6.5 Identification of microbial population*

Presence of VAM fungal spores in soil

### *6.10.7 Results*

#### *6.10.7.1 Soil physical properties*

The soils that were collected from the Navdanya organic farm showed their excellent soil physical properties in terms of texture and structure as compared to the soils from chemical farm.

**Table 6.2 Comparative soil physical properties**

| | *Chemical farming* | *Organic Farming (Navdanya)* |
|---|---|---|
| Soil Texture | | |
| **Sand (%)** | 50-56 | 41-57 |
| **Silt (%)** | 15-18 | 11-36 |
| **Clay (%)** | 28-34 | 19-41 |
| **Textural Class** | Sandy clay loam to sandy loam | Sandy clay loam to sandy loam |
| **Soil Structure** | A and B Type | A Type |

#### *6.10.7.1.1 pH*

The results showed that in Navdanya farm soil pH ranges from 6.8 to 7.4, whereas, in chemical farms pH ranged from 5.3 to 6.5. The soil of Navdanya farm was neutral as compared to chemical farm where the soil was acidic which is harmful for the beneficial microbial population.

#### *6.10.7.1.2 Electrical Conductivity (dScm$^{-1}$)*

There were no significant differences in EC in the soils of both organic and the soil of the chemical farm. In Navdanya farm soil EC ranged from 0.15 to 0.27 dScm$^{-1}$ whereas, in chemical farm EC ranged from 0.12 to 0.25 dScm$^{-1}$.

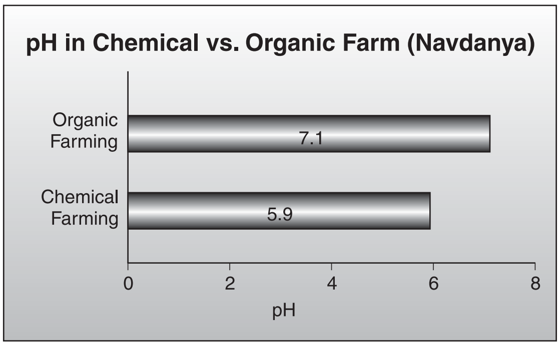



*Figure 6.2 pH status of organic farm soil to that of chemical farm*

#### *6.10.7.1.3 Organic matter (%)*

The data showed that there was a tremendous increase in percent organic matter (OM) content in the organic soil of Navdanya farm. Organic matter content was improved by 124% in Organic soil as compared to chemical ones. In chemical farming system per cent OM ranged from 1.09-1.59% whereas in organic farming it was 1.23-4.55%. The reason of this increase may be the farming practices in the soil of the organic farm.

Organic farming encourages the use of plant refuse viz. the stalk of the crop (multiple crops), which is mixed in the soil after the grain is harvested. The stalk of the crop is ploughed in the field and this when fertilized with compost results in massive build up of microbes. These microbes in turn facilitate the conversion of the complex cellulose to easily available nutrients. The whole phenomenon is reflected in terms of higher organic matter as compared to a chemicalised farm.

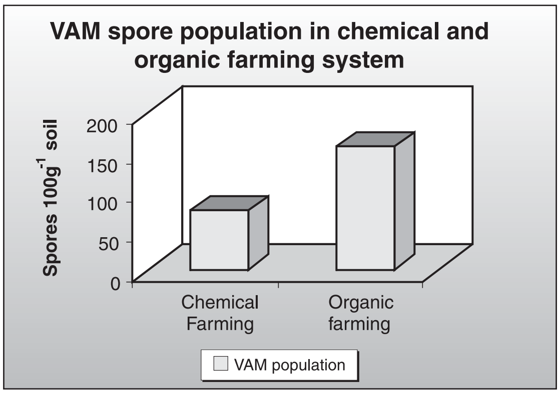



*Figure 6.3 Percent organic matter in soils of organic and chemicalised farm soils*

### *6.10.7.1.4 Soil nutrient status*

The soil showed variations in nutrients in chemical vs. organic farming system. The data indicated an improvement in total nitrogen by 85%, total phosphorus by 10% and available potassium by 25% in organic farming (Navdanya) as compared to chemical farms. The data are given as :

**Table 6.3 Nutrient status of soils from two different farming systems**

| | *Chemical Farming* | *Organic Farming (Navdanya)* |
|---|---|---|
| **Total N (%)** | 0.004-0.017 | 0.011-0.028 |
| **Total P (mg/kg)** | 1029-1194 | 1084-1369 |
| **Available K (mg/kg)** | 6-14 | 8-17 |

### *6.10.7.1.5 Changes in Biological Properties*

The data indicated a variation in biological properties of soil in chemical farming vs. organic farming system. The parameters assessed were C, N and P biomass. The results showed that Biomass C was improved from 162 mg/kg to 284 mg/kg i.e. about 75% more in organic soil as compared to chemical soil. Similarly Biomass N was improved from 11.7 to 18.4 mg/kg i.e. 58% and there was 2 to 4 fold improved P biomass in organic soil of Navdanya farm as compared to chemical ones.

### *6.10.7.1.6 Estimation of enzymatic activity*

The estimation of the activity of enzymes in soil both from organic farm and the chemical farm was done by testing dehydrogenase activity, acid phosphatase activity, alkaline phosphatase activity and phytase activity. The results that are obtained from the analysis are presented below:

**Table 6.4 Enzymatic activity of soils from two different farming systems**

| *Enzyme Activities* | *Chemical Farming* | *Organic farming* |
|---|---|---|
| Dehydrogenase (p kat g$^{-1}$) | 3.4-10.0 | 8.9-28.7 |
| Acid phosphatase (EU´10$^{-4}$) | 70.1-73.5 | 71.8-78.9 |
| Alkaline phosphatase (EU´10$^{-4}$) | 32.1-61.8 | 65.4-69.8 |
| Phytase (EU´10$^{-4}$) | 20.7-81.6 | 52.7-287.1 |

### *6.10.7.1.7 Identification of microbial population*

For assessing the soil health it is imperative that the soil should have a healthy soil microbial population. For this the soil was tested for the microbes and it was revealed that the soil of the organic farm had a much higher population of microbes as compared to than that of the chemical ones. The results of the analysis showed that the microbes had wider taxonomic variety in organic farm soil.

### *VAM spore population*

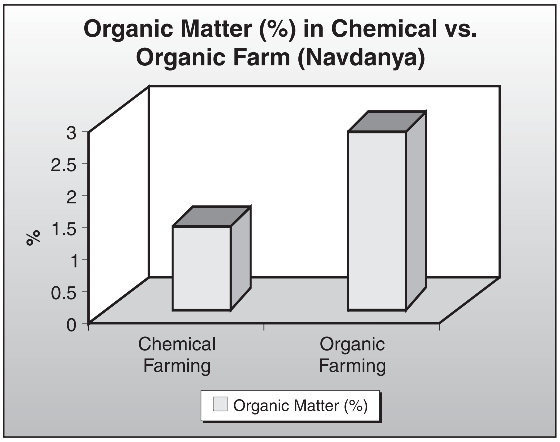



*Figure 6.4 VAM population in organic and chemicalised farms*

Vesicular Arbuscular Mycorrhizae are group of organisms, which stands out among the host of microbes. These are better known as VAM fungi. The fungi penetrate roots of plants without harming them, and their hypha at the same time establishes contact with bulk soil for transporting mineral nutrients to the plant (Reid, 1990). They are, therefore, both agents of plant nutrition and soil nutrition.

The soil analysis indicated that the number of viable VAM spore population in the chemical farm was 60-97 whereas Navdanya's organic farm contained a population of 137-205 viable spores that shows a 2 to 3 fold increase in an organic farm soil.

### *VAM Species identified*

VAM fungi are formed by non-septate phycomycete fungal bodies belonging to the genera *Glomus, Gigaspora, Aculospora* and *Sclerocystis*. These are obligate symbionts and have not been cultured in nutrient media. The vesicular arbuscular mycorrhiza (VAM fungi) are the tools and technology for use in enhancing productivity in agricultural system and soil conservation in the same time. It is suggested that the mycorrhizal habit is evolved as a survival mechanism from both partners of the association allowing each one to survive in the existing environment of low soil fertility, drought, disease and temperature extreme (Rao, 1997). They may transport relatively immobile nutrients (P, Cu, Zn, etc.) to the plants, which is otherwise inaccessible to the plants. They also help in water transport to the plant from distant places due to their long mycelium and help in soil aggregation resulting in increase in water holding capacity and improvement in soil structure.

The first ever species identified in an organic farm are *Glomus constrictum, Glomus indica, Sclerocystis rubiformis and Gigaspora nigra* (refer Plate 1 and 2).

### *Glomus constrictum*

Chlamydospores naked, forms singly or in loose clusters in the soil, globose to sub-globose, 150-330 μm in diameter, dark brown to black, shiny smooth. Spore walls are thick, dark brown, one layered or occasionally seeming two layered base straight with contents of oil globules of widely varying sizes. Attached hypha is straight to recurved.

### *Gigaspora nigra*

Manifestations of root infection in the form of arbuscules, vesicles and hyphae were recorded from all the sites studies. The most common structure observed was hyphe and arbuscules from all the sites.

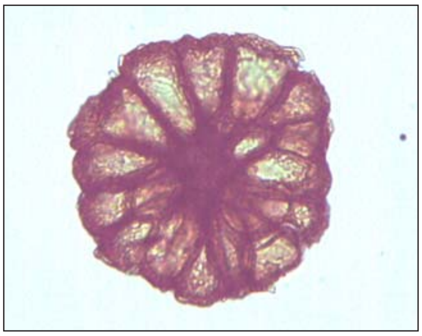
The VAM fungi are aerobic, so moisture and aeration have considerable impact on their distribution and effectiveness (Sylvia and Williams, 1992). It has already been reported that the soil temperature and humidity are the important eco-physiological factors affecting the development and effectiveness of VAM fungi.

*Plate 1 New Mycorrhizal Species Due to Organic Farming*

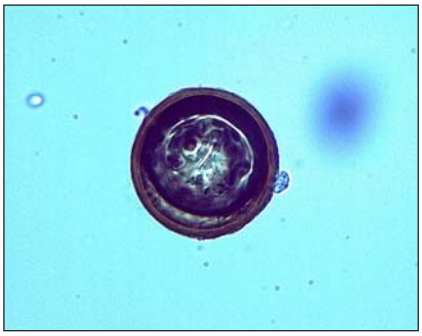
*1. Cluster of spores of Glomus constrictum in rhizosphere (400 x)*

*2. Matured chalmydospore of Glomus indica (1000 x)*

*Plate 2 New Mycorrhizal Species Due to Organic Farming*



*3. Cluster of Sclerocystis rubiformis (400 x)*



*4. Azygospore of Gigaspora nigra (1000 x)*

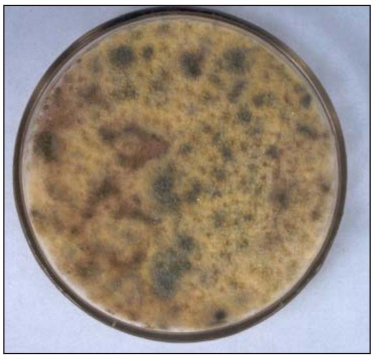
***Phosphatase and phytase producing organism***

The new species that have been observed in the organic farming soil at Navdanya's agro-ecological farms are *Aspergillus flavus, Chaetomium globosum, Curvularia lunata, Paecilomyces variotii*.

These organisms will help to bring unavailable native soil organic phosphorus into plant available form ($H_2PO_4^-$, $HPO_4^=$ ).

*Plate 3. New Phosphatase & Phytase Producing Organisms in Organic Farming*

*Aspergillus flavus*



*Chaetomium globosum*

*Paecilomyces variotii*

*Curvularia lunata*

## 6.10.8 Discussion

The soil properties in the organic farming system has improved soil physico-chemical properties and essential parameters such as organic matter, water holding capacity, total nutrient status showed higher values than that of soils samples that were taken from modern chemical farming systems in the a locality having as same land use system. The microbial activity in an organic farming system was observed to be of a higher magnitude signifying that organic mode of farming encourages indigenous soil microbes to evolve, flourish and function in their ecological niche as help to facilitate the process of mobilisation of nutrients. This enhanced population of microbes in Navdanya farm would therefore, enhance the soil fertility and farm productivity spontaneously in the years to come without application of hazardous chemicals.

### *6.10.8.1 Soil dynamics of organically managed agro-ecosystems of Navdanya*

The higher status of the organic matter, nutrients, higher microbial status and greater C, N, P biomass of the soil in the organic farming systems (Navdanya Agro-ecological farm) may be attributed to the enhanced inputs of leaf litter, compost and the fine rootlets and stalk of the harvested crops that are mixed into the soil after harvesting.

#### *6.10.8.1.1 Soil physical properties*

The textural class similarity between the two farming systems is indicative of the uniformity of the soil types. However, from the investigation it has been revealed that the clay component of the Navdanya agro-ecological farm (organic farming system) was higher (41%) than that of soils from the chemical farms. The higher clay component of the soil in organic farms indicates a higher water holding capacity as the clay component has the ability to hold water five times more than that of the sandy soil. The data thus indicated that the water holding capacity of the organic farming systems was 46% more than that of soil from a chemical farm. The enhanced water holding capacity of the soil may be attributed also to the high porosity of the soil of organic farms, which is indicative of a healthy population of beneficial arthopods such as earthworms in the soil. The pH and the organic matter in the Navdanya farm soil are indicative of the high degree of soil health maintenance of organic soil.

It was observed from the results that there was a 124% increase in content of organic matter in soils of Navdanya Agro-ecological farm (organic farm) when compared to the chemical farm. This increase in the organic matter content is due to high population of soil microbes signifying healthy soil system. These soil microbes ensure that the nutrient cycle is in place and the large organic substrate are broken down to minute inorganic particles that are easy for assimilation in the root system. The reserves are carried in the form of humus, which is the result of the activities of thousands of microbes such as earthworms, burrowing insects, fungus, bacteria etc.

#### *6.10.8.1.2 Soil Chemical Properties*

Higher concentrations of essential nutrients were observed in soils of Navdanya farm. The data indicate that the percent nitrogen concentration was enhanced by 85%, whereas the phosphorus content was improved by 10% and the available potassium content was 25% more than that of the soil samples of the chemicalised farms. The results indicate that the soil processes in an organically managed farm are dynamic and that they maintain normal nutrient cycling in agro-ecosystems (Coleman *et al.*, 1985; Dindal 1990; Ingham and Horton, 1987). The presence of microbes in the healthy soil undisturbed ecosystems, the processes of mobilization and mineralization are tightly coupled to plant growth but following disturbance, this coupling may be lost or reduced (in chemically managed farms). The highest concentration of nitrogen among other parameters is primarily due to the practice of rotation of crop and mixed farming practice adopted by Navdanya.

The high level of phosphorus may be attributed to the presence of mycorrhizal fungi. The VAM fungi are known to facilitate higher nutrient uptake. This could be due to the mycorrhizal plants having more access to growth limiting nutrients as P and N (Bell *et al*., 1989).

#### *6.10.8.1.3 Soil Biological properties*

#### *Soil microbial biomass*

Enhanced microbial biomass/activity is the best bio-indicator to assess the soil health. The study revealed that the microbial biomass in organically managed farm i.e. Navdanya had higher biomass in all the three parameters for which it was assessed. The carbon, nitrogen, and the phosphorus biomass; had higher values as compared to soils from the chemical farm. The reason for high microbial biomass may be due to high organic matter and upturning of the crops that are harvested. Plant roots exude a large number of organic substances and continually slough off root caps into the soil. These materials are food for the many micro-organisms living in a zone of intense biological activity near the roots called the rhizosphere. Bacteria benefit most from the food supplied in the rhizosphere and may form a continuous film around the root. Roots form the microbial highways of the soil.

#### *Enzymatic activity*

It has been observed that the soils of the organic farming showed a 2 to 3 fold improved dehydrogenase activity. The same was observed for the soils of organic farming with respect to the alkaline phosphatase activity that registered a 2-fold increase as compared to the chemical farms. Similar trend was observed for the phytase activity with a 2 to 3 fold increase in the soil parameter. However, not many changes in acid phosphatases activity due to organic farming were observed. Soil phosphatase plays a major role in the mineralization processes of organic phosphorus substrates. Enzymes in soils originate from animal, plant and microbial sources and the resulting soil biological activity includes the metabolic processes of all these organisms.

#### *6.10.8.1.4 Identification of new organisms due to organic farming*

#### *Mycorrhizal Fungi*

The vesicular arbuscular mycorrhiza (VAM fungi) is an important tool to enhance the productivity of an agricultural system. It is suggested that the mycorrhizal habit is evolved as a survival mechanism from both partners of the association allowing each one to survive in the existing environment of low soil fertility, drought, disease and temperature extremes (Rao, 1997). The external mycelium extends several centimeters from the root surface and bypasses the depleted zone surrounding the root surface and exploits microhabitat beyond the nutrient depleted areas. Mycorrhiza has two distinct types of hyphae or nutrient absorbing mechanism, the 'runner' hyphae and the 'absorbing' hyphae. The primary function of this network is the resource allocation i.e. to provide plants growing in poor locations with nutrients from the rich patches in the agricultural fields.

VAM fungi which penetrate to the roots of plants without harming them, and their hyphae at the same time establishes contact with bulk soil for transporting mineral nutrients to the plant (Reid, 1990). They are, therefore, both agents of plant nutrition and soil nutrition. VAM fungi are formed by non-septate phycomycete fungal bodies belonging to the genera *Glomus, Gigaspora, Aculospora* and *Sclerocystis*. These are obligate symbiont and have not been cultured in nutrient media.

### *Phosphatase and phytase producing organisms*

There is enough phosphorus reserve in any agricultural soil for plant nutrition. But only 2 to 3% of the total P present in soil are available (i.e. $H_2PO_4^-$, $HPO_4^=$or $PO_4^{\circ}$) form. 97-98% of P is present either as unavailable inorganic (i.e. Ca-P, Fe-P, Al-P) or as organic (i.e. phytin, lecithin etc. either as inositol hexa phosphate or inositol monophosphate) form. The unavailable inorganic P is hydrolysed by phosphate solubilising organisms and organic P by phosphatase and phytase producing organisms.

The four organisms that were isolated and identified in the Navdanya soils were observed to be releasing a lot of phosphatase and phytase and make use of native soil organic phosphorus to plant available form (i.e. $H_2PO_4^-$, $HPO_4^=$). *Aspergillus flavus* has also the potential to solubilize unavailable inorganic P (i.e. Ca-P & Fe- P) in addition to organic P hydrolysis. These organisms release huge amounts of acid and alkaline phosphatase as well as phytase which cleave C-O-P ester bond of organic P and release P as phosphate form ($H_2PO_4^-$, $HPO_4^=$ ).

Therefore, these organisms have huge potential for use as bio-inoculants to exploit native phosphorus and there is no need to apply P fertilizer from outside resulting in saving of huge amount of money for crop production.

### *6.10.8.2 Soil dynamics of samples of chemicalised farming systems*

The finding from the present study revealed that the soils from chemically managed farms are of a low fertility level and that there is a very low microbial biomass. These findings indicate that the soils of chemically managed farming systems due to over-use of chemical fertilizers and pesticides suffer deleterious effects on soil organisms that are similar to over-using antibiotics. This comparative study indicates that the chemical fertilizer are akin to ecological narcotics that over a time make the soil and the crop in it habituated to inorganic fertilizers and harm both the soil as well as the crop.

As can be inferred from Table 6.4 that the low enzymatic activity which is an index of the activity of bacteria, fungi, protozoa, nematodes and arthropods and the data presented in section 6.9.7.1.5 indicates a low presence of microbial biomass of the beneficial organisms. These indicate that for a particular soil type, the soil's 'digestive system' does not work properly and fails to provide adequate nutrition to the crops. As a result the soil will have low organic matter (Figure 6.4) due to decreased decomposition; nutrients will not be retained in the soil (Table 6.3), and will not be cycled properly. The soils in these systems have poor structure (low porosity) and the soil temperature tends to increase. By monitoring soil organism dynamics, we can perhaps detect detrimental ecosystem changes and possibly prevent further degradation.

The data of Table 6.4 is indicative of the extent of damage done by the chemicals that is used as fertilizers and pesticides in the farming system. If both bacteria and fungi are lost, then the soil degrades and with it other forms of life. If bacteria are killed through pesticide or chemical applications, and especially if certain extremely important bacteria like nitrogen-fixing bacteria or nitrifying bacteria are killed, harmful soil biota can take over and crop production can be harmed. Nutrients are lost, erosion increases and plant yield is reduced.

Soil ecology has just begun to identify the importance of understanding soil food web structure and how it can control plant vegetation, and how, in turn, plant community structure affects soil organic matter quality, root exudates and therefore, alters soil food web structure. Since this field is relatively new, not all the relationships have been explored, nor is the fine-tuning within ecosystems well understood.

Regardless, some relationships between ecosystem productivity, soil organisms, soil food web structure and plant community structure and dynamics are known, and can be extremely important determinants of ecosystem processes (Ingham and Thies, 1995).

### 6.10.9 Summary

With the growing concern for sustainable development, research efforts have been focused on conservation farming including the use of biofertilizers, organic farming, combined protective-productive systems etc. The chemicalised agriculture systems are highly inefficient from overall energy point of view, as 5 to 10 units of energy inputs are required to produce single unit of food energy as out put (Steinhart and Steinhart, 1974).

The input of fertilizers, particularly in low rainfall regions exposes the crop to high risk. With the increased costs of petroleum and naphtha bound external inputs like nitrogenous fertilizers, concept of organic/conservation farming have come to stay. A sustainable approach aims to provide means for reducing the susceptibility of soils to erosion and also to lower energy based inputs (Bethlenfalvay and Linderman, 1992, Peoples and Craswell, 1992). Appropriate technologies are also sought to be developed to integrate the production of the crops and woody species simultaneously from the same piece of land in a sustainable manner.

Management of soils under such systems is a subject of great interest. Based on scientific evidence, beneficial aspect of biofertilizers in agro-ecosystem in terms of soil fertility, nutrient cycling, soil conservation, soil physical properties are well recognized to ensure a healthy soil plant system. This concept of sustenance of productivity is dependent on the unity and interdependence of a healthy plant –soil system in the face of natural and culturable stresses, which depend on the soundness of the interface between plant and soil, the rhizosphere.

In this era of greed and adoption of unsustainable chemicalised farming systems, Navdanya’s agro-ecological farm comes as a fresh breath of air that has adhered to the principle of sustainability by taking care of the water, soil and plant components of the ecosystem. The result of this practice has resulted in the change of inert soil system under the erstwhile Eucalyptus plantation to a living and thriving soil that is teeming with life after it came under the organic practices. The quantitative improvements in soil parameters with the adoption of organic farming have been observed and analysed in this study of Navdanya’s organic farm.

The result of the study thus indicates that adopting traditional practices can enhance the fertility of the soil. This adoption will help in the enhanced agricultural output and will result in the sustained availability of natural resources. This will not only minimize the biotic pressure on agro-ecosystem but will, also ensure long term development of the local economy.

Also in continuance, Navdanya has done a study on the changes in percent organic matter in soil over a period of time. The soil samples were collected from organic farm (Navdanya), chemical farm and barren soil. The results showed that in organic farming system there was an increase in organic matter content in the soil as compared to chemical farms. The data are presented in the following graphs, that depicts the enhanced percess organic carbon and percent organic matter from organic farms and compares with that of chemical farms.

**Fig. 6.6 Changes in % organic carbon from 2001-2003**

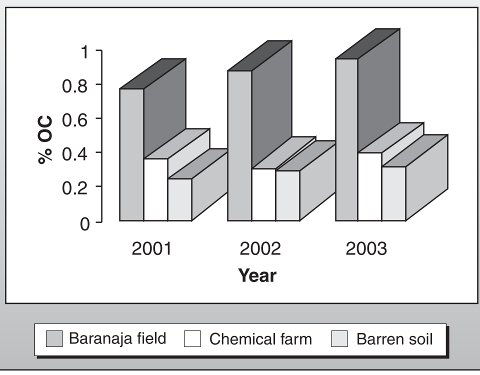



**Fig. 6.7 Changes in % organic carbon from 2001-2003**

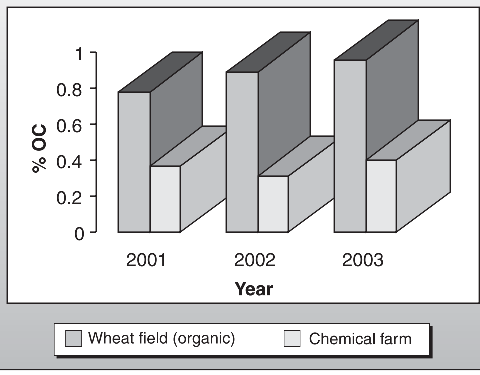


**Fig. 6.8 Changes in % organic carbon from 2001-2003**

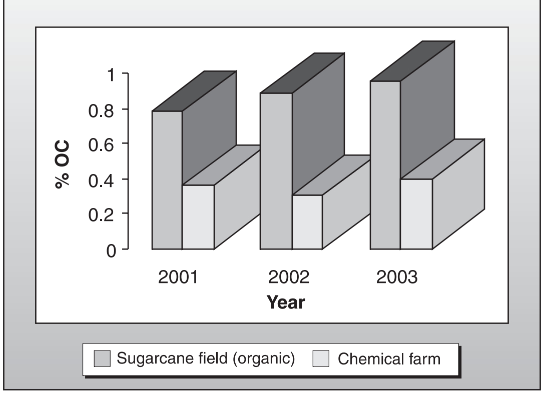



**Fig. 6.9 Changes in % organic carbon from 2001-2003**

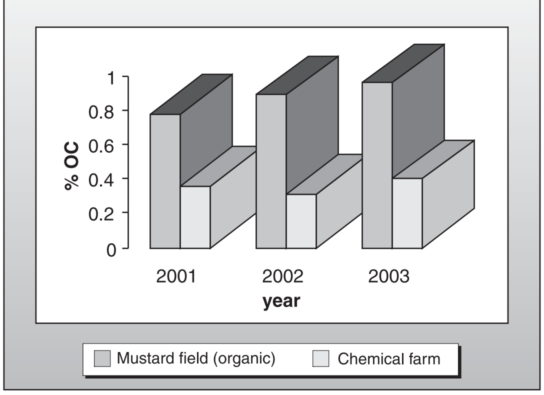



**Fig. 6.10 Changes in % OM from 2001-2003**

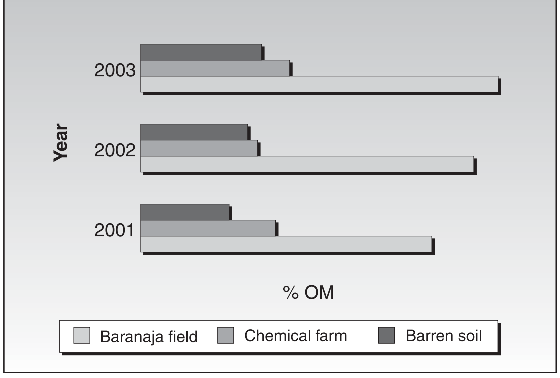



**Fig. 6.11 Changes in % organic matter from 2001-2003**

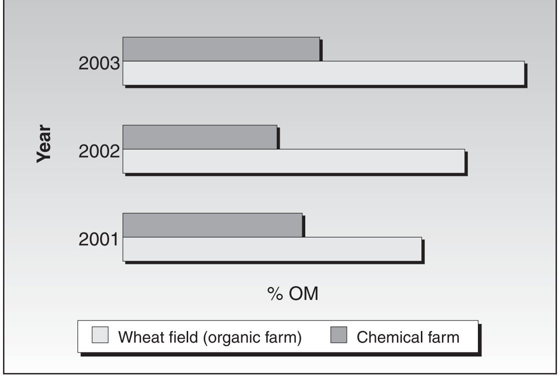



**Fig. 6.12 Changes in % organic matter from 2001-2003**

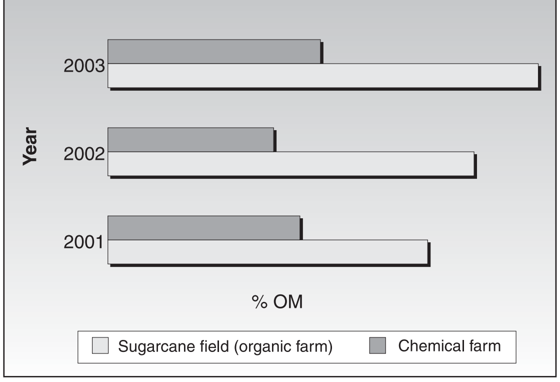
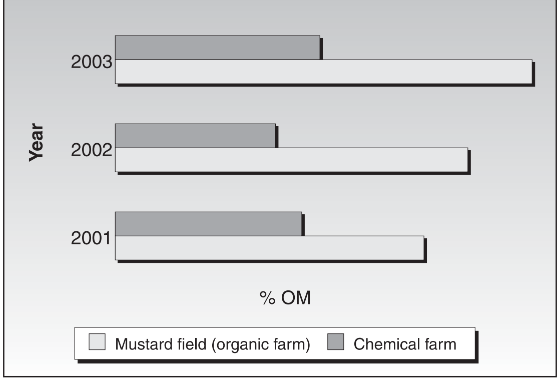



**Fig. 6.13 Changes in % organic matter from 2001-2003**



## 6.11 Interpretation and indicators of soil health and structure

### *6.11.1 Ratio of total fungal to total bacterial biomass*

By examining the structure of the soil foodweb in a range of soils, all grassland and most agricultural soils have ratios of total fungal to total bacterial biomass less than one (F/B< 1). Another way to interpret this is that the bacterial biomass is greater than the fungal biomass in these soils. In the most productive agricultural systems, however, the ratio of total fungal to total bacterial biomass equals one (F/B= 1) or the biomass of fungi and bacteria is even. When agricultural soils become fungal-dominated, productivity will be reduced, and in most cases, liming and mixing of the soil (plowing) is needed to return the system to a bacterial-dominated soil.

All conifer forest soils are fungal dominated, and the ratio in all forest soils in which seedling regeneration occurs is above 10. In general, productive forest soils have ratios greater than 100. This means that fungal biomass strongly outweighs the bacterial biomass in forest soils. In the case where forest soils lose this fungal-dominance, it is not possible to re-establish seedlings. When forest soil becomes bacterial-dominated, conifer seedlings are incapable of being re-established.

The ratio of total fungal to total bacterial biomass has been related to ecosystem productivity, but numbers or length of active and total bacteria and fungi are also indicative of the health of soil. For different soils, vegetation and climate, the density of bacteria or fungi indicate the past degradation of the soil. As explained above, bacterial numbers should be greater than one million for all agricultural soils, preferably nearer 100 million for the most productive soils.

### 6.11.2 Biomass of total fungi

Fungal biomass is extremely important in all soils as a means of retaining nutrients that plants need in the upper layers of the soil, i.e., in the root-zone. Without these organisms to take-up nutrients, and either retain those nutrients in their biomass, or to sequester those nutrients in soil organic matter, nutrients would wash through the soil and into ground or surface water. Plants would suffer from lack of nutrient cycling into forms that the roots can take-up, if these nutrients aren't first immobilized in the soil through the action of fungi or bacteria.

In soil in which only fungi are present, the soil will become more acidic, from secondary metabolites produced by fungi. Aggregates are larger in fungal-dominated soils than in bacterial-dominated soils, and the major form of N is ammonium, since fungi do not nitrify N. These conditions are more beneficial for certain shrubs, and most trees. Total fungal biomass varies depending on soil type, vegetation, organic matter levels, recent pesticide use, soil disturbance and a variety of other factors, many of which have not been researched completely. However, for normal grassland soils, total fungal biomass levels are usually around 50 to 500 meters per gram of soil. For agricultural soils, fungal biomass is around 1 to 50 meters per gram soil, while for forest soils, fungal biomass is between 1000 meters to 60 km per gram of soil. More work is necessary to establish what the optimal fungal biomass value should be for each type of crop, soil, organic matter, climate, etc. Very little information is available for tropical systems, but that small amount of data indicates that temperate systems perform very differently from tropical soils.

The average diameter of hyphae in most soils is about 2.5 micrometers, indicating typical mixtures of zygomycetes, ascomycete and basidiomycetes species. On occasion the average diameter may be greater than 2.5 micrometers, indicating a greater than normal component of basidiomycete hyphae, while on other occasions, the average diameter of hyphae may be less than 2.5 micrometers, indicating a change in species composition of soil fungi to a greater proportion of lower fungi. Actinomycetes are not usually differentiated from fungi, since actinomycetes are hyphal in morphology and are rarely of significant biomass. In some agricultural soils, this narrow diameter "hyphae" are of considerable importance, as demonstrated by Dr. A. Van Bruggan.

### 6.11.3 Numbers of total bacteria

Just as fungi are the most important players in retaining nutrients in forest soil, bacteria are the important players in agricultural and grassland soils. Bacteria retain nutrients first in their biomass, and second, in their metabolic by-products. In soil in which only bacteria are inoculated, the soil will become more alkaline, will have small aggregates, and generally will have nitrate/nitrite as the dominant form of N. These conditions are beneficial for grasses and row crop plants.

Numbers of total bacteria generally remain the same regardless of soil type or vegetation. Total bacterial numbers range between 1 million and 100 million per gram soil in agricultural soils and between 10 million and 1,000 million in forest soils. Bacterial numbers can be above 100 million in decomposing logs, in anaerobic soils, in soil amended with sewage sludge or in soil with high amounts of comported material. In some instances following pesticide treatment, bacterial numbers can fall below 1 million, and this has been correlated with signs of severe nitrogen deficiency in plants. Bacterial numbers can drop to extremely low levels, below 100,000 per gram of soil, in degraded soils where nutrient retention is a problem.

### 6.11.4 Nematode numbers, community structure

There are four major types of nematodes, which include bacterial-feeding, fungal-feeding, root-feeding and predatory nematodes. All nematodes are predators, and thus, reflect to some extent the availability of their prey groups. However, other organisms prey upon these nematodes as well and nematode numbers can also reflect the balance between the availability of nematode prey, as well as feeding by nematode predators.

Both bacterial-feeding and fungal-feeding nematodes mineralize N from their prey groups. Bacterial-feeding nematodes are more important in bacterial-dominated soils (agriculture and grassland systems), while fungal-feeding nematodes are more important in fungal dominated soils (conifer and most deciduous forests). Between 70 and 80% of the nitrogen in rapidly-growing trees has been shown to come from interactions between nematode predators and their prey. Between 30 and 50% of the N in crop plants appears to come form the interactions of bacterial-feeding nematodes and bacteria. Thus, the presence and numbers of bacterial- and fungal-feeding nematodes is extremely important for productive soils.

### 6.11.5 VAM spore numbers

Vesicular-arbuscular mycorrhizal (VAM) fungi are critically important for all crop plants, except species of the *Brassica* family (e.g., mustards, kale). A number of researchers have shown that the lack of VAM inoculum, or the lack of the appropriate inoculum can result in poor plant growth, in poor competition with other plants or inability to reproduce or survive under certain extreme conditions. However, most crop fields have adequate VAM spores present, especially if crop residue is placed back into the field. Only in a few situations where soil degradation has been severe, such as with intensive pesticide use, fumigation, or intense fertilizer amendment, will VAM inoculum become so low that plant growth will be in jeopardy.

In restoration studies, the lack of appropriate inoculum is more likely to be a problem than in other situations where sources of appropriate VAM spores are nearby. Thus, the presence of at least 1 to 5 spores per gram of soil is adequate for most crop fields. When the number of spores falls below one per gram, then addition of compost containing high numbers of VAM spores (for example from an alfalfa field, or other legume), or inoculation of VAM spores from a commercial source generally results in positive effects.

### 6.11.6 Percent VAM colonization

At least 12% of the root system of grasses, (i.e., most crop plants), should be colonized by VAM in order to obtain the minimum required benefits from this symbiotic relationship. Colonization upwards of 40% is usually seen in healthy soils. VAM colonization can limit root-feeding nematode attack of root systems, if the nematode burden is not too high. A great deal knowledge of the relationship between plant species, VAM species and soil type, including fertility, is needed in order to fully predict the optimal relationship between crop plant, VAM species and soil.

## 6.12 Disruption of soil fertility: Reasons of web of life being degraded

The interactions between soil organisms form a web of life, just like the web that biologists study above ground. Soil biology is understudied, compared to the above ground, yet it is important for the health of gardens, pastures, lawns, shrublands, and forests. If garden soil is healthy, there will be high numbers of bacteria and bacterial-feeding organisms. If the soil has received heavy treatments of pesticides, chemical fertilizers, soil fungicides or fumigants that kill these organisms, the tiny critters die, or the balance between the pathogens and beneficial organisms is upset, allowing the opportunist, disease-causing organisms to become problems.

Two measures of ecosystem processes are the ratio of fungal to bacterial biomass (Ingham and Horton, 1987) and the Maturity Index for nematodes. Both appear to be useful predictors of ecosystem health, although they must be properly interpreted given the successional stage being examined. For example, recently disturbed systems have nematode community structures skewed towards opportunistic species and genera, while the less opportunistic, more K-selected species of nematodes return as time since-disturbance increases. Thus, healthier soils tend to have more mature nematode community structures. However, as systems mature, nutrients tend to be more sequestered in soil biomass and organic matter, and thus the maturity index reflects an optimal, intermediate disturbance period in which greatest ecosystem productivity is likely to occur.

Much work is still required at the bacterial and fungal species level. While the species of protozoa and nematodes have been researched in soils of this area of the west, publication of much of this information has yet to occur. Up-dates will be required, as this information becomes available.

Over-use of chemical fertilizers and pesticides have effects on soil organisms that are similar to over-using antibiotics. When we consider human use of antibiotics, these chemicals seemed a panacea at first, because they could control disease. But with continued use, resistant organisms developed, and other organisms that compete with the disease-causing organisms were lost. We found that antibiotics couldn't be used willy-nilly, that they must be used only when necessary, and that some effort must be made to replace the normal human-digestive system bacteria killed by the antibiotics.

Soils are similar, in that plants grown in soil where competing organisms have been knocked back with chemicals are more susceptible to disease-causing organisms. If the numbers of bacteria, fungi, protozoa, nematodes and arthropods are lower than they should be for a particular soil type, the soil's "digestive system" doesn't work properly. Decomposition will be low, nutrients will not be retained in the soil, and will not be cycled properly. Ultimately, nutrients will be lost through the groundwater or through erosion because organisms aren't present to hold the soil together.

Chapter VII

# Rebuilding Soil Health

The best way to manage a healthy microbial ecosystem is to routinely apply organic material, such as compost. To keep soil healthy, the amount of organic matter added must be equal to what the bacteria and fungi use each year. Indiscriminate use of chemical fertilizers and pesticides should be avoided. If the soil is healthy for the type of vegetation desired, there should be no reason to use pesticides, or fertilizers. If both bacteria and fungi are lost, then the soil degrades. If bacteria are killed through pesticide or chemical applications, and especially if certain extremely important bacteria like nitrogen-fixing bacteria or nitrifying bacteria are killed, fungi can take over and crop production can be harmed. For example, current research indicates that the reason moss takes over in degraded ecosystems is because the soil is converted from a bacterial dominated system to one dominated by fungi. Nutrients are lost, erosion increases and plant yield is reduced. If inorganic fertilizers are used to replace the lost nitrogen, the immediate effect may be to improve plant growth. However, as time goes on, it is clear that inorganic fertilizers can't replace the other kinds of food that bacteria and fungi need. After a while, fertilizer additions are a waste of money, because there aren't enough soil organisms to hold on to the nutrients added. Surface and groundwater will become contaminated with the lost nutrients, causing problems.

## Enhancing soil fertility

Soil is a living system and soil fertility is the key to agricultural productivity. Any input that destroys this living system and undermines soil health basically undermines the agricultural productivity. The maintenance of the fertility of soil is the primary step in any permanent system of agriculture. The soil carries a lot of fertility of its own. The plethora of micro-organism inherent in any soil system ensures that the nutrient cycle is in place and the large substrate are broken down to minute particles that are easy for assimilation in the root system. The reserves are carried in the form of humus, which is the result of the activities of thousands of microbes such as earthworms, burrowing insects, fungus, bacteria etc. The extent of the enormity is only realized when pouring of chemicals in soil for petty and short-term gains devastate the soil fertility.

A living soil is a fertile soil. The fertility of the Indian soil in the past is an expression of the sustainability of Indian agriculture, where people, livestock and the forest worked together synergistically and in harmony. Chemicals have destroyed the life in soils by making them inert. Healing the dead soil requires reviving life in the soil.

Some soils can be highly productive without the addition of purchased external inputs. Farmers should maintain the inherent fertility of these soils by replacing the nutrients removed by crops or livestock grazing by using green manures, animal manures (raw or composted) and other organic fertilizers. Other soils, however, may be deficient in one or more essential nutrients and this deficiency must be corrected. Truly sustainable farming protects the fertility of the soil and improves towards higher productivity.

It has been experienced that the farm organic certification bodies increasingly request and lay stress on the farm to have a long-term, soil-building plan. The input and output of plant nutrients must be monitored through a soil-testing program to ensure that severe nutrient depletion (or "mining" of the soil) does not take place. Soils deficient in nutrients cannot support either crop production or active populations of beneficial microorganisms, which are essential for a productive soil.

Results from different European countries comparing phosphorous and potassium balances of conventional and organic farms are presented in Table 7.1 even though the values vary a great deal, it can be concluded that the phosphorous and potassium surpluses of organic farms are significantly lower than on conventional ones.

Due to negative nutrient balances as shown in Table 7.1, the question arises whether organic agriculture methods cause gradual loss of soil minerals. First of all, the proportion of soluble nutrients is lower on organically-managed soils. On the other hand, Mäder *et al.,* (2000) found no decrease in organic yields as an indicator for nutrient deficiency on farms which are managed organically for more than 30 years. As discussed later, higher biological activity and higher mycorrhizal root colonization counteract nutrient deficiency, thus as Oberson *et al.,* (2000) state, for phosphorus, the aim of organic agriculture of increasing nutrient supply through increased biological activity has been achieved.

Higher biological activity and higher mycorrhizal root colonization counteract nutrient deficiency.

**Table 7.1 Examples for P, K balances (kg/ha) comparing organic with conventional farms from different European countries**

| | ***P balance (kg/ha)*** | | ***K balance (kg/ha)*** | |
|---|---|---|---|---|
| | ***Organic*** | ***Conventional*** | ***Organic*** | ***Conventional*** |
| Sweden | -12 | +37 | -4 | +39 |
| Netherlands | | | | |
| cash crop farm | +18 | +23 | +31 | +25 |
| Horticulture | +32 | +60 | +119 | +110 |
| Dairy farm | +8 | +31 | – | – |
| Germany | | | | |
| Mixed farm | -4 | +13 | -27 | +31 |
| Dairy farm* | -2 | +5 | +7 | +20 |

*Source: Stolze et al., 2003, and *Haas et al., 2001*

Improvement in agricultural sustainability requires, alongside effective water and crop management, the optimal use and management of soil fertility and soil physical properties. Both rely on soil biological processes and soil biodiversity. This calls for the widespread adoption of management practices that enhance soil biological activity and thereby build up long-term soil productivity and health.

The major steps to enhance soil fertility are:

- **Composting and Vermicomposting**
- **Mixed Cropping**
- **Crop rotation and Selection**
- **Green Manuring**
- **Cattle dung**
- **Oil seed refuge**
- **Leguminous plants**
- **Increasing beneficial microorganism by inoculating the soil with inoculum**

## 7.1 Organic farming practices

### *Composting Methods*

The bacteria and fungi occurring in the soil convert dead organic matter present on its surface into a nutrient rich medium. This is called composting and the nutrient rich medium is called compost. The following are the benefits of compost as compared to using raw manure.

**Table 7.2 Benefits of compost as compared to raw manure application**

| *Impact of use of Raw Manure* | *Benefits of Composting* |
|---|---|
| Supplies organic matter and nutrients to soil. | Supplies organic matter and nutrients to soil. |
| Initially cheaper than compost | Controlled process ensures organic material is broken down and nutrients mineralized into plant available form. |
| Rocks and clumps remains in raw manure | Rocks and clumps may be removed by screening |
| Bad odour | Minimal odour |
| Pathogen are present | Safer handling through destruction of pathogens. |
| Big particle size | Small particle size for easier application |

### *Composting*

Composting is a process where microorganisms break down organic matter to produce humus like substance called compost. The process occurs naturally provided the right organisms, water, oxygen, organic material and nutrients are available for microbial growth. By controlling these factors, the composting process can occur at a much faster rate.

***The Phases of Composting Process:***

There are three main phases of composting process:

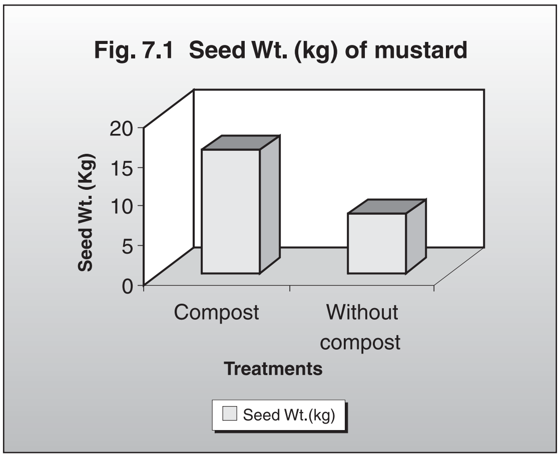
1. **The heating phase:** In this phase the temperature of the compost heap rises to 60° to 70°C. The decomposition of the materials used in compost pits occurs during the heating phase. Bacteria are mainly active during the first phase. The heat destroys diseases, pests, weeds, and roots.
2. **The cooling phase:** The second phase of composting is cooling phase in which the temperature in the compost heap declines slowly and will remain 25-45$^0$ C. In this phase fungi start the decomposition of straw, fibers and wooden material.
3. **The maturing phase:** During this phase nutrients are mineralized and humic acids and antibiotics are built up. At the end of this phase the compost needs much less water than in the heating phase.

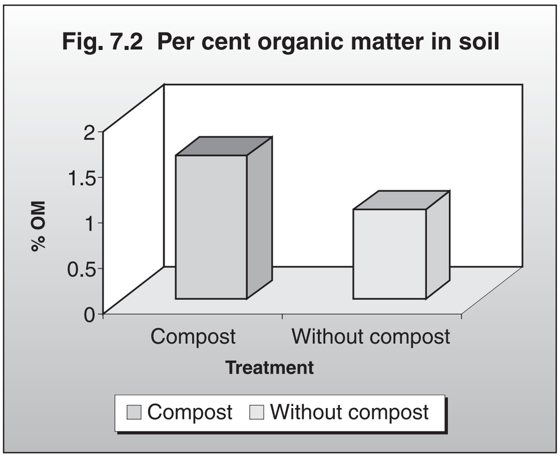
***What benefits can the farmers expect from composting?***

The benefits of using composts are as follows:

- **Value addition** – turning waste into a marketable resource.
- **Improved handling**– fine particles can be screened and incorporated into soil better than raw organic materials
- **Reduced odour** – odour associated with anaerobic decomposition of organic materials is minimized through composting
- **Environmentally friendly** – promote industry sustainability through incorporating cleaner production practices
- **Soil conditioner**: application of compost to fields adds organic material, improving the soil structure and water retention of the soil
- **Source of nutrients:** reduces requirement for inorganic fertilisers
- **Nutrients mineralized:** nutrients are in more plant-available forms
- **Pathogen destruction:** heat generated during the process can destroy pathogens
- **Weeds suppressed:** heat can denature weed seeds
- **Slow release nutrient:** nutrients are released to the plants slowly, reducing the loss of nutrients to the environment.

A study on the effect of compost on different crops was done by Navdanya. Results showed that % organic carbon and % organic matter was higher in compost plots as compared to control pots. The seed yield was higher in compost plots as compared to control. The data on % soil organic matter and seed yield are given in the following graphs:




## 7.2 Various methods of composting practiced in Navdanya farm:

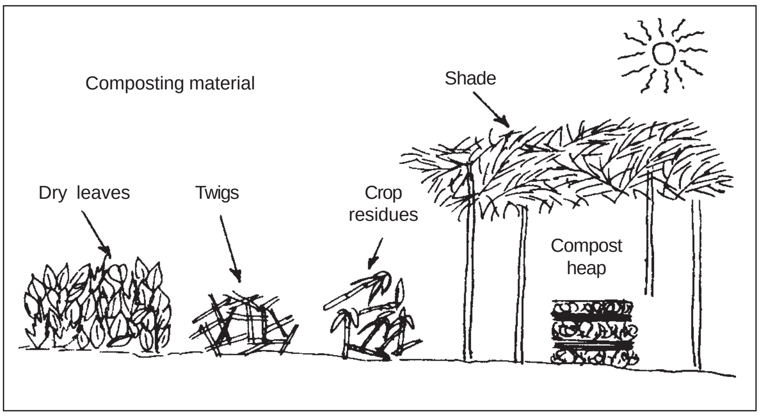
The following are the most common methods of composting in organic farming which are used in Navdanya farm:

Nadep composting

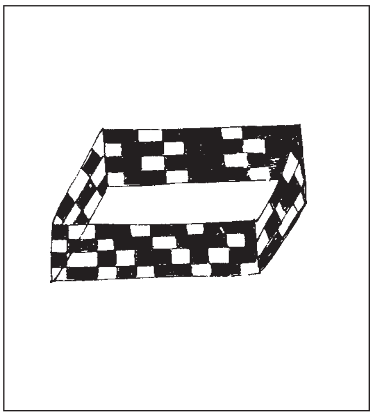
Vermi-composting

### *7.2.1 NADEP Composting:*

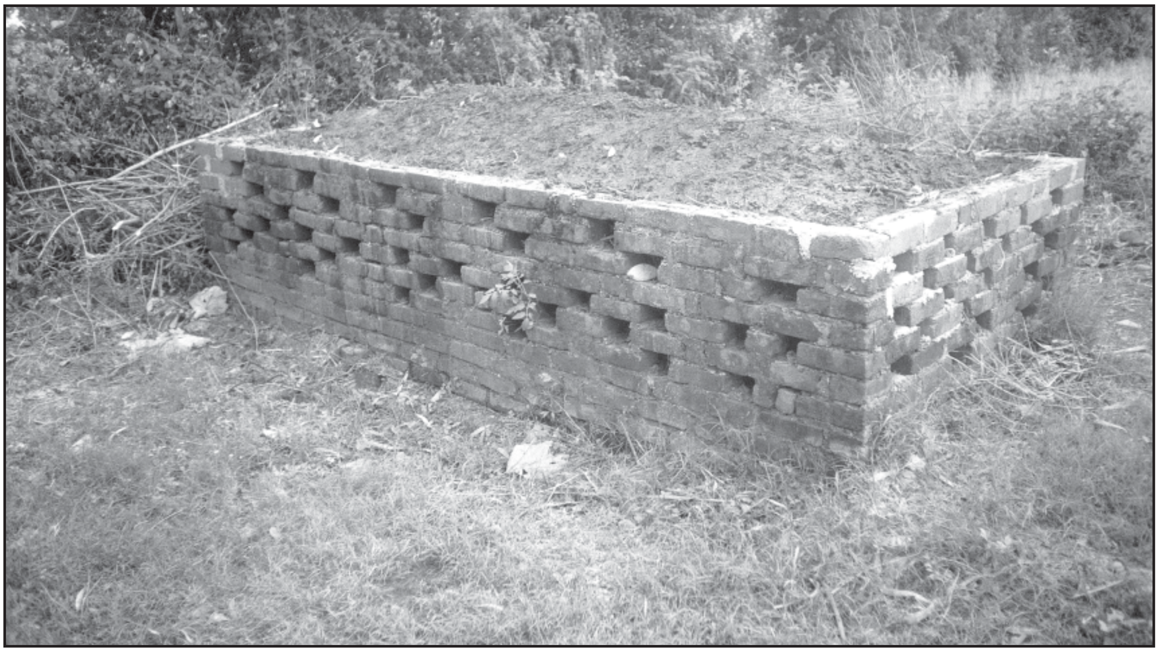
The Nadep method of making compost was first invented by a farmer named N.D. Pandharipande (also popularly known as "Nadep kaka") living in Maharashtra (India). The process basically involves placing select layers of different types of compostible materials in a simple, mud-sealed structure designed with brick and mud water. The system permits conversion of approximately 1 kg of animal dung into 40 kg of rich compost, which can then be applied, directly to the field.




*Digram 7.1 Compost formation*



*Digram 7.2 Perforated tank for Nadep Composting*



*NADEP Tank at Navdanya Farm*

The Nadep method of making compost involves the construction of a simple, inexpensive rectangular brick tank with enough spaces maintained between the bricks to provide for necessary aeration.

The recommended size of the tank is of the order of 10 ft (length) × 6 ft (breadth) × 3 ft (height). If more material is available for composting, then the length should be increased. However, the breadth should never exceed six feet.

Once the tank is completed, there comes the important task of placing the layers of organic material within the structure. The quantities required are as follows:

(a) 1,500 kg of plant and farm waste, including dried husk, twigs, stalks, roots, leaves, etc. from which all-plastic, glass and stones have been removed. Other materials, which can be used in compost making include the green biomass of all crop plants (available after the grain has been removed), spent sugarcane stalks after sugarcane juice has been extracted.

(b) 90-100 kg of cow dung. In place of this, the slurry from biogas plants can also be used.

(c) Dried, filtered soil (from the fields) from which again all materials like glass, stones and plastic have been removed.

(d) Water requirements will vary from season to season, but generally, the quantity will be the same as the weight of the organic mass being fed to the tank.

The important technique in the manufacture of Nadep compost is that the entire tank should be filled in one operation. Filling should be completed within 24 hours and should never go beyond 48 hours, as this would affect the quality of the compost.

***Methodology:***

**First layer:** Plant waste is filled up to a height of six inches. This will take up at least 100 to 120 kg of the material.

**Second layer:** 4 kg of cowdung should now be mixed well in 125 to 150 litres of water and sprinkled on the plant waste in such a way that the material is completely wet with it. More water will be required in summer for the wetting.

**Third layer:** The wet cowdung-sprinkled waste is covered with another 60 kg of clean, filtered soil and water is sprinkled on it again.

Thereafter, the tank continues to be filled with this series of three layers in the same sequence up to one and a half feet above the rim of the tank in the shape of a cone.

Usually, the standard tank can take 11 or 12 series of layers.

Then, once the filling is completed, the tank is to be sealed. This is done by covering the top with a three-inch layer of soil all around. The soil layer is then plastered with liquid cow dung slurry carefully so that no cracks emerge

After a period of 15-20 days, the material for compost reduces its volume as the process of degradation by microbial and release of nutrients sets in

The tank should be opened and filled again with the same sequence of layers up to a height of one and a half feet above the tank rim. Once again, the material should be covered in three inches of soil and sealed with liquid cow dung slurry.

Thereafter, in order to maintain the moisture level (which should be about 15% to 20%) and also to prevent cracking, cow dung mixed with water is sprinkled on the compost heap. Water may also be sprayed through the holes on the tank sides.

The entire tank is covered with a thatched roof to prevent excessive evaporation of moisture. At no point of time should the compost be allowed to become dry. Under no circumstances should any cracks be allowed to develop. If they do, they should be promptly filled up with slurry. Grass that sprouts should be removed.

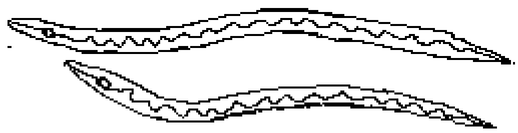
Depending on the way in which the preparations have been done, the compost will take between 90 and 120 days to be completely ready for removal and use.

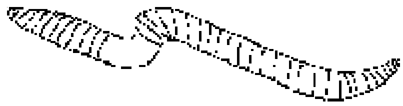
When the tank is opened, the compost will be a deep brown colour with a pleasant smell. It should be removed and sieved through a grill. The filtered bio-fertilizer should be used and the remains placed back into the tank for the next composting process.

**(Source:** Dr. Kumarappa Gowardhan Kendra at Pusad)

## Members for decaying the material in compost heap

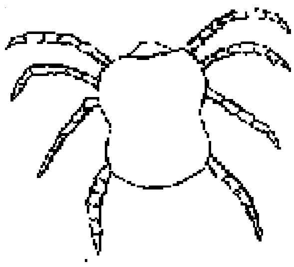
Many kinds of worms, including earthworms, nematodes, red worms and potworms eat decaying vegetation and microbes and excrete organic compounds that enrich compost. Their tunneling aerates the compost, and their feeding increases the surface area of organic matter for microbes to act upon. As each decomposer dies or excretes, more food is added to web for other decomposers.





**Nematodes**: These tiny, cylindrical, often transparent microscopic worms are the most abundant of the physical decomposers - a handful of decaying compost contains several million. It has been estimated that one rotting apple contains 90,000. Under a magnifying lens they resemble fine human hair.

Some species scavenge on decaying vegetation, some feed on bacteria, fungi, protozoa and other nematodes, and some suck the juices of plant roots, especially root vegetables.



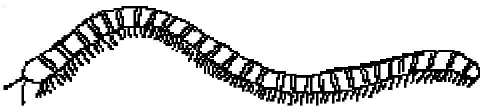
**Mites**: Mites are the second most common invertebrates found in compost. They have eight leg-like jointed appendages. Some can be seen with the naked eye and others are microscopic. Some can be seen hitching rides on the back of other faster moving invertebrates such as sowbugs, millipedes and beetles. Some scavenge on leaves, rotten wood, and other organic debris. Some species eat fungi, yet others are predators and feed on nematodes, eggs, insect larvae and other mites and springtails. Some are both free living and parasitic. One very common compost mite is globular in appearance, with bristling hairs on its back and red-orange in color.

**Springtails**: Springtails are extremely numerous in compost. They are very small wingless insects and can be distinguished by their ability to jump when disturbed. They run in and around the particles in the compost and have a small spring-like structure under the belly that catapults them into the air when the spring catch is triggered. They chew on decomposing plants, pollen, grains, and fungi. They also eat nematodes and droppings of other arthropods and then meticulously clean themselves after feeding.

**Earthworms**: Earthworms do the lion's share of the decomposition work among the larger compost organisms. They are constantly tunneling and feeding on dead plants and decaying insects during the daylight hours. Their tunneling aerates the compost and enables water, nutrients and oxygen to filter down. "As soil or organic matter is passed through an earthworm's digestive system, it is broken up and neutralized by secretions of calcium carbonate from calciferous glands near the worm's gizzard. Once in the gizzard, material is finely ground prior to digestion. Digestive intestinal juices rich in hormones, enzymes, and other fermenting substances continue the breakdown process. The matter passes out of the worm's body in the form of casts, which are the richest and finest quality of all humus material. Fresh casts are markedly higher in bacteria, organic material, and available nitrogen, calcium, magnesium, phosphorus and potassium than soil itself." (Rodale)

**Slugs and snails**: Slugs and snails generally feed on living plant material but will attack fresh garbage and plant debris and will therefore appear in the compost heap.

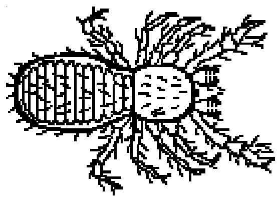
**Centipedes**: Centipedes are fast moving predators found mostly in the top few inches of the compost heap. They have formidable claws behind their head which



possess poison glands that paralyze small red worms, insect larvae, newly hatched earth-worms, and arthropods - mainly insects and spiders.

**Millipedes**: They are slower and more cylindrical than centipedes and have two pairs of appendages on each body segment. They feed mainly on decaying plant tissue but will eat insect carcasses and excrement.

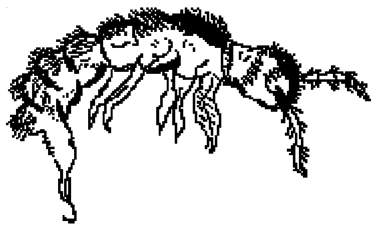
**Beetles**: The most common beetles in compost are the rove beetle, ground beetle and feather-winged beetle. Feather-winged beetles feed on fungal spores, while the larger rove and ground beetles prey on other insects, snails, slugs and other small animals.



**Ants**: Ants feed on aphid honeydew, fungi, seeds, sweets, scraps, other insects and sometimes-other ants. Compost provides some of these foods and it also provides shelter for nests and hills. Ants may benefit the compost heap by moving minerals especially phosphorus and potassium around by bringing fungi and other organisms into their nests.

**Flies**: During the early stages of the composting process, flies provide ideal airborne transportation for bacteria on their way to the pile. Flies spend their larval phase in compost as maggots, which do not survive thermophilic temperatures. Adults feed upon organic vegetation.

**Spiders**: Spiders feed on insects and other small invertebrates.



**Pseudoscorpions**: Pseudoscorpions are predators which seize victims with their visible front claws, then inject poison from glands located at the tips of the claws. Prey includes minute nematode worms, mites, larvae, and small earthworms.

**Earwigs**: Earwigs are large predators, easily seen with the naked eye. They move about quickly. Some are predators. Others feed chiefly on decayed vegetation.

### *7.2.2 Vermi-composting*

Vermi-composting is composting that is brought about by vermi i.e. principally earthworms. Earthworms speed up the composting process, aerate the organic material and enhance the finished compost with nutrients and enzymes from their digestive tracts. Vermi-composting, or composting with earthworms, is an excellent technique for recycling food waste in the apartment as well as composting yard wastes in the backyard.

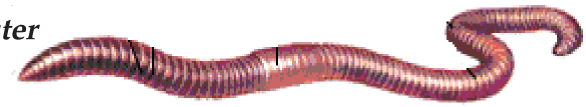
*Vermes* is Latin for worms and Vermicomposting is essentially composting with worms. In nature all organic matter eventually decomposes. In Vermicomposting you speed up the process of decomposition and get a richer end product called "worm castings."

Vermicomposting has the added advantage of allowing you to create compost round the year; indoors during the winter and outdoors during the summer. The consumption of organic wastes by earthworms is ecologically safe methods to naturally convert many of our organic wastes into an extremely environmentally beneficial product.

#### *7.2.2.1 Types of Earthworms*

The most common types of earthworms used for vermi-composting are *Eisenia foetida*.

### *Earthworms: The Principle Vermi composter*

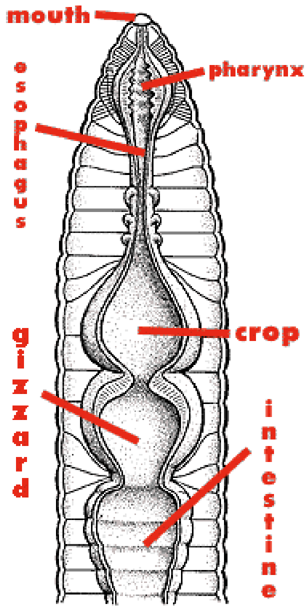


### *Anatomy of Earthworms*

The earthworm has a long, rounded body with a pointed head and slightly flattened posterior. Rings that surround the moist, soft body allow the earthworm to twist and turn, especially since it has no backbone. With no true legs, bristles (setae) on the body move back and forth, allowing the earthworm to crawl.

The earthworm breathes through its skin. Food is ingested through the mouth into a stomach (crop). Later the food passes through the gizzard, where ingested stones grind it up. After passing through the intestine for digestion, what is left is eliminated.

The Red Wiggler ingests waste at the front, through a soft mouth with a lip that can seize or grasp whatever the worm is trying to eat. The throat, or "phraynx" can be pushed forward to help pull matter in. They have no teeth so they coat their food with saliva, which makes it softer and easier to digest. After the food is swallowed, it passes through the esophagus to the crop and then to the gizzard, where small stones grind it up. The food is passed into the intestine, which is almost as long as the worm, itself. At the end of the intestine is the anus, for passing out the castings.



*Digram 7.3 Anatomy of earthworm*

Worms have a brain and five hearts. They have neither eyes nor ears but are extremely aware of vibrations such as thumps or banging on the composter. They have a well-founded hereditary aversion to bright lights. Ultraviolet rays from the sun are very harmful to earthworms. One hour's exposure to strong sunlight causes partial-to-complete paralysis and several hours are fatal. A worm breathes when oxygen from the air or water passes through its moist skin into the blood capillaries. If the body covering dries up, the worm suffocates. Thus, it is important that the worm bin should have moisture at all times which prevents the desiccation of earthworm. Below are mentioned the promising indigenous varsities.

*Castings*

When worms expel their manure there is a bit of mucus surrounding each granule. This hardens when it is exposed to air. When granular castings are mixed into garden or houseplant soils there is a slow "time release" if nutrients to feed the plants. However, the hardened particles of mucus to not break down readily, and they act to break up soils providing aeration and drainage, creating an organic soil conditioner as well as a super, natural fertilizer.

Castings compared to soil has:

- 5 times the nitrate
- 7 times the phosphorus
- 3 times the exchangeable magnesium
- 11 times the potash
- 1.5 times the calcium

***India Blue: (Perionyx excavatus) -* A burrowing earthworm**

This worm is known for it's mass migrations and has been found on top of buildings during rainstorms. Some authors seem to think that it is the presence of a toxin produced by anaerobic bacteria that trigger this mass migration. This worm is a prolific breeder and consumes large amounts of organic waste.

A combination of this species and the redworm (*Eisenia foetida*) in vermicomposting mixed produce waste. The redworms will consume feed that is below the surface as well as feed on the surface. Whereas the *Perionyx* is strictly a top feeder and if you cover the old feed with new feed, they will not consume the old feed and therefore the castings will not be pure. By the addition of the redworms you will end up with 95% to 99% pure castings. The *Perionyx* is often confused with the Redworm because their color is identical. The easiest way to identify them is to compare the location of the band (clitellum). The *Perionyx* clitellum is much closer to the front of the worm.

These worms are raised in the ground beds just as you would the standard redworm. The worms are very prolific and will live in the natural surrounds and invade any new beds that you build. Their egg capsules look just likes the redworm. They consume any type of organic waste. During migration they will cover up to 200 feet per night and this is with or without lights. These worms are very tough and are harvested with the mechanical worm harvester. They are good shippers when packaged in the correct shipping medium.

***7.2.2.2 What is Vermicompost?***

Vermicompost contains not only worm castings, but also bedding materials and organic wastes at various stages of decomposition. It also contains worms at various stages of development and other microorganisms associated with the composting processing.

Earthworm castings in the home garden often contain 5 to 11 times more nitrogen, phosphorous and potassium than the surrounding soil. Secretions in the intestinal tracts of earthworms, along with soil passing through the earthworms, make nutrients more concentrated and available for plant uptake, including micronutrients

*Producing compost by using earthworms, also referred to as farmers' best friends, is called Vermicomposting. For this, the earthworms are cultured in vermibeds and then they are fed on organic waste, which they convert into nutrient- rich vermicompost. This vermmicopost is an excellent alternative to expensive and harmful chemical fertilizers.*

### *Earthworm collection*

Placing handful lumps of fresh cowdung, topped by leaf litter randomly over a 1 sq.m area and covered with jute or cloth bag and watering this heap regularly attracts earthworms in about two weeks time.

Alternatively, mixing 1 kg of jaggery and 1 Kg of fresh cowdung in 20 litres of fresh water and sprinkling this on the jute bag once or twice a week is sure to attract the earthworms, if they are present in the soil.

It is always better to collect and use locally occuring worms for vermicomposting.

### *7.2.2.3 How to start a vermi composting unit?*

### *Method:*

- To make a vermibed, choose a cool shady place protected from Sun, wind and rain.
- Digging a trench 2m × 1m × 1m in the soil, a wooden crate or any other container having drain holes to drain out excess water, can be used to make a vermi bed.
- To ensure proper drainage, arrange pebbles or broken pieces at the bottom of the pit/crate.
- Next fill coarse sand to a depth of 6-7 cms. This also helps in drainage.
- The next layer is loamy soil to a minimum thickness of 15 cms.
- On this layer introduce about a 100 earthworms.

**Materials Required:**

Locally occurring earthworms

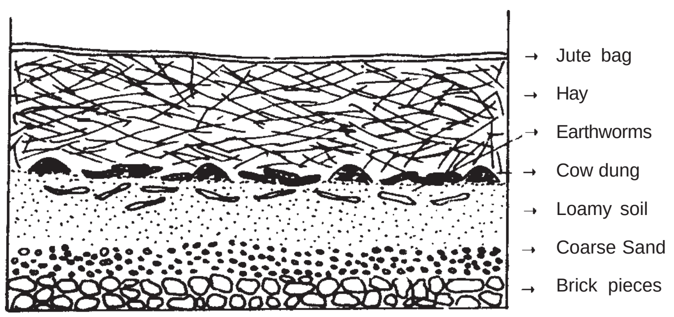
Organic matter (green/dry leaves, kitchen wastes, agricultural wastes).

Dung (cow, goat, pig) either fresh or dried.

Pebbles or broken brick pieces.

Coarse sand and loamy soil.

Water




*Digram 7.4 Material layout in Vermicompost unit*

*Navdanya's Vermicompost Unit*

Then put small lumps of either fresh or dried dung on the soil.

- Cover this with a layer of hay up to a thickness of 10 cms.
- Sprinkle water till all the layers in the unit get moist. Over-watering should be avoided. This is the vermibed.
- Cover the entire unit with coconut leaves or other broad leaves. If this is not available use jute bags. Never use plastic as this leads to heat accumulation within the unit.
- For the next 30 days watch and monitor the unit, watering whenever required. The earthworms will multiply during this period.
- From the 31$^{st}$ day start adding organic waste to a maximum thickness of 5cms.
- Sprinkle water regularly to keep the unit moist. Continue adding waste till the trench/crate is full and then cover it up either with large leaves or jute.
- Turn the waste once in a while but take care that the vermibed is not disturbed.
- The compost is ready for harvest 45 days after the last application of waste.

#### *7.2.2.4 How to take a harvest?*

Stop watering 42 days after the last filling. The worms will go to the bottom of the vermibed. Pile up the compost in a heap in a sunny area and leave it there for about 24-36 hours. Any worms present would go to the bottom of the pile. Spread out the compost and collect the worms seen at the bottom and use them to start a fresh unit.

** To have a continuous supply of vermicompost two units (twin system) can be set up. The second unit should be started 45 days after the first one is started. Each harvests which takes about 120 days yields 1500 kgs of vermicompost. Six such harvests are possible from a twin system in a year.*

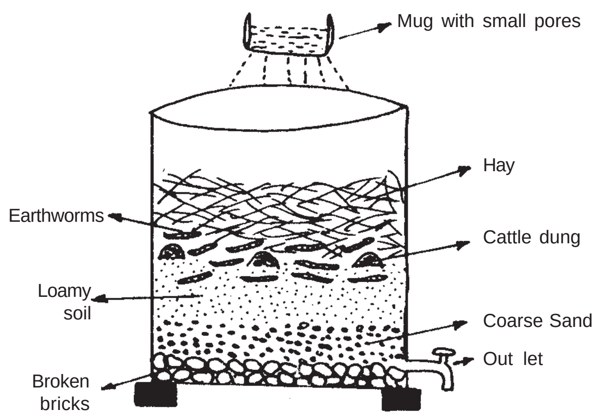
### *7.2.2.5 Setting up a vermiwash unit*

***Method:***

- At the bottom of the bucket fill broken brick pieces to a thickness of 25-30 cms. Keep the tap at the bottom of the bucket open and pour water till all the brick pieces are completely wet.
- Next fill sand to a thickness of 20-30 cms and allow water to flow through this too till it is wet.
- Next is a 30-45cm thick layer of loamy soil. This is also watered thoroughly. The earthworms are released here.
- Small pats of cattle dung are scattered on the soil.
- Cover with organic waste. Moisten this layer too and after all the excess water drains off close the tap at the bottom.
- For the next 16 days continue to moisten the unit keeping the tap open to drain off excess water.
- After 16 days, every night suspend the perforated 5 litre mug filled with water over the vermiwash unit (the tap must remain closed all through the night).
- As the water slowly percolates down the unit it carries with it the nutrients in suable form which may be utilised diverctly.

**Materials Required:**

- An earthen pot or a plastic or metal bucket with a tap at the bottom
- Broken brick pieces
- Sand
- Cattle dung
- Loamy soil
- Earthworms
- Organic waste
- A 5 litre mug with minute holes




*Digram 7.5 Setup of Vermiwash Unit*

### *7.2.2.6 Do's and don'ts of vermi composting*

- The best approach is prevention. By always *burying the food waste* you will discourage fruit flies. Keep a tight lid on the container you use to store waste before adding them to the bin. This will prevent flies from laying eggs in the scraps.
- It is unlikely that your worm bin will have an unpleasant odour. If it does, there are a number of possible causes and steps you can take to remedy the problem.
- You have overloaded your bin with too much food waste. Solution: Don't add any more food for a week or two.

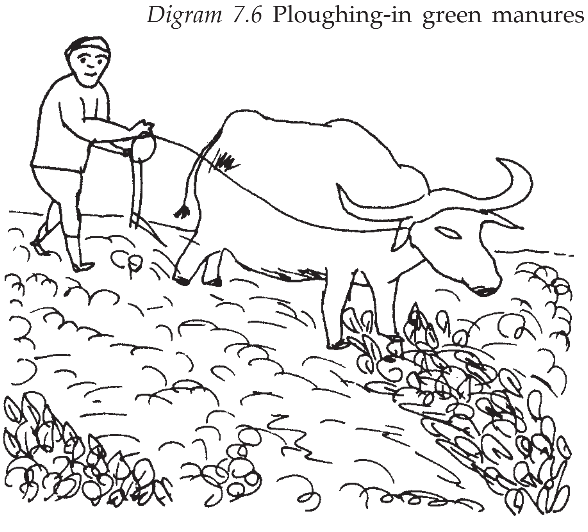
- The bedding is too wet and compacted. Solution: (a) gently stir the entire contents to allow more air in and stop adding food waste for a week or so. Make sure that your food waste is still buried. (b) lid can be removed or left slightly ajar to allow the contents to dry out.
- Your bin is too acidic. Solution: Add some calcium carbonate and cut down on the amount of citrus and other acidic food waste.

***Don'ts***

- Worms hate light and prefer to remain in the dark of their bin. They will not leave there home. They are very sensitive to vibrations. Please try not to disturb them unnecessarily.
- Worms are living creatures with their own unique needs, so it is important to create and maintain a healthy habitat for them to do their work. If you supply the right ingredients and care, your worms will thrive and make compost for you.
- Don't put plastic bags, bottle caps, rubber bands, sponges, aluminum foil and glass in the bin. These materials will be there forever and make your worm bin look like trash.
- Don't let your pets use your worm bin as a litter box. If you have pets, provide a screen or other device to keep them from using the worm bin as a litter box.
- Don't use insecticides around your worm bin. Don't use garden soil as bedding for the worms.
- Don't mix fresh cow, horse and especially chicken manure into your bedding. These manures will heat up the bedding and literally cook your worms.

### *7.2.3 Green manuring used in Navdanya farm*

*Digram 7.6* Ploughing-in green manures



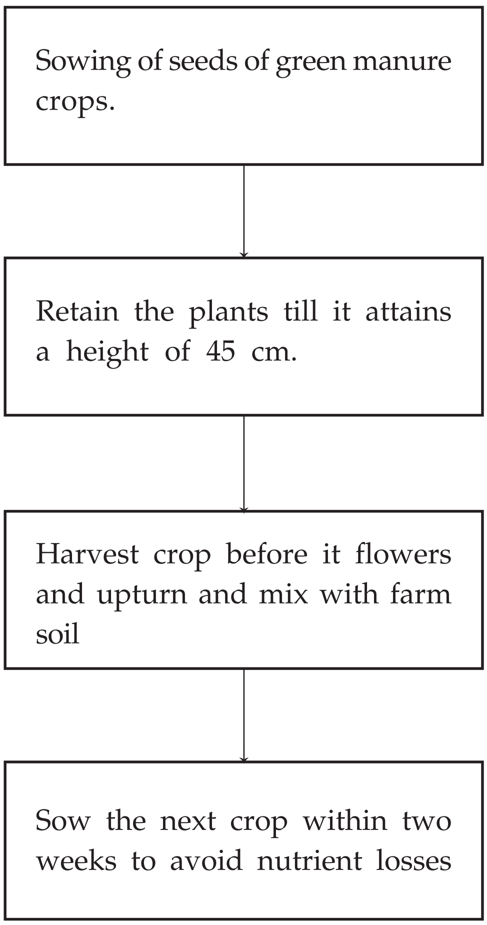
Soil fertility maintenance through the use of legume green manures is integral part of farming in the Navdanya organic farm to enhance its soil fertility and productivity status. As no chemical fertilisers in the form of external output are applied, the Nitrogen requirements for crop production are met either through the application of raw or composted livestock manures or through the use of legume green manures. Rhizobium bacteria on legume roots fix atmospheric nitrogen; legumes incorporated into the soil can be used as a source of nitrogen and organic matter.

Annual or biennial legumes are the best plants to use as green manures. Green manuring improves the soil structure and thus increases soil productivity of soil.

Table 7.3 Some of the commonly used tree species for green manuring are:

| | |
|---|---|
| Ubiquitous in distribution | *Pongamia pinnata, Morianga oleflorea, Agave sisalana, Thesphesia populanea, Cassia siamea, Vitex negundo, Anacardium spp., Bauhina vahii, Bretusa spp., Leucenea lecocephala* Lentil, *Pisum sativum, Chrysopogon, Musa sapietum etc.* |
| Lesser Himalayan region | *Quercus leucotrichophora, Quercus semicarpifolia, Daphiniphyllum himalayaense, Bridelia retusa, Nyctanthes arbortristis.* |
| Deccan Plateau | *Bamboo-Hebu; Melia azidirach, Cocos nucifera, Pongamia pinnata.* |
| Western Ghats | *Mangifera indica, Artocarpus spp., Adina cardifolia,Terminalia paniculata, Pterocarpus marsupium, Gmelina arborea, Tectona grandis* |
| West Bengal | *Syzgium cumini, Terminalia bellerica, Cleistanthes collinus, Glyricidia spp.* |

**Methodology for green manures: Practices in Navdanya's organic farm:**



Some of the commonly used green manure crops at Navdanya organic farm are as follows:

*Phaseolus aureus* (Mung)- leguminous

*Paseolus mungo* (Urad) – leguminous

*Sesbania aculeate* (Daincha) – leguminous

*Dolichus biflorus* (Horse gram) – leguminous

*Vigna catjung* (Cowpea) – leguminous

**Table: 7.4 Nitrogen status of Green Manure:**

| ***Crop*** | ***N %*** | | ***Dry matter per cent*** |
|---|---|---|---|
| | FW basis | DW basis | |
| *Sesbania aculeate* | 0.50-0.56 | 2.62-2.67 | 22-23 |
| *Ipomoea carnea* | 0.25-0.30 | 1.00-1.25 | 24-25 |
| *Glircidia maculata* | 0.85-0.86 | 3.39-3.46 | 23-24 |

*Source: Khan et al., 2001.*

### *Why are legumes important?*

Each year legume-*Rhizobium* symbiosis generates more useful nitrogen for plants than all the nitrogen fertilizers produced industrially — and the symbiosis provides just the right amounts of nitrogen at the right time at virtually no cost to the farmer.This symbiotic nitrogen fixation is very beneficial for two reasons:

- It supplies the legume with nitrogen,
- It can significantly decrease spending on N-containing fertilizers for the subsequent crops.

In case of legume *Rhizobium* symbiosis, a legume provides the bacteria with energy-rich carbohydrates and some other compounds, while Rhizobium supplies the host legume with nitrogen in the form of ammonia. Unlike any plant, rhizobia (and some other microorganisms) can fix inert $N_2$ gas from the atmosphere and supply it to the plant as $NH^{4+}$, which can be utilized, by the plant.

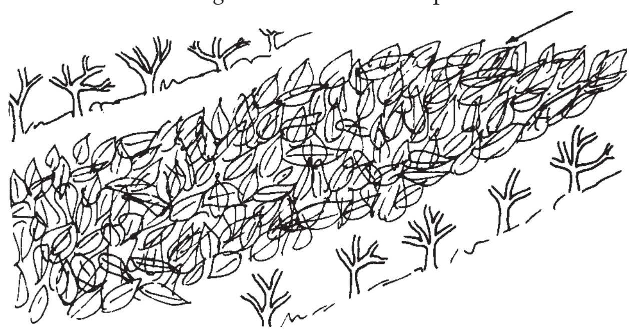
When legumes die, the nitrogen stored in the nodules is released into the soil. This is why green manure crops contain a high percentage of annual legumes, such as field peas or tick beans, usually mixed with field mustard, rape, which provide sulphur. This is an excellent way of enriching & improving soil. Simply sow the green manure crop thickly where required - over a whole bed, or between the rows of trees or perennials, in early autumn. When the plants have made good growth, but before they flower, mow or chop them down & incorporate directly into the soil where they stand, then cover with a layer of mulch. The roots, which have opened up the soil, remain there as humus, nitrogen is released from the roots of the legumes & the rich green foliage supplies a well-balanced mix of nutrients & organic matter, which actually warms the soil as it decomposes. This gives the garden a wonderful boost, is less work than composting, & much less expensive than buying in manure or fertiliser.

### *7.2.4 Cover crops*

Cover crops are crops that are planted to cover the surface of soil during fallow period of the cropping cycle. The benefits of the cover crops are as follows:

***Benefits of cover crop:***

*Digram 7.7* Cover Crop



- Improves soil fertility
- Suppresses weed growth
- Improves soil structure
- Reduces labour costs in soil preparation and weeding
- Fertilizer requirements are reduced
- Helps in soil and water conservation

***Selection of cover crops:***

- Plants should be fast growing
- Pest and disease resistant plants
- Tolerance to wide range of soil types

***Commonly used cover crops***

- *Dolichus lablab*
- *Crotalaris* sp.
- *Canavalia* sp.
- *Vigna* sp.
- *Tephrosia* sp.
- *Dioscroea* sp.
- *Ipomea batatas*

### *7.2.5 Role of biofertlizers in enhancing soil fertility*

One of the major concerns in today's world is the pollution and contamination of soil by the excessive use of chemical fertilisers. The use of chemical fertilizers and pesticides has caused irreparable damage to the environment. The only solution for the recuperation of the damaged soil system is the application of biofertilizers, an environmentally friendly fertilizer now used in most countries. Biofertilizers are organisms that enrich the nutrient quality of soil. The biofertilizers are beneficial organisms that when applied to soil and left with minimal tillage practices help in the building up the population in the farm field. To name some of the biofertilisers are bacteria, fungi, and cyno-bacteria (blue-green algae), mycorrhizae, azospirillium, rhizobium and azotobacter etc. The most striking relationship these have with plant is symbiosis, in which the both the partners derive benefits from each other and in turn help the soil to built and heal the damage done by excess use of chemicals.

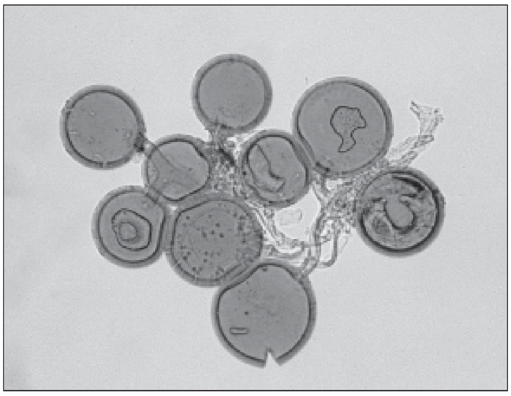
Plants have a number of relationships with fungi, bacteria, and algae, the most common of which are with mycorrhizae, rhizobium, and cyanophyceae etc. These are known to deliver a number of benefits including plant nutrition, disease resistance, and tolerance to adverse soil and climatic conditions. These techniques have proved to be successful biofertilizers that form a health relationship with the roots.The following are different kinds of biofertilizers:

### *Rhizobium*

Bacteria of the genus *Rhizobium* play a very important role in agriculture by inducing nitrogen-fixing nodules on the roots of legumes such as peas, beans, clover and alfalfa. This symbiosis can relieve the requirements for added nitrogenous fertilizer during the growth of leguminous crops. Various institutes are studying the bacterial and legume genes involved in establishing and maintaining the symbiosis.

### *Mycorrhizae*

Mycorrhizae are a group of fungi that include a number of species based on the different structures formed inside or outside the root. These are specific fungi that match with a number of host plants on which it grows. These fungi grow on the roots of the agricultural crops. In fact, seedlings that have mycorrhizal fungi growing on their roots survive better after transplantation and grow faster. The fungal symbionts gets shelter and food from the plant, which, in turn, acquires an array of benefits such as higher uptake of phosphorus, salinity and drought tolerance, maintenance of water balance, and overall increase in plant growth and development.



*Mycorrhiza a useful Biofertilizer*

### *Blue-green algae*

Blue-green algae are considered the simplest, living autotrophic plants, i.e. organisms capable of building up food materials from inorganic matter. They are microscopic. Blue-green algae are widely distributed in the aquatic environment. Certain blue-green algae live intimately with other organisms in a symbiotic relationship. Some are associated with the fungi in form of lichens. The ability of blue-green algae to photosynthesize food and fix atmospheric nitrogen accounts for their symbiotic associations and also for their presence in paddy fields. Blue-green algae are of immense economic value as they add organic matter to the soil and increase soil fertility.

### *Azolla*

Azolla is an aquatic fern (pteridophyte), floating on water surface of flooded rice fields, small ponds, and canals. Azolla is useful as a "soybean plant in rice field", because it can assimilate atmospheric nitrogen owing to the nitrogen fixation by blue green algae living in the cavities located at the lower side of upper (dorsal) lobes of leaf.

### *Azotobacter*

*Azotobacter* is an aerobic soil-dwelling organism with a wide variety of metabolic capabilities, which include the ability to fix atmospheric nitrogen by converting it to ammonia. It fixes nitrogen in the free-living state and does not enter into symbioses with plants.

### *Major biofertilisers and target crops*

**Rhizobium** - Leguminous crops (Pulses, oilseeds, fodder)

**Azatobacter** - Wheat, rice, vegetables

**Azospirillum** - Rice, sugarcane

**Blue green algae** (BGA) - Rice

**Azolla** - Rice

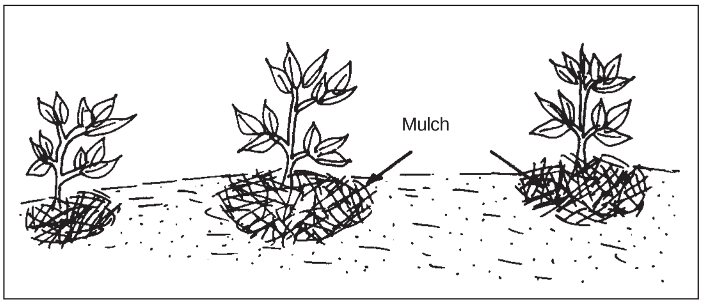
***(Source: A study of biopesticides and biofertilisers in Haryana, India Ghayur Alam, 2000)***

## *7.2.6 Mulching*

Mulching is the method of covering the surface of the soil with any decomposable material (grass, hay, paper, kitchen wastes, leaves, twigs, and plant residues) so that the soil is not exposed to the drying action of the sun or the desiccating action of the wind.

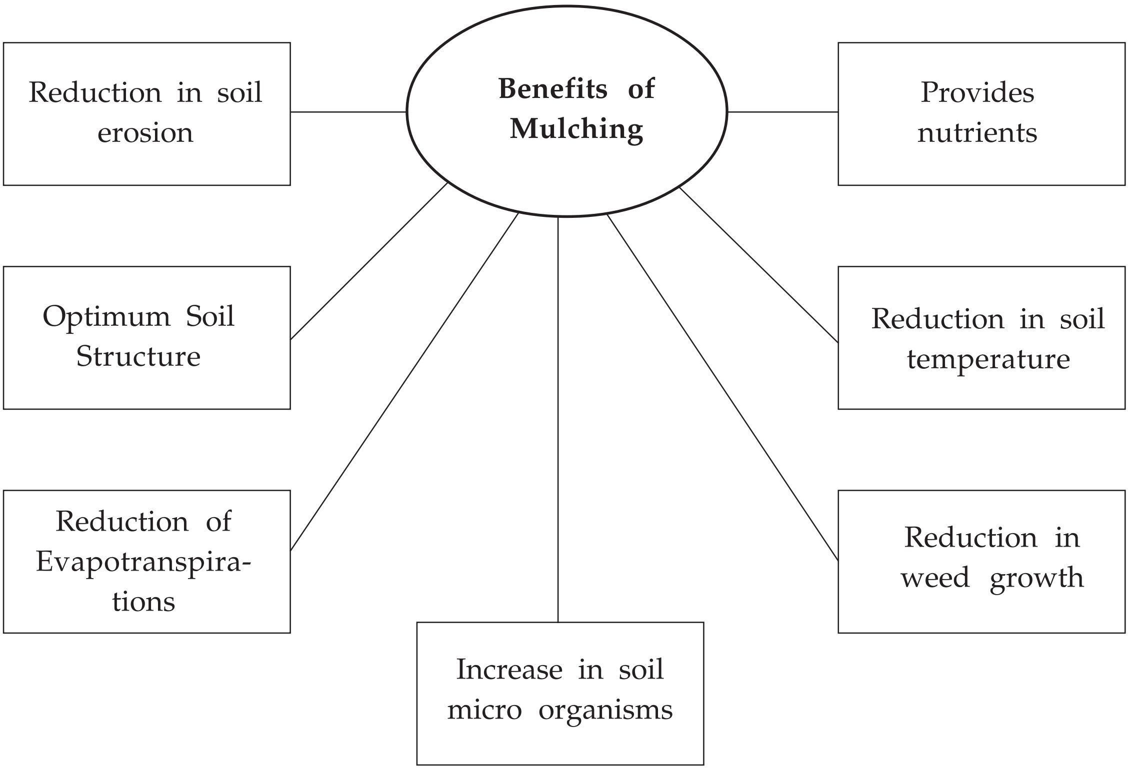
### *Benefits of mulching*

- Soil does not get dried out as it is not exposed to the sun
- Soil retains moisture for a longer time
- Prevents soil erosion



- Improves soil life
- Mulch provides nutrient rich humus on decomposition
- Improves drainage of the soil
- Improves soil quality

Soil moisture conservation can be done by various methods. Crop residue on the soil surface will help prevent excessive evaporation during early crop growth. The amount of water conserved in this way is directly related to the amount of residue present on the soil surface. Increased infiltration of rainfall also occurs when crop residue remains at or near the soil surface. For better soil moisture management, crop residue left at the soil surface is essential.




### *7.2.7 Crop rotations*

The practice of growing crops sequentially on a unit of land is called crop rotation. The crops may be annual, biennial or perennial. Annual crops are rotated by choice of crops in accordance to the prevailing climatic and seasonal changes. Rotations such as rice-wheat and maize-wheat-mung are examples of annual crop rotations with seasonal crops in a unit of a land that will enhance the productivity of land.

Table: 7.5 Different crop combinations used in crop rotations

| S.N. | Crop Combinations | Rotation period (years) |
|---|---|---|
| **Irrigated:** | | |
| 1. | Paddy-wheat + barley | 1 |
| 2. | Paddy-onion + garlic | 1 |
| 3. | Paddy-tomato-wheat-cheena | 2 |
| **Unirrigated:** | | |
| 1. | Paddy-wheat +barley/lentil | 1 |
| 2. | Ragi-fallow-chillies-wheat | 2 |
| 3. | Jhingora-wheat-chillies-lentil | 2 |
| 4. | Ragi + Bhat (black soybean)-fallow-jhingora-wheat | 2 |
| 5. | Ragi + Rajmah-fallow/lentil | 2 |
| 6. | Jhingora + Kulth-wheat + barley | 2 |
| 7. | Rajmah-wheat-maize-lentil | 2 |

### *7.2.8 Mixed cropping*

The practice of cultivation of a number of crops that are cultivated in a unit of land is called mixed cropping. Navdanya agro-biodiversity farm is a living example of mixed farming. In the farm, one can observe a combination of crops in a unit of land. Also there are a number of patterns of mixed cropping practices in the same unit of land. Mixed cropping is a strategy for crop protection. Likewise, many farmers practice mixed cropping wherein, they grow ginger or turmeric as cash crops, maintain castor plants along the borders of their fields in order to check the spread of diseases. In the wheat-chickpea association, chickpea serves to stop rats from entering wheat crop.

Mixed cropping and rotation of crop has been traditional practice in Indian farming. It is not an infrequent practice, when drilling a cereal crop, such as jowar (*Sorghum vulgare*) or some other millet, to put at few drills of some leguminous crop such as arhar (*Cajanus cajan*). The grain crop grows more rapidly and keeps the others back that is duly harvested when it is ripe, and the land which it occupies is then ripped. The pulse crop, thus free to extend itself, grows on a pace, spreading partly over the intervening areas, and becoming the crop of the field, until in the due time it is also reaped. The same year the 'mixed crop' may be sown again, and for the causal observer, it might appear that continuous cropping was practiced. This, however is not so, for there is a perfect rotation of cereal and legume. This is the simplest form of rotation, but there are many complicated than that of 'mixed cropping'. (*These were the observation made by Voelcker in 1897*). Cereals crops, which were the most dominant-millet, wheat, barely, maize are mixed with an appropriate subsidiary pulse, some times a species that ripen later than the cereal.

In the North, there is already a long standing history of multiple cropping system. In Garhwal Himalayas the practice of *Baranaja* a mixture of 12 grains is still prevalent. The grains are Phapra *(Fagopyrum tataricum),* Mandua *(Eleusine ocracana),* Marsha

*(Amaranthuys frumentaceous)*, Bhat *(Glycine soja)*, Lobia *(Vigna catiang)*, Gahath *(Dolichos biflorus)*, Rajma *(Phaselous vulgaris)*, Jakhia *(Cleome viscosa)*, Navrangi *(Vigna umbellata)*, *Jowar (Sorghum vulgare)*, Urad *(Phaselous mungo)*. In the hill system, amaranth/mandua based cropping system prevail (60%). There are also sesamum based cropping systems (30%), buckwheat (kuta) based farming systems and fruits (5%). This agro biodiversity is yet one of the important aspects of the sustainable food system that has been practiced in the Himalayan region of the country.

In the West, arid zone of Rajasthan the practice of mixed cropping is still a prevalent practice wherein the farmers grow a multitude of crop in the same patch of field. It is a survival imperative in which the farmers manage to harvest crop diversity during the kharif season, which is the only season they can grow crop due to paucity of rains. The crops grown primarily are millets-bajra and then jowar are the most important grain crops and guar-the main pulse-often with mung, moth, lobia, arhar and urad also being added as mixture. The grain varieties that provide fodder are a very important consideration with these farmers, as a large percentage of the population is pastoral.

In the Southern part India, the farmers' totally relied on the indigenous varieties of ragi, pulses and groundnut. In Karnataka e.g. ragi or finger millet (*Eleusine cora*cona) is the staple crop of the area. This crop is extremely drought resistant. As there are varieties of ragi available, the farmers chose the variety they wish to sow keeping its gastronomic, nutritional quality in mind. The grain of some of the varieties can be kept upto as long as 50 years. It has been observed that mixed agro-forestry is also practiced in the Western Ghats of Karnataka and Kerela. The spice gardens nowadays are grown in a 3 tier fashion in which in the first year Banana saplings are planted, during the second year, areca saplings are planted at a distance of 16 feet in a triangular shape. After a span of 15-20 years they again grow the third canopy of young sapling. The saplings of the next crop replace the old tree. Thus, a system has been evolved that ensures a systematic and sustained yield for the farmer. The spice garden has banana, cardamom and black pepper as an intercrop. Each one of these crops has its own advantage and they contribute to healthy growth of spice gardens.

Likewise Tamil Nadu, the southern most state of India, has a rich agro-biodiversity of millets, oilseeds (sesame and sometimes cardamom), and pulses such as red gram and lablab seeds dropped separately by hand in the furrows and covered with the plough. When the crop is about a foot high it is weeded with the hand hoe and the crop is thinned. While paddy remains the main crop, with two harvests, many of the other corps are grown, particularly in the drier areas in the drier seasons. Some of the other crops that are grown in this part of the country need the whole year to grow such as, sugar cane, or even three years (plaintains, betel vines) for their cultivation.

### *Random mixed cropping*

Here seeds of several crops are mixed together and sown in the same units of farmland with no separate rows for a particular crop.

*Line sown mixed cropping*

Here the method involves sowing of crops cultivated in separate rows in a unit of land.

*Strip cropping*

Here each crop is cultivated in patches or strips consisting of a number of lines of the same crop. In this system greater care of crops can be taken as compared to line sown multiple cropping.

*Mixed cropping with crop of same canopy size*

When a crop of lesser canopy is located in the inter-space of plants with bigger canopy a cropping pattern adjusted to crop canopy size is created. For example growing areca nut trees between four adjacent coconut trees is an example of mixed cropping adjusted to crop canopy size.

## 7.3 Economics of mixed farming: A case study of Navdanya

A study conducted by Dr. Debal Deb Navdanya's West Bengal Coordinator shows and confirm the current ecological theory that suggests that more complex systems are likely to impart greater resilience to the system than less complex systems (Pimm 1991; Schulze and Mooney 1993). More precisely, the time taken for a complex system (with high species diversity and inter-specific linkages) to return to its equilibrium following a perturbation is quicker than that for a simpler system (Pimm 1982). In agricultural context, this ecological resilience is translated into sustainability of production.

His objective of the study was to compare the market value of the green revolution based farming crop produced in intensive farming system with that of an average farm producing a variety of crops in multiple cropping system.

The sites selected by Dr. Deb were farms located at Bankura, Medinipur and Birbhum districts.

The cost of production was estimated as the sum total of expenditures towards:

a) Cost of seeds, if purchased

b) Cost of fertilizers

c) Cost of pesticides

d) Cost of irrigation

e) Cost of labour for tilling, manuring, sowing, transplanting, weeding, threshing, etc.

Production of all usable biomass from the farm was taken into account. Thus, quantities of paddy straw, in addition to rice grains, and jute leaves (to be consumed as vegetable), in additon the jute fibres were also measured. The value of total usable production was estimated as the market price averaged over the year for the item of produce.

The net value was thus estimated as the difference between the gross values of the produce and the total production cost.

Table 7.6 Estimate of mean production value for multicropping (MC) and green revolution (GR) farms

| *District* | *Species* | *No. of crops* | *Cost of production (Rs/ha/yr)* | *Total production (Rs/ha/yr)* | *Net Production (Rs/ha/yr)* |
|---|---|---|---|---|---|
| Multicropping farm (MC farm) | | | | | |
| Bankura | 10 | 12 | 14033.00 | 69935.00 | 55902.00 |
| Medinipur | 5 | 8 | 7264.50 | 36060.50 | 28796.00 |
| Birbhum | 5 | 5 | 7330.00 | 26695.00 | 19365.00 |
| Green revolutionary farms (GR farms) | | | | | |
| Bankura | 10 | 2 | 10441.00 | 25078.00 | 14637.00 |
| Howrah | 10 | 3 | 15234.00 | 30422.00 | |

The summary of the findings is presented in Table. The data clearly show that the net value of the annual production of an average multiple cropping (MC) farm is uniformly more than that of an average green revolution (GR) farm. Amongst the MC farms, the dry upland farms of Birbhum district are the least productive (5 crops a year), chiefly because (a) lack of irrigation facility, and (b) paucity of vegetable varieties suitable for upland farming. The medium-lowland farms of Bankura are under rotational cropping, growing 10 crops a year including rice. The GR farms, by contrast, grow 2 rice varieties in Bankura and 3 rice varieties (all HYV) in the district of Haora. While the absolute production of indigenous rice is consistently lower in the MC farms than in the GR farms, the value of the paddy straw yield in the MC farms is about three times higher than in the GR farms.

The data show that the net production value of crops from the least productive MC farms of Birbhum was considerably higher than the most productive GR farm production. When there is greater crop variety, the value of the farm produce substantially increases. Interestingly, there appears to be a unimodal distribution of the value of the produce vis-a-vis crop diversity. The findings contradict the prevailing mainstream agronomic conjecture that intensive cropping of a staple crop would enhance productivity of the land. Many farmers in Bankura and Medinipur have realized that over years, the yield of the GR crops are unsustainable, and have reverted back to traditional farming systems involving folk crop varieties. Some of them have experimented with a hybrid system of rotational cropping of a large number of "secondary" crops and a HYV rice. However, most of these MC farmers reported that "the cost of inputs eat away the extra production of HYV rice", and that the best means to cut down on the extraneous inputs is to "give the land a recess" by growing vegetables and fruits for a few years before replanting it with rice.

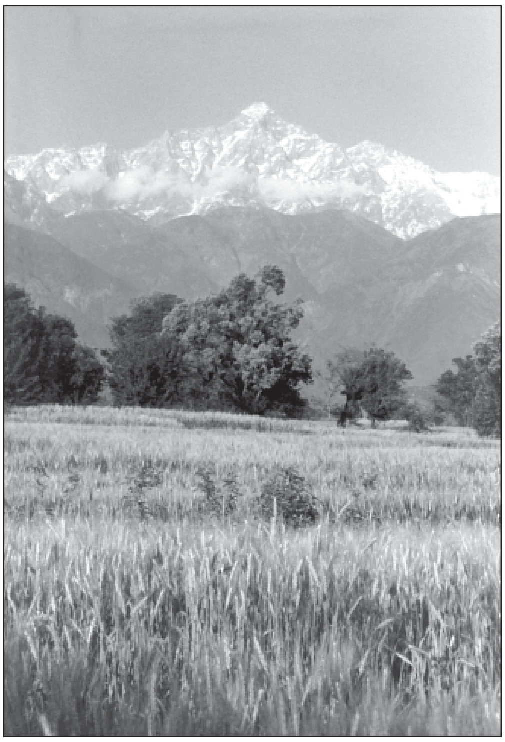
According to Dr. Debal Dev traditional mode of farming involving intercropping, multiple cropping and rotational cropping is more productive than HYV monocultures where only single crop of rice is produced. The reason for this difference is that in traditional farming, a range of secondary crops are also grown, which not only serve to fill the bread basket of the household, but also adds nutrients to soil. A range of vegetables, pulses and oilseeds are likely to fetch extra earnings from the market to the farmers.

## 7.4 The role of agroforestry as a sustainable land use system in sustainable agriculture:

Let us now understand the concept of agroforestry and farm-forestry as the land use system of farmlands in the Sustainable Farming System. In India, integrated land use planning was the core of sustainability. With the passage of time the people started for monocultures that resulted in the loss of the philosophy of integrated Landuse system wherein the concept of agro-forestry is paramount. Agroforestry is the combination of agriculture and tree growing so as to produce both agricultural products and tree products on a sustained basis.

The purpose of this is to gain positive interactions between the two systems at both the paddock level and the enterprise level. The two systems may be fully physically integrated, or treated as separate entities within a single landuse pattern. It is therefore ideally suited to the landholder seeking to enter agro-forestry on a small scale, whilst maintaining an existing agricultural enterprise.

The definition of agroforestry in the land use system should involve the production of agricultural crops in combination with the perennials in the same unit of land, which are in accordance with the prevalent practices of the region.



*Agroforestry in Himalayan Region*

### *The role of agroforestry in sustainable agriculture:*

Tree is considered to act as insurance against climatic oscillations and in the event of crop failure. Trees are the source of food, fuel, fodder and fuelwood. In agroforestry the major landuse systems are

| | |
|---|---|
| **Silvi-pastoral** | Tree and grasses in combination |
| **Agri-silvi-horticulture** | Agricultural crop + trees + fruit trees |
| **Silvi-pastoral-horticulture** | Trees + grasses (fodder) + fruit trees |
| **Forage and alley cropping** | Grasses interspersed between crops |
| **Multi-story cropping** | Multiple level of crops |

The Benefits of agroforestry system in respect of sustainable farming are:

i. Maintaining a healthy environment

ii. Trees serve as a wind break and reduce soil moisture

iii. They reduce the rate of transpiration of the crop underneath

iv. They help to maintain a healthier moisture regime for crops underneath

v. They add organic manure to the soil

vi. They improve the fertility, water holding capacity and biological activities of the soil

vii. The litter cover provided by them help in harvesting the running water of rains

viii. Trees planted in slope help in soil and water conservation

ix. Trees provide additional income by providing fuel and fodder and other variety of commodities

***Farm forestry***: Is a land use system wherein, if the soils are degraded and not suitable for agriculture, the farmer can grow suitable trees in the site that would ameliorate the environment and heal the soil. This is the management of trees can also increase his income.

***Benefits of agroforestry and farm forestry***

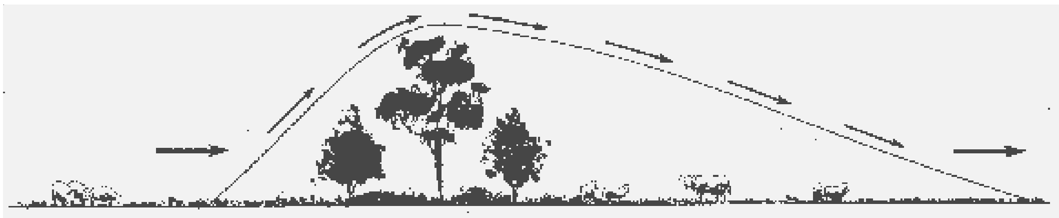
Agroforestry can produce multiple benefits for the farm, the environment and the community.

***Benefits to the landholder include:***

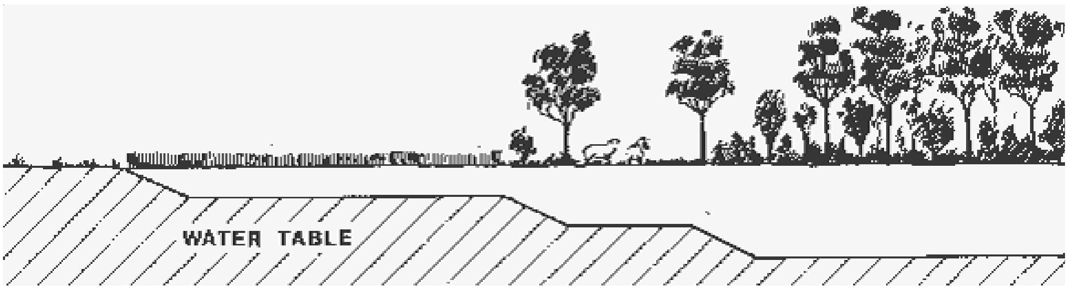
1. Shelter for stock, pasture and crops.
2. Additional and diversified earnings
3. Improved living environments
4. A buffer against the cyclical downturns in prices and drought, frost and flood events.
5. Improvement and maintenance of soil and water health.
6. Increases in capital value

Table 7.7 Choice of multi-purpose tree species (MPTs) for agroforestry

| Species | Climatic zone | Uses |
|---|---|---|
| *Acacia albida* | Semi arid zone, tropical, sub tropical | Fuel |
| *Acacia auriculiformis* | Tropical, sub-tropical and sub-tropical | Fuel |
| *Acacia catechu* | Tropical, sub-tropical and sub-tropical | Fuel wood, katha and fodder |
| *Acacia nilotica* | Tropical, sub-tropical and sub-tropical | Fuel, fodder and agricultural implements |
| *Ailanthus excelsa* | Semi arid, tropical and semi arid | Gum fuel, fodder, agricultural implements |
| *Albizia lebbeck* | Sun tropical montane, sub humid and semi arid | Fodder, fuel, cartframe and boats |
| *Alnus nepalensis* | Temperate Himalayas and sub humid | Fuel, tea chest, pencil and writing paper |
| *Cassia siamea* | Tropical, sub tropical, semi arid and sub humid | Ornamental, wood pulp and boats |
| *Celtis australis* | Temperate himalayas and sub tropical | Fodder, wood for sport, goods and fuel |
| *Cedrus deodara* | Temperate himalayas and sub tropical | Wood as sleepers, boards for buildings etc. |
| *Dalbergia sissoo* | Tropical, sub tropical, semi arid and sub humid | Plywood, timber, furniture, fodder, poles and wood articles |
| *Pongamia pinnata* | Tropical, arid and semi arid | Seeds, medicinal value, oil manure, furniture and paper pulp. |
| *Azadirachta indica* | Tropical, sub tropical, semi arid and sub humid | Fodder, timber, small wood, enhances soil fertility, biopesticidal properties in seed etc. |
| *Tamarindus indicus* | Tropical, sub tropical, semi arid and sub humid | Wood, ship building, piles and harbour, jellies and jams |
| *Terminalia bellerica* | Tropical, sub tropical, semi arid and sub humid | Fruit, bark, tannins and dyes |
| *Terminalia arjuna* | Tropical, sub tropical, semi arid and sub humid | Fodder, timberbark, tannins and dyes |
| *Prosopis cineraria* | Tropical, sub tropical and semi arid | Fodder, fuel, soil fertility enhancement |
| *Quercus leucotrichophora* | Montane and sub humid | Fodder, fuel, furniture and fuel |
| *Salvodora oleoides* | Tropical, arid and semi arid | Fruit, medicine, seed cake and manure |
| *Zizyphus nummularia* | Sub tropical, tropical, arid and semi arid | Fodder, fuel, fruit amd handles of small tools |



*Digram 7.8 Windbreaks provide protection for livestock, crops and pastures.*




*Digram 7.9 Trees lower watertables - this helps to combat a salinity problem.*

Other benefits to the environment and community by adopting agroforesty landuse are:

1. The creation of new jobs and cottage industries
2. Sustainable management of natural resources
3. Increase in biodiversity

CHAPTER VIII

# Insect Pests:
## *Reducing their Threat to Agriculture*

Insects are the dominant life form on earth. Millions may exist in a single acre of land. About one million species have been described, and there may be as many as ten times that many yet to be identified. Of all creatures on earth, insects are the main consumers of plants. They also play a major role in the breakdown of plant and animal material and constitute a major food source for many other animals.

Insects are extraordinarily adaptable creatures, having evolved to live successfully in most environments on earth, including deserts and the Antarctic. The only place where insects are not commonly found is the oceans. If they are not physically equipped to live in a stressful environment, insects have adopted behaviors to avoid such stresses. Insects possess an amazing diversity in size, form, and behavior.

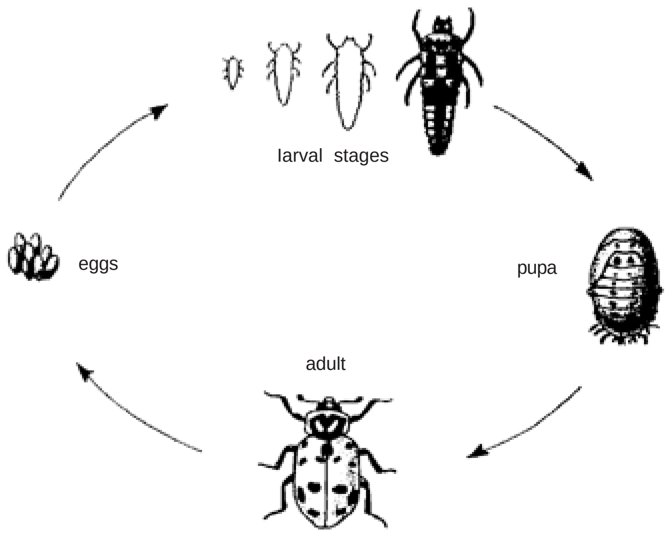
It is believed that insects are so successful because they have a protective shell or exoskeleton, they are small, and they can fly. Their small size and ability to fly permits escape from enemies and dispersal to new environments. Because they are small they require only small amounts of food and can exist in very small niches or spaces. In addition, insects can produce large numbers of offspring relatively quickly. Insect populations also possess considerable genetic diversity and a great potential for adaptation to different or changing environments. This makes them an especially formidable pest of crops, able to adapt to new plant varieties as they are developed or rapidly becoming resistant to insecticides.

Insects are directly beneficial to humans by producing honey, silk, wax, and other products. Indirectly, they are important as pollinators of crops, natural enemies of pests, scavengers, and food for other creatures. At the same time, insects are major pests of humans and domesticated animals because they destroy crops and vector diseases. In reality, less than one percent of insect species are pests, and only a few hundred of these are consistently a problem. In the context of agriculture, an insect is a pest if its presence or damage results in an economically important loss.

### 8.1 Insect reproduction

Most species of insects have males and females that mate and reproduce sexually. In some cases, males are rare or present only at certain times of the year. In the absence of males, females of some species may still reproduce. This is common, particularly among aphids. In many species of wasps, unfertilized eggs become males while fertilized eggs become females. In a few species, females produce only females.

A single embryo typically develops within each egg, except in the case of polyembryony, where hundreds of embryos may develop per egg. Insects may reproduce by laying eggs or, in some species, the eggs may hatch within the female which shortly thereafter deposits young. In another strategy common to aphids, the eggs hatch within the female and the immatures remain within the female for some time before birth.




*Digram 8.1 Complete Metamorphosis: Life cycle of the convergent lady beetle*

## 8.2 Insect growth and development (metamorphosis)

Insects typically pass through four distinct life stages: egg, larva or nymph, pupa, and adult. Eggs are laid singly or in masses, in or on plant tissue or another insect. The embryo within the egg develops, and eventually a larva or nymph emerges from the egg. There are generally several larval or nymphal stages (instars), each progressively larger and requiring a molt, or shed of the outer skin, between each stage. Most weight gain (sometimes > 90%) occurs during the last one or two instars. In general, neither eggs, pupae, nor adults grow in size; all growth occurs during the larval or nymphal stages.

## 8.3 Insect ecology

Ecology is the study of the interrelationships between organisms and their environment. An insect's environment may be described by physical factors such as temperature, wind, humidity, light, and biological factors such as other members of the species, food sources, natural enemies, and competitors (organisms using the same space or food source). An understanding or at least an appreciation of these physical and biological (ecological) factors and how they relate to insect diversity, activity (timing of insect appearance or phenology), and abundance is critical for successful pest management.

Some insect species have a single generation i.e. per season (univoltine), while others may have several (multivoltine). The striped cucumber beetle, for example, overwinters as an adult, emerges in the spring, and lays eggs near the roots of young cucurbit plants. The eggs hatch, producing larvae that emerge as adults later in the summer. These adults overwinter to start the cycle again the next year. In contrast, egg parasitoids like *Trichogramma* overwinter as immatures within the egg of their host. During the summer they may have several generations.

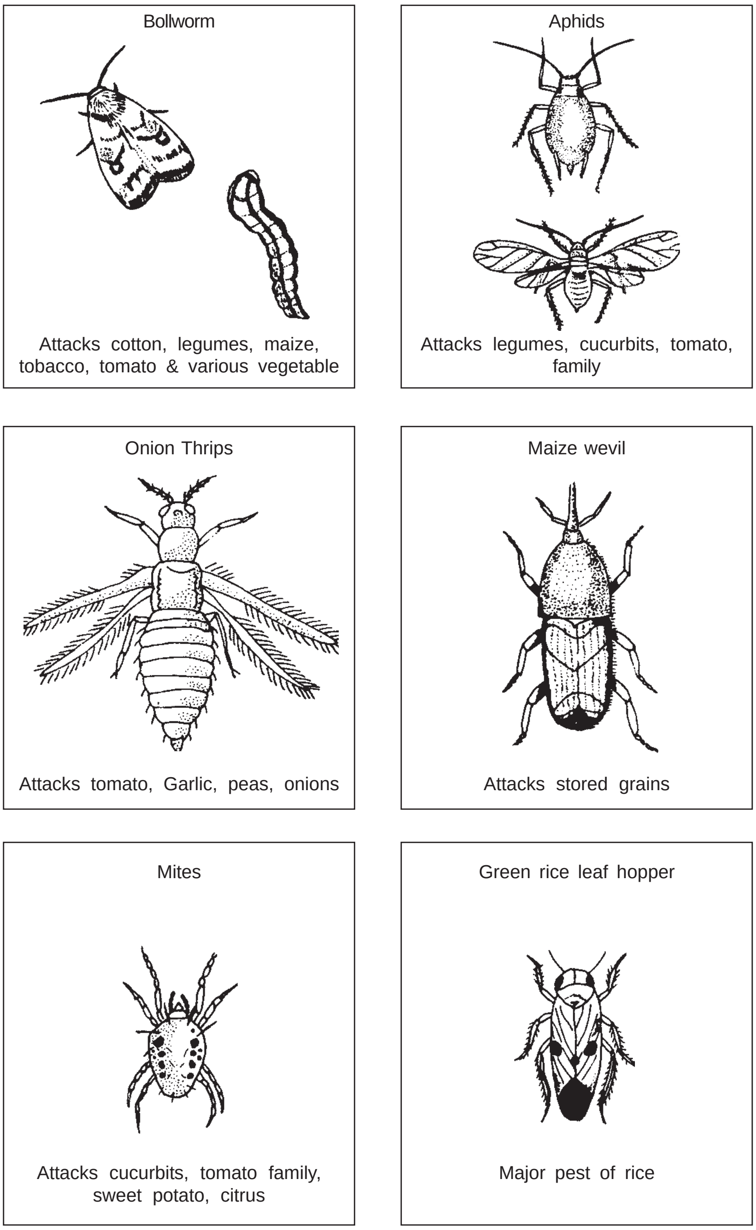
Insects adapt to many types of environmental conditions during their seasonal cycle. To survive the harsh winters, cucumber beetles enter a dormant state. While in this dormant state, metabolic activity is minimal and no reproduction or growth occurs. Dormancy can also occur at other times of the year when conditions may be stressful for the insect.

It is often better to consider insects as populations rather than individuals, especially within the context of an agroecosystem. Populations have attributes such as, density (number per unit area), age distribution (proportion in each life stage), and birth and death rates. Understanding the attributes of a pest population is important for good management. Knowing the age distribution of a pest population may indicate the potential for crop damage. For example, if most of the striped cucumber beetles are immatures, direct damage to the above ground portions of the plant is unlikely. Similarly, if the density of a pest is known and can be related to the potential for damage, an action may be required to protect the crop. Information about death rates due to natural enemies can be very important. Natural enemies do nothing but reduce pest populations and understanding and quantifying their impact is important to effective pest management. This is even more reason to conserve their numbers.

## 8.4 What is a pest?

There are thousands of organisms in the world but we do not consider all of them pests. When the population of an organism reaches a level where it can cause considerable damage to the crop it becomes a pest. They can be either crop pests or storage pests depending on whether they destroy crops on the field or during storage. Pest damage is a function of the vulnerability of the crop as well as the pest, population, which is determined by the ecology of the farm. Organic crops are less pest prone than chemically produced crops. Diverse crops reduce pest population through pest predator balance while monocultures increase vulnerability of pests.

What are the pests we are so very concerned about in controlling or destroying using all the means at our command? A variety of animal plant and microbial pests cause a wide range of damage on the farms, in the gardens, landscapes including trees, buildings, to humans, pets and livestock For a variety of reasons the human beings wish to control or eliminate these pests largely because of economic losses they




*Digram 8.2 Common pests of Agriculture crops*

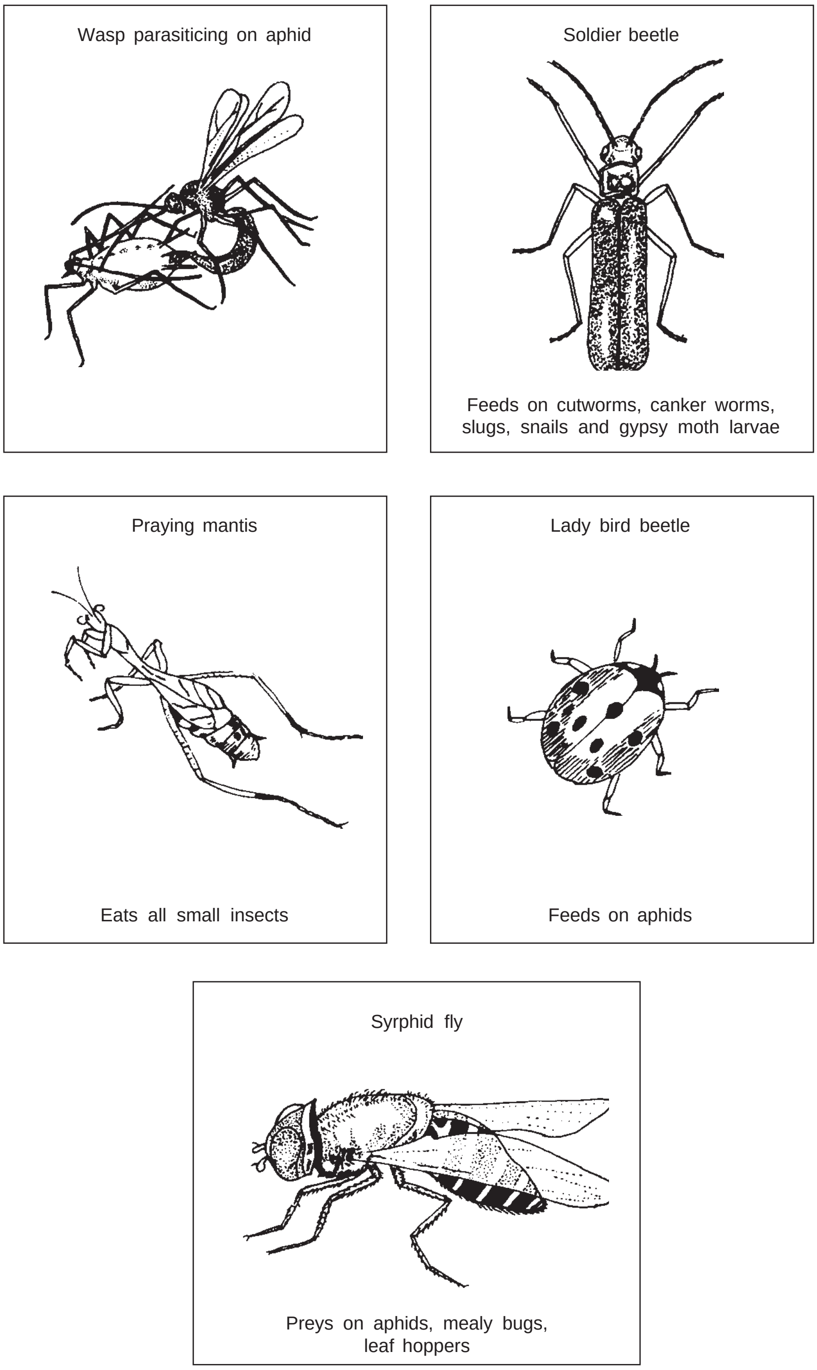
cause through causation of disease, leading to destruction of standing crops or even during storage. These pests are equally or sometimes more frighteningly harmful for humans and wildlife, animals and to environment and ecology including buildings.

These pests could be insects, mites, weeds, fungi, bacteria, viruses, rodents etc. even though as a class these are a natural part of our environment. In fact less than one out of every one thousand of insects are pests. Unfortunately insecticides kill indiscriminately both pests and natural enemies of these pests – what are referred to as predators. It has been postulated that there are some one million species of insects on this earth of which some 5000-15000 have turned into pests. Many of the other insects, which have a potential of turning into pests, are kept in check by climate, food or natural enemies- the predator and the parasite. The introduction of chemical pesticides in the complex interplay of predators, crops, farm animals and man has raised three key problems-

a. Creating susceptibility to pests by destabilizing the plant metabolism

b. Killing of natural enemies of the target pest leading to explosion in the population of the original pests and

c. Destruction by pesticides of the large number of non target species of natural enemies, leading to a class of evolution of new secondary pests in the form of resistant varieties of pests.




*Digram 8.3 Common Predators of Agricultural Pests*

Chebonsson, an eminent French Scientist has shown (Chebonsson, Navdanya, forthcoming) the relationship between plants and parasites are first and foremost in nature. Healthy and balanced plant nutrition in the form of organic farming increases the plant resistance and its immunity. Chemical fertilizers and chemical pesticides increase the plant susceptibility to pests.

**Table 8.1 Outbreaks of rice insect pests and diseses in Punjab:**

| *Year* | *Insect pests/diseases* |
|---|---|
| **1967** | Leaf fodder |
| **1972** | Root weevil, Whitebacked plant hopper |
| **1973** | Brown plant hopper |
| **1975** | Bacterial blight |
| **1978** | Whitebacked plant hopper Sheath blight |
| **1980** | Bacterial blight, Stem rot |
| **1981** | Whitebacked plant hopper |
| **1982** | Whitebacked plant hopper |
| **1983** | Brown plant hopper, whitebacked plant hopper, Yellow stem borer, Thrips, Hispa |

*Source: Shiva, 2000*

The introduction of high yielding varieties has brought about a marked change in the status of insect pests like gall midge, brown planthopper, leaf folder, whore maggot etc. Most of the high yielding varieties released so far is susceptible to major pests with a crop loss of 30 to 100%.

CHAPTER IX

# Ecological Management of Pest

In a biological system, every organism has a niche and is a part of the delicate web of the food system. Spraying of chemicals leads to mass destruction of the beneficial insects such as the soil nematodes, the pollinating insects, etc. which in turn leads to reduction in cross-pollination that reduces the genetic base of the region. This in turn affects the resilience and ecological amplitude of the ecosystem.

From time immemorial farmers had the wisdom and knowledge of biological pest management had been the part and parcel of farming in India. The farmers understood the delicate web of nature and understood the intricacies of the foodweb. The traditional organic farming has in its normal procedures of growing diverse crop, which is the basis of ecological pest management.

## 9.1 Pest predator balance

In nature we find that every pest has a predator (an organism which feeds on the pest), which helps to keep pest populations in check. A sudden decrease in the predator population could lead to an increase in pest population causing extensive damage to crops. The predator and prey populations are so interdependent that an increase or decrease in either population causes drastic changes in the population of the other.

## 9.2 Recognizing the role of natural enemies of pest insects

Natural enemies play an important role in limiting the densities of potential pests. This has been demonstrated repeatedly when pesticides have devastated the natural enemies of potential pests. The non-toxic method to control a key pest, the reduced use of pesticides and increased survival of natural enemies frequently reduces the numbers and damage of formerly important secondary pest species.

Applying a chemical insecticide then has several direct and indirect effects: primarily it kills pests, thereby immediately reducing their population size. But there are then indirect effects that increase pest abundance.

### *Pest resurgence*

Pesticide kills the predators of pests; thereby indirectly benefiting the pests. The pests rebound. And they rebound to higher density than previously expected because their equilibrium density is increased.

*Example: Bollworm in cotton.*

***Secondary pest outbreak***

It kills the predators of other herbivorous insects that were not yet pests, thereby allowing these insects to reach higher densities and become pests. Table 9.1 depicts the data showing pest incidence in cotton.

**Table 9.1 Increase in pests incidence, due to pesticide applications in cotton in Nicaragua**

| *Year* | *Number of pest species* | *Number of Pesticide Applications* | *Relative crop yield* |
|---|---|---|---|
| 1950 | 2 | 0-5 | 100% |
| 1955 | 5 | 8-10 | 80% |
| 1965 | 8 | 25-30 | 70% |
| 1979 | 24 | 50-60 | – |

***Pesticide resistance***

Pesticide selects for pesticide resistance in the pest populations. Herbivorous insects already have evolved ways of overcoming toxins produced by plants and are able to quickly evolve means of detoxifying or avoiding pesticides.

These effects combine to put the farmer on an escalating pattern of applying more and more pesticide and more kinds of pesticide to control more and more pests. It is called a pesticide treadmill, but it really isn't a treadmill because the farmer is continually losing ground. Pesticide application is really like an addiction to narcotics, in that once started creates its own demand.

The three categories of natural enemies of insect pests are:

1. Predators
2. Parasitoids and
3. Pathogens

***Predators***

Many different kinds of predators feed on insects. Insects are an important part of the diet of many vertebrates, including birds, amphibians, reptiles, fish, and mammals. These insectivorous vertebrates usually feed on many insect species, and rarely focus on pests unless they are very abundant. Insect and other arthropod predators are more often used in biological control because they feed on a smaller range of prey species, and because arthropod predators, with their shorter life cycles, may fluctuate in population density in response to changes in the density of their prey. Important insect predators include lady beetles, ground beetles, rove beetles, flower bugs and other predatory true bugs, lacewings, and hover flies. Spiders and some families of mites are also predators of insects, pest species of mites, and other arthropods.

### *Parasitoids*

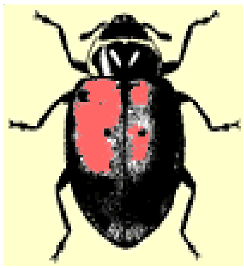
Parasitoids are insects with an immature stage that develops on or in a single insect host, and ultimately kills the host. The adults are typically free-living, and may be predators. They may also feed on other resources, such as honeydew, plant nectar or pollen. Because parasitoids must be adapted to the life cycle, physiology and defenses of their hosts, they are limited in their host range, and many are highly specialized. Thus, accurate identification of the host and parasitoid species is critically important in using parasitoids for biological control.

### *Pathogens*

Bacteria, fungi, protozoans and viruses that cause disease infect insects and plants. These diseases may reduce the rate of feeding and growth of insect pests, slow or prevent their reproduction, or kill them. In addition, insects are also attacked by some species of nematodes that, with their bacterial symbionts, cause disease or death. Under certain environmental conditions, diseases can multiply and spread naturally through an insect population, particularly when the density of the insects is high.

## 9.3 Predators occurring in the field

### *Lady beetles*



These familiar creatures, in both larval and adult stages, feed on soft-bodied insects, especially aphids. You can attract them by planting nectar plants (nectar is an alternate food source) and those that attract aphids. These include alyssum, legumes, and flowers in the Umbelliferae family (dill, wild carrot, fennel, yarrow, and so on).

### *Target pests*

Aphids, leafhoppers, scales, mites, mealybugs

Parasitic or predatory wasps

*Encarsia formosa* are small wasps that parasitize greenhouse whiteflies. *Trichogramma* wasps parasitize eggs of leaf-eating caterpillars such as cabbage loopers.

### *Target pests*

Caterpillars, aphids, mealybugs, leafhoppers, greenhouse whiteflies

### *Praying mantis*

They can be wonderful allies for gardeners (and great fun to watch), but they eat such a variety of insects that you wouldn't want to use them for an outbreak of any one pest.

***Target Pests***

Most pest insects and eggs

## 9.4 Non-chemical methods of pest control

The range of non-chemical options available may vary with the pest species, pest intensity or severity, and effectiveness of the option. Several key non-chemical options that may help reduce the amount of pesticides used in and around homes are listed below.

**Exclusion:** Any measure used to prevent entry of organisms in the farm field by digging trenches.

**Sanitation:** Maintaining clean surroundings in the farm where pests can feed, breed, and hide. Sanitary measures include cleanliness in and around the farm by discarding plastics, or any other inorganic substance. The on-farm refuge should be transferred to the compost bins that are to construct near the farm fields.

**Habitat modification**: Creating a live barrier around the perimeter of the farm fields that will reduce incidence of many ground-dwelling pests as the allelo-pathic effects of the roots will ensure that the pathogens are not freely invading the farm soil. A suitable example is the *Prosopis juliflora* live fencing in the bunds of agriculture fields in Rajasthan.

***Mechanical control***

A bin with tweezers is the best mechanical tools used for killing visible and less mobile or immobile pests. On infested plants, hand-picking insects (e.g., hornworms) is a partially effective means of pest control. Infested leaves must be excised from plants, bagged, and discarded.

***Traps***

Traps are escape-proof devices that capture highly mobile and active pests. Colored (yellow) sticky traps are effective in capturing whiteflies and aphids. Sticky traps can be baited with commercial lures (pheromones and food attractants) to enhance trap catch. These methods are used in places where the pests have a crawling feature of movement.

Traps are useful for early detection and continuous monitoring of infestations. They are not effective in reducing populations unless the pest population is isolated or confined to a small area. The chance of detecting the presence of pests in a given area is related to the number of traps used. Therefore, when pests are present in very low numbers, it is advantageous to use more than a few traps. Pests must be active or mobile to be captured in traps. Therefore, any environmental variable (temperature, humidity, wind, light, or food) or biological factor (age, sex, mating status, etc.) that influence pest activity, affects trap catch.

***Biological control agents***

Parasitic and predatory insects, mites, and nematodes are now commercially available to control pests. For example, lacewing larvae and ladybird beetle larvae and adults are predators of aphids. Parasitic and predatory organisms should be used only where pesticides are discontinued or were not previously used, because these beneficial organisms are highly susceptible to pesticides.

Natural environments tend to be balanced environments, where organisms depend on one another and also constrain one another by competition for resources or by parasitism, predation, etc. But human influences can upset these balances, and this is most evident when an exotic organism is introduced on purpose or by accident. Many of the most serious pests, crop diseases or invasive weeds are the result of "introductions" from foreign lands. The newly introduced organisms find a favourable environment, free from their previous constraints, and they proliferate to achieve "pest" status. Entomologists has a useful term for this - they refer to the constraining organisms in the region of origin as "the natural enemy complex".

We can define Biological control (biocontrol) as:

**The practice or process by which an undesirable organism is controlled by means of another (beneficial) organism**.

In other words, biocontrol is both a naturally occurring process (which we can exploit) and the purposeful use of one organism to control another.

In practice, biocontrol can be achieved by three methods.

- ***Inundative release*** (also termed "classical biocontrol") in which a natural enemy of a target pest, pathogen or weed is introduced to a region from which it is absent, to give long-term control of the problem.
- ***Biopesticide approach*** in which a biocontrol agent is applied as and when required (often repeatedly), in the same way as a chemical control agent is used. Examples of this include the use of *Bacillus thuringensis*, *Phoebiosis gigantean*, and *Agrobacterium radiobacter*.
- ***Management and manipulation of the environment to favour the activities of naturally occurring control agents.***

Biological control is the use of living organisms to suppress pest populations, making them less damaging than they would otherwise be. Biological control can be used against all types of pests, including vertebrates, plant pathogens, and weeds as well as insects, but the methods and agents used are different each type of pest.

## 9.5 Biological control in the field

There are three primary methods of using biological control in the field:

1) Conservation of existing natural enemies
2) Introducing new natural enemies and establishing a permanent population (called "classical biological control")
3) Mass rearing and periodic release, either on a seasonal basis or inundatively.

## 9.6 Biological pest management

This topic aims to reduce or even eliminate the use of chemicals to control pests, diseases and weeds related to plants of economic interest, and to develop and apply specific products that are not dependent on foreign technologies and imported raw materials.

The biological methods of pest control are economic, environmentally safe, preserve the health of rural workers and their families, and provide the production of healthier food.

### *Pest-resistant crops*

One of the mainstays of integrated pest management is the use of crop varieties that are resistant or tolerant to insect pests and diseases. A resistant variety may be less preferred by the insect pest, adversely affect its normal development and survival, or the plant may tolerate the damage without an economic loss in yield or quality. Disease-resistant vegetables are widely used, whereas insect-resistant varieties are less common but nonetheless important. The best method is to use the indigenous seeds of the locality, which is the result of years of selection of the farmer.

Advantages of this tactic include ease of use, compatibility with other integrated pest management tactics, low cost, and cumulative impact on the pest (each subsequent generation of the pest is further reduced) with minimal environmental impact. The development of resistant or pest-tolerant plant varieties, however, may require considerable time and money, and resistance is not necessarily permanent. Just as insect populations have developed resistance to insecticides, populations of insects have developed that are now able to damage plant varieties that were previously resistant.

### *Cultural control*

There are many agricultural practices that make the environment less favorable to insect pests. Examples include cultivation of alternate hosts (e.g., weeds), crop rotation, and selection of planting sites, trap crops, and adjusting the timing of planting or harvest.

***Crop rotation***, for example, is highly recommended for management of Colorado potato beetle. The beetles overwinter in or near potato fields and they require potato or related plants for food when they emerge in the spring. With cool temperatures and no suitable food, the beetles will only crawl and be unable to fly. Planting potatoes well away from the previous year's crop prevents access to needed food and the beetles will starve. The severity and incidence of many plant diseases can also be minimized by crop rotation, and selection of the planting site may affect the severity of insect infestations.

### *Trap crops*

Trap crops are planted to attract and hold pest insects where they can be managed more efficiently and prevent or reduce their movement onto valuable crops. Early planted potatoes can act as a trap crop for Colorado potato beetles emerging in the spring. Since the early potatoes are the only food source available, the beetles will congregate on these plants where they can more easily be controlled. Adjusting the timing of planting or harvest is another cultural control technique.

***Importance of integrated pest management (IPM)***

Integrated Pest Management is a method of pest control that keeps the environment safe and is ecologically sound and economically viable. The main strategies of the IPM are:

- Tilling the soil
- Timing of sowing, planting and harvesting
- Crop rotations
- Destroying crop residues of infested plants
- Using resistant varieties
- Using good quality seeds

In other words IPM combines biological and agronomic approaches making up a strategy that is not only sustainable over a time frame but also least damaging to the environment.

## 9.7 Traditional / indigenous methods of pest control

***Vrikshayurveda***

India has a rich tradition of rigorous study of plant diseases. The compendium of plant medicine is called Vrkshayurveda. This compendium records diverse methods of ancient treatments against insect attack. Some of the treatments are as follows:

- Nutmeg (Asafoetida) is mixed with two kinds of sweet flag (Vacha), pepper (*Erycibe paniculata*), marking nut (lappiga aliona), mustard and paste of cow's horn. It is mixed in cow's urine and applied around the trees or plants. This keeps away insects.
- Fumigation of cow's horn, marking nut, neem, nut grass (Musta), sweet flag (Vacha), viranga (Vidanga), Aconite (Atibhisa) and Indian beech (Karanja) in conjuction with resin of sal tree (Aarjarsa), white mustard (Siddhartha) and five-leaved Chaste tree (Sinduvara) destroys insects of trees.
- Use of tobacco as a natural pesticide
- Use of buttermilk in controlling diseases of cotton. Buttermilk is kashaaya (astringent) and amla (sour), and is also a digestive

***Traditional techniques for prevention of pest attack***

Listed below are some examples of traditional pest control techniques:

- The grain/seeds may be periodically dried in the sun. This chases away adult insects. However, eggs and larvae may still remain.
- Storage rooms may be smoked regularly with neem leaves to keep away moths, weevils and beetles.
- Wood, cowdung ash and sand may be mixed with the grain. One effect of adding these is that they fill the inter-granular spaces and therefore, restrict insect movement.
- Adding inert mineral dust and special types of clay (including activated charcoal and heat activated clay dust) to the grain is also practiced. These scratch the thin waterproofing layer, which exists on the outside surface of the insect's body wall, causing a loss of water and its death from desiccation. Wood ash and sand can also have this effect.
- A small clay lamp filled with oil may be lit and placed inside the storage container before it is sealed. The lamp will burn until the oxygen in the container is exhausted, this will lead to the insects also dying from lack of oxygen.
- Dirt or cow urine is often sprayed to keep away insects.

Table 9.2 Some inorganic and organic pesticides traditionally used for the control of major crop pests and pathogens

| ***S.N.*** | ***Common name of pest/pathogen*** | ***Material used*** |
|---|---|---|
| **A.** | **For pulses and vegetables** | |
| 1. | Bacterial blight | Leaf extracts of Neem and Tobacco (5:1); cattle urine (2-3 days old) |
| 2. | Aphid | Calcium oxide and wood dust mixture |
| 3. | Fungal and leaf spot | Leaf extracts of Vilayati Babul (*Prosopis juliflora*) mixed with water and (3lt. Extract/acre) |
| 4. | Viral disease of chili | Aquatic solution of alum |
| 5. | Insect attack on pulses, lemon and watermelon | Extract of *Bassia latifolia* or *Pongamia glabra* |
| 6. | Heliotis and Hairy caterpillar | One kg of garlic, crushed and soaked overnight in 200 ml of kerosene. Add two kg of ground green chili and 200 lit of water for spraying. |
| 7. | Aphid attack on *Foeniculum vulgare* | Dry leaves of Eucalyptus species, green as well as dry are burnt in the early morning when wind velocity is not high. |

| | | |
|---|---|---|
| **B.** | **For Storage Pests** | |
| 8. | Storage pest of paddy | Leaf powder of *Vitex negundo*. |
| 9. | Storage pest of pulse | Split seed coat pieces of Cashew (*Anacardium occidentale*), leaves of *Moringa pterygosperma*. |
| 10. | Storage pest of groundnut | Camphor |
| **C.** | **For paddy** | |
| 11. | Leaf rollers and hoppers | Leaves of *Sphaeranthus indicus*. |
| 12. | White flies, leaf roller and gundhi bug | Leaf extract of *Lasiosiphon eriocephalus*. |
| 13. | Aphids | Mixture of Asaphoetida and cattle urine or mixture of garlic, chilli and nutmeg in water. |
| 14. | Stem borer and bacterial diseases Termites | Neem cake |
| 15. | Termites in Sugarcane | Dry cowdung and vegetable waste brunt before planting of the crop, in furrows opened for planting sugarcane cuttings. |
| 16. | Termite in Coconut plant | Coal tar applying on the lower part of the stem. |

To increase soil fertility, we can take 10 kilos of cow dung and add 250 gm of ghee, stir for 4 hrs, to it add 500 gm of honey of 1 kg of jaggery than again stir for 4 hours. After that it becomes very good food for soil microorganisms. To it add 200 litres of water. It is known as Amrit pani/Sanjivani pani. Apply it to one acre of land. Then mulch it. Fourteen hundred farmers of Maharashtra, Goa are using this method to increase their wealth of earthworms in the soil. A farmer Pandharpur in Maharashtra has a 23-acre vineyard, where he is using this method. His farm yielded grapes to a tune of one tonnes per acre, which is a record.

*Kunwarji Bhai Zadav, All India Kisan Sabha*

## 9.8 Biopesticides

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria and certain minerals.

### *Advantages of using biopesticides*

- Biopesticides are usually inherently less toxic than conventional pesticide
- Biopesticides generally affect only the target pest and closely related organisms, in contrast to broad-spectrum conventional pesticides that affect organisms as different as birds, insects and mammals
- Biopesticides often are effective in very small quantities and often decompose quickly,

thereby resulting in lower exposures and largely avoiding the pollution problems as in conventional pesticides

- Biopesticides are safer to humans and the environment than conventional pesticides
- Present no residue problems because they disintegrate in nature very rapidly

### *9.8.1 Plants as biopesticides*

#### 9.8.1.1 Coriander *(Coriandrum sativum)*

Coriander plant

This is an annual herb that grows upto 1-3 feet in height. It is generally grown as a rainfed crop either in pure strands or mixed with other crops. In certain areas, it is grown as an irrigated crop. The leaves, seeds and oil are used for pest control.

***Pest controlled: Aphids***

#### 9.8.1.*2* Ginger *(Zingiber officinalis)*

This is a perennial herb reaching upto 90 cm in height. Rhizomes are thick, lobed and yellow in colour. Ginger requires a warm and humid climate. It is propagated by seed rhizomes. Plant parts used for pest control are rhizomes.

**Pest controlled: American Boll worm, Aphids, Mango Anthracnose, Pulse beetles, Root knot Nematode, White fly, Yellow vein mosaic etc.**

#### 9.8.1.*3* Lemon Grass *(Cymbopogan citrates)*

This is a perennial grass that grows in tufts. It grows well in mountainous areas. It acts as repellant and growth disrupter. The roots, leaves, seeds and oil are used for pest control.

Pest controlled: Fruit flies, mites, mosquitoes and storage pests.

Neem

#### 9.8.1.4 Neem *(Azadirachta indica)*

This is an evergreen tree growing upto an average of 18-m height. Leaves, seeds, cake and oil extracts could be prepared for spraying. It acts as feeding, deterrent, oviposition deterrent and insect growth regulator.

**Pest controlled: Aphids, Brown plant hopper, diamond black moth, green leafhopper, root knot nematodes, termites, stem borers etc.**

#### 9.8.1.5 Onion *(Allium cepa)*

This is bulbous biennial and can be cultivated throughout India. Onion bulbs are used as extracts for pest control.

Pest controlled: Nematodes pulse beetle, ticks, tobacco mosaic virus etc.

### 9.8.1.6 Tobacco *(Nicotiana tabacum)*

It is stout annual with a thick erect stem and few branches, and propagates through seeds. The leaves, stalk and stem can be used for pest control.

**Pest controlled: Aphids, Citrus leaf miner, and Rice stem borer, Mites etc.**

### 9.8.1.7 Turmeric *(Curcuma longa)*

This is a perennial herb with a short stem and tufted leaves, and is propagated by rhizomes. The rhizome extract can be used for pest control.

Pest controlled: Armyworm, aphids.

### 9.8.1.8 Garlic *(Allium sativum)*

Garlic is a hardy perennial, attaining a 30-100 cm. The bulbs, leaves, flowers and oil are used for pest control.

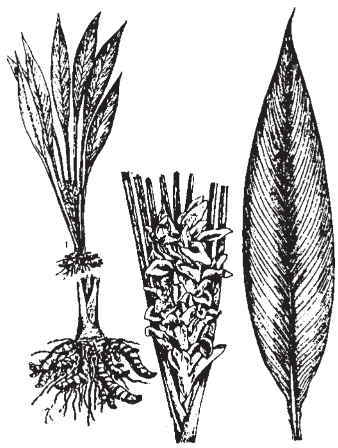
Pest controlled: Aphids, Armyworms, Bacteria, Colorado beetle, Mites, Root knot nematode, Rice blast fungi etc.

### *9.8.2 Methodologies to prepare biopesticides*

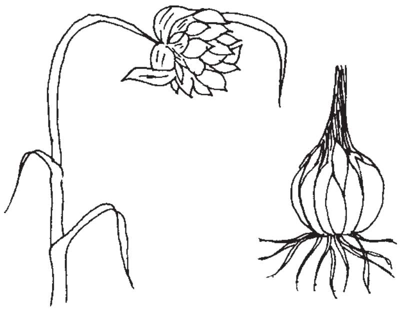
Neem has attracted worldwide attention in recent decades mainly due to its bioactive ingredients that find increasing use in modern crop and grain protection. Research has shown that neem extracts have an effect on nearly 200 species of insects. It is significant that some of these pests are resistant to pesticides, or are inherently difficult to control with conventional pesticides (floral thrips, diamondback moth and several leaf miners). Most neem products belong to the category of medium- to broad-spectrum pesticides, i.e., they are effective over a wide range of pests.

A range of neem products such as the neem leaf extract, the neem seed kernel extract, the neem cake extracts, neem oil emulsion and also neem in combination with other plant extracts for the control of a variety of pests. The technologies using neem are simple and the farmer in his own backyard can make these products. They have been tested in the farmers' fields and satisfactorily proven to be effective in controlling a wide range of pests. They have also been used in controlling stored grain pests.

Tabacco



Turmeric



Garlic

#### 9.8.2.1 *Preparation of extracts*

### *Neem kernel extract*

- Fifty grams of neem kernel are required for use in 1 litre of water
- Pounded gently in such a way that no oil comes out. The outer coat is removed before pounding. This is used as manure
- Put the pounded seeds into a muslin cloth and soak overnight in a litre of water
- Squeeze the pouch and the extract is filtered
- Add 1ml non-detergent based soap (khadi soap) solution to the filtrate. This acts as an emulsifier
- Ten milliliter of emulsifier is added to 1 litre of water. The emulsifier helps the extract to stick well to the leaf surface

**Remarks:** The kernel extract should be milky white in colour and not brownish. The kernel extract does not control sucking insects like aphids, white flies and stem borers. In these cases, one could use the neem oil spray solution.

### *Neem leaf extract*

For 5 liters of water, 1 kg of green neem leaf is required. Since the quantity of leaves required for the preparation of this extract is quite high (nearly 80 kg is required for 1 hectare), this can be used for nursery and kitchen gardens. The leaves are soaked overnight in water. The next day, they are ground and the extract is filtered. The extract is suited for use against leaf-eating caterpillars, grubs, locusts and grasshoppers. To the extract, emulsifier is also added.

**Remarks:** The advantage of using neem leaf extract is that it is available throughout the year. There is no need to boil the extract since boiling reduces the Azadirachtin content. Hence the cold extract is more effective. Some farmers prefer to soak the leaves for about one week, but this creates a foul smell.

### *Neem cake extract*

A hundred grams of neem cake are required for 1 liter of water. The neem cake is put in a muslin pouch and soaked in water overnight. It is then filtered and an emulsifier is added at the rate of 10 milliliter for 1 liter of water, after which it is ready for spraying.

### *Neem oil spray*

Thirty milliliters of neem oil are added to the emulsifier and stirred well to ensure that the oil and water can mix well. After this, 1 litre of water is added and stirred well. It is very essential to add the emulsifier with the oil before adding water. It should be used immediately; otherwise oil droplets will start floating. A knapsack sprayer is better for neem oil spraying than a hand sprayer.

***Pongam, aloe and neem extract***

One kilogram of pounded pongam cake, 1 kg of pounded neem cake and 250 g of pounded poison nut tree seeds are put in a muslin pouch and soaked overnight in water. In the morning, the pouch is squeezed and the extract is taken out. This is mixed with 1/2 litre of aloe vera leaf juice. To this, 15 litres of water are added. This is again mixed with 2-3 litres of cow's urine. Before spraying, 1 litre of this mixture is diluted with 10 litres of water. For an acre, 60-100 litres of spray are used. This is effective in the control of pests of cotton and crossandra.

***Custard apple, neem, chilli extract***

Five hundred millilitres of water are added to 2 kg of ground custard apple leaves and stirred. This is filtered to get the extract and the filtrate is kept aside. Separately, 500 g of dry fruits of chilli is soaked in water overnight. The next day, this is ground and the solution filtered to get the extract. One kilogram of crushed neem fruits is soaked in 2 litres of water overnight and the extract is filtered. All the three filtrates are subsequently mixed with 50-60 litres of water filtered again and sprayed over the crops.

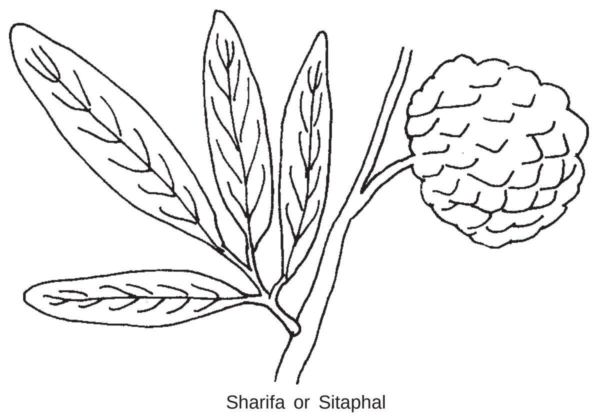
Note: For the above extracts, 250 millilitres of khadi soap solution should be added as an emulsifier before spraying.

***Pongam or karanj extracts:***

***Leaf extract:***

- Soak 1 kg of Pongam leaves in 5 litres of water overnight
- Grind leaves next morning and filter
- Add 10 ml of emulsifier (khadi soap solution) for every litre of water)
- Use as spray against leaf eating caterpillars

Pongam or Karanj



Sharifa or Sitaphal

- To spray an acre, 20 kgs of leaves, and 100 litres of water and 100 ml of emulsifier is required

***Kernel extract***

- Remove outer coats of seed and pound gently. 50 grams of this is used for 1 litre of water
- Place kernel powder in a muslin pouch and soak overnight
- Squeeze the pouch and filter the extract
- Add 10 ml of emulsifier for every litre of water and use as a spray
- To spray an acre, 5 kgs of cake, and 100 litres of water and 100 ml of emulsifier is required

***Cake extract***

- Take 100 grams of Pongam cake and powder it well
- Fill a muslin pouch with the powder and soak it overnight in 1 litre of water
- Squeeze out the pouch and filter the solution
- Add emulsifier at the rate of 1 ml for every litre. Mix well and use as spray
- To spray an acre, 10 kg of Pongam cake, 100 litres of water and 100 ml of emulsifier is required

***Oil spray:***

- To make 1 litre of spray 30 ml of Pongam oil is used
- This added to the emulsifier (khadi soap solution at the rate of 10 ml for every litre of water) and mixed well
- This solution is added to water and is ready for spraying
- It is important that the spray be used immediately after it is made
- To spray an acre, 3 litres of oil, and 100 litres of water and 100 ml of emulsifier is required

***Garlic (Allium sativum) extract:***

- Use 100 grams finely ground garlic
- Soak finely ground garlic in 2-tablespoon liquid paraffin for 48 hours
- Add 30 gms khadi soap to ½ litre water and mix well
- Filter the solution and store in a plastic container

- To prepare 1 litre spray, add 15 ml of extract and mix well
- To spray an acre, 15 litres of extract and 100 litres of water are required

***Tobacco (Nicotiana tobacum)***

- Take 250 gms tobacco and boil it in 4 litres of water for 30 minutes.
- Add 30 gms khadi soap and mix well
- Dilute 1 part extract with 4 parts water and use as a spray
- Adding a little slaked lime increases the potency of the extract
- This extract is extremely poisonous. Even in very minute quantities it causes death in animals and humans. Do not use sprayed plants for at least 4-5 days afrter spraying

### *9.8.3 Few tips in plant protection: (collected from farmers)*

***Seed treatment***

***Panchgan***

**Table 9.3 Composing of Panchgan**

| *Material* | *Quantity* | *For 10 kg of seed* |
|---|---|---|
| Cowdung | 1 part | 1 cup |
| Cow urine | 1 part | 1 cup |
| Freshmilk | 1 part | 1 cup |
| Curd | 1/2 part | 1/2 cup |
| Ghee | 1/10 part | 1 spoon |

***Seedling stage:*** to dip the seedling; dilute the above proportion in water 5-6 times. (10 times dilution for sugar cane)

- Use fresh milk with 10% dilution of chilly & tomato to control virus.
- Use 2% lime water for cut warms: 2% of lime water – keep it for overnight-take out (siphon) clean water-add 2kg ash (white ash)

***Seedbed treatment in cabbage:***

- Use 10% fresh milk spray
- Use ash + turmeric powders; dust it on seedbed at 10 days interval

***Bud sprout in grape/ udar beetle:***

Take 2-3 lit. of fresh milk

↓

Add 8 lit. of kerosene

↓

Mix 100-lit. of water (per 1 acre)

↓

Stir It

↓

Spray after 4 pm

***Repellent to termites:***

Use tea powder and agave's leaf extract spray.

**Table 9.4 Concation to replace bavistine/ carbandizime**

| *Material* | *Quantity* | |
|---|---|---|
| Cowdung | 40 parts | Add 0.2% (200gms) yeast |
| Cow urine | 40 parts | Add 0.1% salt |
| Freshmilk | 6 parts | Mix it & keep it for 8 days |
| Curd | 5 parts | Filter through cloth |
| Ghee | 1part | Dilute it to 10 times |
| | | Spray it. |

***Powdery mildew in grapes***

Plant Tulsi & marigold in grape garden, and Lemmon grass on boarders.

***Wet rot in ginger***

Keep *Calotropis* (Aak) twigs in irrigation channel.

***Rat control***

To control rats, pieces of papaya fruit are spread near the bunds of the field. Papaya has a chemical substance, which causes tissue damage in the mouth of the rats feeding on it.

***Bird attractant***

One Kg of rice and 50 gms of turmeric powder is required to treat an acre. The rice is cooked and excess water is filtered. This is mixed with turmeric powder. Small lumps of yellow colored rice is taken in small vessels and placed in the main field at 8 to 10 places. This is kept during early morning and afternoon. When the birds feed on the rice, they feed on the semi looper larvae prevent in the field. This procedure is repeated till the crop attains the flowering stage thereby reducing the pest attack. These control pests occurring in rice namely, the Rice stem borer and armyworm.

### *General remarks about spraying*

(a) Spraying should be undertaken in the morning or late in the evening. Under hot conditions, the frequency of spraying should be increased. In winter, spraying once in 10 days and every day in the rainy season is recommended.

(b) Insects lay eggs on the underside of the leaves. Hence it is important to spray under the leaves also.

(c) While using a power sprayer, the quantity of water used should be halved.

(d) It is better to use low concentrations of extracts frequently.

(e) As a general guideline, it can be said that each acre of land to be protected can be sprayed with 60 litres of ready-to-use solution (not the concentrate). Of course, the volume may have to be varied depending on the exact conditions prevailing, such as the intensity of the pest attack.

The use of insecticidal plants or plant substances in storage protection

- The insecticidal plants are helpful in storage protection of many crops.
- For example leaves or seeds of neem are stored together with cereals or beans thus diminish storage losses.
- Use powdered rhizomes of the sweet flag (*Acorus calamus*), at a ratio of 1 kg to 50 kg of grain. Mixed well with the grain and applied before storage. It can effectively reduce infestation by important storage pests such as the rice weevil, the khapra beetle, the lesser grain borer and adzuki bean beetle.
- To protect beans in storage from infestation with bruchids each kg of beans should be mixed with 2-3 ml of neem oil. It is important to ensure that the oil is well mixed so that each bean is coated. Thus, beans can be protected for six months.

### *Treatment of stored grains*

Grains and pulses can be stored by mixing them with neem products like dried leaf powder, kernel powder or oil. The neem oil used against stored grain pests should be 1% by weight of the grain. If the grain is used for seed purposes, 2% can be used. Using oil is easier than using leaves. The active ingredients of the neem plant are located in their maximum amounts in the seed and kernel.

### *Storage pest control*

*For Pulses alone:*

1 kg of any pulse should be coated with 2-5 ml of castor oil before storage. This gets rid of storage pests for 6 months to 1 year.

**For vegetables and Fruits:** Seeds should be treated with wood ash at the rate of 5-10 kg per quintal (100 kg) of seeds, before storage.

**For cereals:** Datura leaf dust should be mixed with grain at a rate of 10 gm per kg of grain.

### *Wood ash in storage pest control:*

It is very effective pesticide. It is harmless to health. It can be mixed in equal quantity to the total amount of grains. It offers good protection against the beetles and other storage pests. Ashes from the leaves of *Lantana* are very effective against pests attacking the sprouts of stored potato

### *Traditional methods of storage*

1. Neem leaves and Pongam leaves can be spread on the floor where stored grains are kept in gunny bags. In Tanjore, farmers spread these leaves in between the bags at regular intervals.
2. Add neem leaf powder to the clay soil and swab it on the inner surface of the storage bins. For 1 kg of clay soil, add 10 gms of neem leaf powder. After swabbing, they store the grains by putting one layer of neem leaves and one layer of grains alternatively. In this way, the stored grains are protected from the pest attack for year.

***Source:*** *(Dr. K. Vijayalakshmi and Subhashini Sridhar, CIKS Chennai. Pesticide Monitor Volume 8, No. 3, October 1999).*

### *Treatment of jute bags for storing grains*

The jute bag is dipped into a 10% neem kernel solution (here, no emulsifier need be added to the solution) for 15 minutes. After having been dried in the shade, the bag can now be used for storing grains. The stored grain pests will be repelled by the action of neem.

If the jute bags are new, they should be soaked for half an hour. For jute bags with close meshes and small pores, a thinner solution can be used. It should be ensured that the bags

**How neem works**

Neem products such as oil, cake etc. contain a substance called Azadirachtin. The substance reduces the egg laying capacity of insects. Same substance goes into the plant and sucking insects cannot feed on the plants. Azadirachtin alters the physiology of insects and breaks their life cycle, reducing the spread of pests.

are soaked on all sides in the extract. If the seeds or grains are kept inside the house or in a godown, where the temperature is stable and sunlight minimal, longer residual action of the neem product is obtained and the repellent effect will persist for four months.

In storerooms, along with the cowdung that is used for cleaning the mud floor, neem cake or neem oil can be used straightaway (in the same concentration as used for spraying purposes). The same could also be used for the mud walls. Neem cake solution or neem kernel extract could also be sprayed. If one is using bamboo bins for storage, then one can paint the bins with a solution prepared from neem cake. To the dry neem cake powder, water is added, and a thick paste of this is painted all over the grain bin. If one wishes to store it for more than four months, the process should be repeated every four months. Neem products work by intervening at several stages of the life of an insect. They may not kill the pest instantaneously but incapacitate it in a number of ways.

## 9.9 Crop disease management

Disease control measures such as the use of disease-free seed; good crop rotations and other cultural methods become very important in organic farming situations. For example, increasing the length of crop rotations by including perennial forages for several years can significantly decrease the amount of common root rot inoculum present in the soil. Burying crop residue is not recommended due to the potential for soil erosion and degradation. Crops, which are susceptible to similar diseases, should not be grown within the recommended number of years of each other for each particular disease.

Weed control is also a key factor in disease management. If weeds that carry a disease or are susceptible to it are allowed to persist, crop rotation will not effectively control disease. For example, if the rotation includes a canola crop every fourth or fifth year, to avoid sclerotinia stem rot, such susceptible weeds as wild mustard cannot be allowed to proliferate, and susceptible crops such as field peas, field beans or lentils should not be grown.

### *Protecting seeds from insects*

Seeds are commonly spoiled by particular insects, which feed on stored seeds and grains. There are a number of ways to protect seeds in storage.

Fresh ash and not old ash should be used, as old ash is usually wet and contaminated with microorganism. Do not use hot ash since the seeds may be killed. For every kilogram of seeds to be stored, use half a kilogram of fresh, dry wood ash a little more ash can be added to cover the seed in the container.

Dry, clean sand mixed with the seeds will provide protection against weevil as the coarse sand grits will provide discomfort for the movement and existence of the weevil.

This chapter aims to provide and disseminate information on controlling insect and pest of agriculture crops.

Chapter X

# Seeds and Biodiversity Conservation for Organic Farming

Seed is the embodiment of the ideas and the knowledge, of the culture and the heritage of a people. It is an accumulation of philosophy, of tradition, of knowledge of a people. Seed thus, represents the wisdom of the years of research of the farmers, who have meticulously worked the process in perfect coordination and harmony of the nature- taking into consideration the climatic and hydro-geographical parameters of the region. There exists a complete harmony in the ecological niche of the crop grown in the region. The seed is the first link in the food chain and is the ultimate symbol of food security.

## Navdanya's initiative for the conservation of seed biodiversity

The conservation of biodiversity requires action at many levels. It requires in-situ or on-farm conservation of all biodiversity, especially agricultural biodiversity. Navdanya pioneered the setting up of community seed banks and biodiversity conservation centres and seed exchange of traditional varieties by local groups and communities for the preservation of agricultural biodiversity and to protect farmers right to seed. The movement has grown into a national network of community seed banks and in situ conservation programs. Navdanya's efforts have resulted in the conservation of more than 1000 rice varieties from all over the country including indigenous rice varieties that have been adapted over centuries to meet different ecological demands. Crops such as millets, amaranth, buckwheat, pulses have been promoted and saved from being pushed out by expanding monoculture. The objective of the conservation programme is to empower local farming communities to protect and regenerate genetic diversity and the knowledge systems that support it.

## 10.1 Strengthening community seed supply: A case of Navdanya conservation of agricultural biodiversity

Conservation of agricultural biodiversity is impossible without the participation of the communities who have evolved and protected the plants and animals that form the basis of sustainable agriculture.

The Navdanya programme works for promoting ecological agriculture based on biodiversity, for economic and food security. Agricultural diversity can only be conserved by biodiversity-based production systems. The programme works with farmers helping them shift from monoculture to agriculture - sustainable agriculture based on biodiversity-through demonstrations and workshops on seed conservation, seed development, pollinators, maintaining soil fertility through composting and use of soil nicro-organisms, biodiversity based pest and disease control.

The Navdanya Movement - nine seeds movement - for conservation of agricultural bodiversity on farmer's field is one such movement, where farmers in many parts of the country are actively involved in conserving not just hundreds of varieties of rice and wheat, but are striving to bring back into cultivation the numerous ecologically prudent crops that have almost vanished -millet varieties, pseudocereals, pulses, etc.

### Displacement of biodiversity by monocultures:

With agriculture increasingly viewed as an industry, uniformity of crops through monocultures is becoming an imperative leading to a loss of diversity. This has generated the paradoxical situation in which plant improvement using diversity as raw material has led to the destruction of same diversity.

The erosion of this diversity in agriculture was mainly through the manipulation of seeds and plant breeding by scientists in laboratories and not on the farm, resulting in the disasppearance of traditional crop varieties.

Agriculture shifted to few varieties of wheat and rice derived from a narrow genetic base. Green revolution reinforced laboratory – orianted methods of plant breeding to produce high yielding varieties, hybrid varieties, genetically engineered seeds and tissue culture.

## 10.2 Different kinds of seeds

Seeds of agricultural crops have been developed over centuries by farming communities across the world. These seeds have been freely exchanged with other communities again across the world and have led to the development of new varieties. Today, with the entry of the commercial sector in seed production and supply as well as new technologies for producing seed, seed varieties have been given a variety of names depending on who evolved it, how it was evolved, and its potential for making profits.

**Farmer's varieties** are those varieties which have been developed by farmers over the years to suit their ecological, nutritional, taste, medicinal, fodder, fuel and other needs. These have sometimes been called **land races** to distance from the contributions that farmers have made toward their evolution through selection. They have also evolved by scientists. Farmer's varieties like any other seed variety, are embodiments of intellectual contribution. **Farmer's varieties are perennial and sustainable.** Farmer's varieties are also referred to as indigenous seeds, native seeds, organic seeds, heirloom seeds and heritage seeds, jwaari, nate, desi, etc.

**High yield varieties (HYVs)**, or green revolution seeds are misnamed because the term implies that the seeds are high yielding in and of themselves. The distinguishing feature of these seeds, however, is that they are highly responsive to certain key inputs such as fertilizer and irigation. They are actually, **high response varieties. Though these seeds can be saved by farmers, they are non-sustainable due to vulnerability to diseases and pests and therefore, need to be replaced after every few years.** These seeds are also called "Sarkari" or "government" seeds as they have been developed and/or distributed primarily by the public sector.

**Hybrid Seeds** are the first generation seeds ($F_1$) produced from crossing two genetically dissimilar parent species. The progeny of these seeds cannot economically be saved and replanted, as the next generations will give much lower yields.

**Hybridisation** is only one of the breeding techniques. It does provide high-yielding varieties, but so do other breeding techniques. Why did hybridisation gain such predominance over other methods? Using the example of hybridisation of corn in the US, Jack Kloppenberg in **First the Seed** explains:

"There is an even more compelling reason to examine closely the historical choice of breeding methods in corn, for the use of hybridisation galvanised radical changes in the political economy of plant breeding and seed production. There is a crucial difference between open-pollinated and hybrid corn varieties: Seed from a crop of the latter, when saved and replanted exhibits a considerable reduction in yield. Hybridisation thus uncouples seeds as "seed"from seed as "grain" and thereby facilitates the transformation of seed from a use-value to an exchange value. The farmer choosing hybrid varieties must purchase a fresh supply of seed each year".

Hybridisation is thus, like biologically patenting the seed. No one else, neither the farmer nor a rival company can produce exactly similar seeds unless they know the parent lines, which are the company's secrets. This characteristic of the hybrid seed has been fundamental to the rapid growth of American seed industry. The corporate seed sector in India is also involved mainly in the development of hybrid seeds including seeds of maize, sorghum, vegetables, and foodgrains. Hybrid seeds are genrally called **sankar beej**.

## 10.3 The new biotechnologies

The new biotechnologies include tissue or cell culture, cloning and fermentation methods, cell fusion, embryo transfer, and recombinant DNA technology (genetic engineering).

### *10.3.1 Tissue or cell culture*

This is among the most commonly used new technologies. A tiny piece of plant material-tissue or isolated cells-are grown in an artificial medium that keeps them alive. Special hormones like rooting hormones, etc. help them to develop into complete plants. These baby plants are identical to the parent plant and to each other.

### *10.3.2 Cloning and fermentation*

Cloning is the process of forming a cell culture strating from a single cell, which can

**Why do farmers reject HYV's and hybrids:**

1. HYV's and hybrids are susceptible to pests and diseases.
2. They are not tasty, and their straw yield is less.
3. If the native varieties are grown with care, they are not less productive than HYV's.
4. In some agro-climatic conditions, the harvest of HYV's coincides with the rains, and hence much of the harvest is lost.
5. Harvesting of HYV's is labour intensive.
6. HYV's and hybrid seeds are expensive.
7. The cost of cultivating HYV's is high. The recovery of even the costs is myth.

multiply itself. The culture thus contains cells with identical characteristics. Each of these cells can than be used to mass propagate new plants through tissue culture. Fermentation generally means a natural process in which the biological activity of a microorganism (bacteria, or virus) is vital, for example, making yoghurt, wine, etc. Such processes using genetically engineered bacteria can produce vanilla, jasmine and citrus fragrance out of a totally unrelated medium, eg. ordinary edible oil can be converted into cocoa butter using this method.

### *10.3.3 Cell fusion and embryo transfer*

These technologies are used mainly for dairy and livestock breeding purposes.

### *10.3.4 Recombinant DNA technology (genetic engineering)*

This technology involves transferring of genes from one cell to another. Genetic engineering crosses the boundaries of nature by allowing genes from one life form to be introduced into a totally unconnected life form, eg. genes from fireflies have been introduced into tobacco to create a variety that glows naturally; genes from a fish found in Arctic Ocean have been introduced into soybean and tomato so that soybean and/or tomato plants can withstand cold and frost and also be refrigerated for long periods. Genes have also been introduced into plant varieties to make them resistant to a particular brand of herbicide.

Genetically engineered cells are mass propagated through tissue culture methods to produce thousands of new life forms with the new characteristics. Such life forms are often called transgenic. The new biotechnolgies are even more disruptive of the social fabric as they further distance the farmer from seed development. Any development takes place not merely in laboratories, but within the seed itself. The farmer becomes further dependent on outside agents for resources and information about how to use them.

The seeds produced by the new technologies are in no way superior to either farmer's varieties or to the seeds of the green revolution. By their very nature, they are monocultures, and will therefore have the same vulnerability to diseases and pests.

As their characteristics have been modified at the level of the gene, their progeny will have the same characteristics. Thus, a plant that is engineered to produce its own pesticide will pass on this property to its progeny, who will continue to release it into the environment irrespective of any harm that it can cause. Further, products of genetic engineering not have been tested for adequate periods to see their long-term effects on the environment. Once released into the environment, there is no way to recall these products.

## 10.4 Who are the producers of seeds?

***Today there are three kinds of producers of seed:***

- The farmer has historically been the producer of perennial varieties, which could reproduce themselves eternally.
- Public sector research institutions have bred short-term varieties for "high yield". These seeds could for some time be saved and used by the farmer, but their yield reduces after a few years.
- Transnational corporations produce non-renewable and therefore non-sustainable seeds through hybrids and tissue culture, where the farmer has to return the company for fresh seed, each time, he has to sow.

The last is called biological patenting of seed. Patents give the owner of the seed the exclusive right to multiply, save, develop further varieties and sell seeds. Biological patenting effectively prevents the farmer from multiplying, saving and selling the seed.

During the period when hybrid seeds are still being developed, the farmer still has some control over the seed. Agribusiness use legal patents in agriculture to take over this control.

Navdanya has set up directly or with partners 20 community seed banks in 9 states. More than 2000 farmers are primary members of Navdanya and more than 200,000 have benefited through Navdanya training programme and one partner programmes. Navdanya initiated seed banks in Karnataka, Tamil nadu, Orissa, West Bengal, M.P. Rajasthan, U.P., Uttaranchal and Laddakh. The Navdanya programme operates through a network of community seed banks in different ecozones of the country, and thus, facilitates four types of rejuvenation:

- Rejuvenation of agricultural biodiversity as a common property resource.
- Rejuvenation of farmer's self-reliance in seed locally and nationally.
- Rejuvenation of sustainable agriculture as the foundation for food security.
- Rejuvenation of farmer's rights as common intellectual and biodiversity rights of agricultural communities.

The Navdanya Conservation centers are designed with the aim of widening the genetic resource base to make indigenous resources available to farmers. The main objectives are as follows:

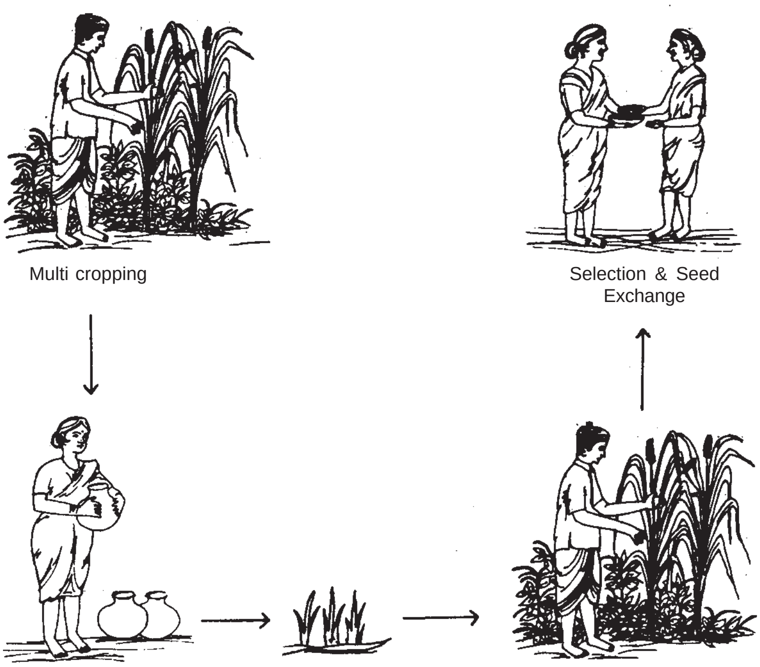
- Collection and Storage of seeds.
- Plant regeneration and maintenance of viability.
- Multiplication and stabilization of seed.
- Site for trials and scientific evaluation of plant characteristics.

*Seeds Diversity*

### *Conserving biodiversity*

The rate of ecological destruction and the accompanying loss of biodiversity has forced nations and international organisations to make efforts to prevent it.

There are two types of conservation activities. One type is farm based, where the farmer conserves a variety by continuing to cultivate regularly. This kind of conservation is called *in situ* conservation. The second kind of conservation is when




*Digram 10.1 In-situ Conservation*

seeds and propagating material of plants are collected by groups of people not necessarily farmers), and are stored in special gene banks again away from the field. This kind of conservation is called *ex-situ* conservation.

**In situ *conservation has been proposed as a method to:***

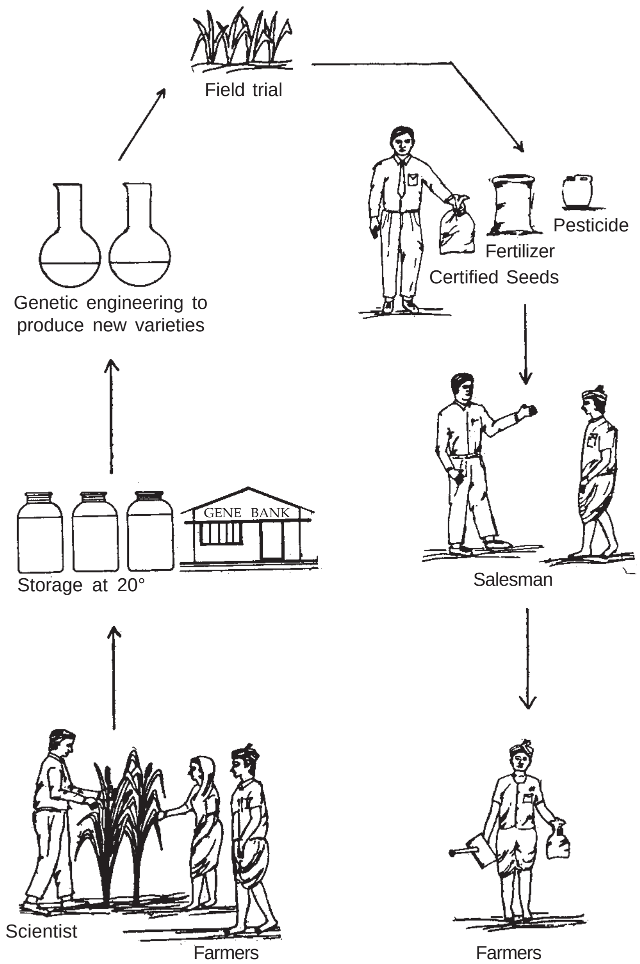
- Conserve the processes of evolution and adaptation of crops to their environment
- Conserve diversity at all levels — ecosystem, species and within species
- Improve the livelihood of resource-poor farmers
- Support agro-ecosystem health
- Maintain or increase farmers' control and access over their genetic resources
- Integrate farmers into national plant genetic resources systems (IPGRI, 1997).

***Seed selection***

The farmers select seeds with specific characteristics to meet their particular needs.

***The salient features are:***

- Yield
- Quantities like colour, palatability, texture and flavour etc.
- Adaptations to climatic oscillations
- Pest and disease resistance
- Fodder value
- Soil enrichment by mechanism of nitrogen fixation or extensive root system

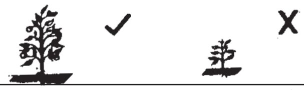
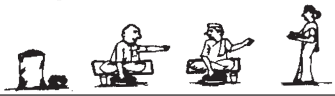
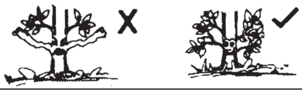
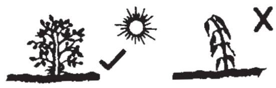



*Digram 10.2 Ex-situ Conservation*

## 10.5 Seed evaluation, characterisation and multiplication

The seed varriety must be characterised and evaluated according to the farmer's requirements. Therefore the criteria for characterisation and evaluation must reflect these requirements.

The following criteria are usually included in such characterisation and evaluation.

| | | |
|---|---|---|
| 1. | High yield without use of external input |   |
| 2. | Early Maturity |  |
| 3. | Good eating Quality |  |
| 4. | Pest resistant |  |
| 5. | Medium Height |  |
| 6. | Drought Resistant |  |
| 7. | Strong Stems |  |
| 8. | Good tillering quality |  |
| 9. | Erect Leaves |  |
| 10. | Big Grains |  |
| 11. | Non-Shattering |  |
| 12. | Cost Beneficial |  |
| 13. | Fodder Value |  |

*Digram 10.3 Farmers' Criteria for Selection of Variety*

### *Gastronomic criteria including*

- Taste
- Cooking time

### *Preparation and processing opportunity*

### *Storage quality*

### *Agronomic criteria including*

- Ability to compete with weeds.

- Variable maturity period
- Tolerance to drought.
- Resistance to bird damage.

***Morphological criteria include***

- Grain and fodder yield
- Plant height
- Tillering potential

Evaluation of the genetic resources includes details such as yields, quality, resistance to diseases and pests, adaptation to the environment and cultural value.

***Seed collection:***

The quality of seed collected depends on the timing and method of seed collection. Seeds should be collected only from plants showing the following characteristics:

- Vigorous growth
- Resistance to pests and diseases
- Good quality fruits
- High yielding plants

## 10.6 Importance of traditional seed varieties

- Traditional seeds are locally available because farmers collect good seeds from their own plots and keep them for the next season.
- Farmer either buys or exchanges their seeds with other farmers or grows their own seed. So the cost of seed is either minimal or almost nil.
- Native seeds are geared to a subsistence economy as the farmer first grows food for his sustenance and markets only the surplus.
- Native seeds embody indigenous knowledge. A farmer who uses native seeds uses his traditional knowledge, skills and wisdom to grow them. He does not depend on an "expert". It therefore promotes self-reliance.
- An outstanding feature of native seeds is diversity.
- Native seeds are hardy, as they have, over the years, developed resistance to the pests and disease-causing organisms in the system.
- Traditional seeds have high levels of tolerance to condition of stress and are adapted to local agroclimatic conditions.

*Indigenous Wheat variety grown at Navdanya Farm*

*Indigenous variety of barnyard mullet grown at Navdanya*

### *10.6.1 Conservation and propagation of indigenous varieties*

Indigenous varieties are called by many local names, to distinguish them from HYV seeds. In coming from the earth and returning to it, indigenous seeds maintain and multiply diversity and permanence. These seeds have a relationship with local farming communities. Seeds protect the farmers and farmer protects seeds. Some of the indigenous varieties grown at Navdanya farm are presented in the table below:

**Table 10.1 Indigenous crops grown at Navdanya farm and yield data from 2000-01 (rabi season)**

| *Name* | *Yield /Acre* | *Straw /Acre* | *Total Biomass/Acre* |
|---|---|---|---|
| **Wheat varieties:** | | | |
| DW25 | 11.25 | 23.35 | 34.6 |
| D30 | 17.62 | 30.85 | 48.47 |
| DW 21 | 15.75 | 24.25 | 40 |
| Navdanya No. 1 | 10.50 | 19.85 | 30.35 |
| Navdanya No 3 | 18.00 | 25.98 | 43.98 |
| Mundri | 10.60 | 19.82 | 30.42 |
| Narmada | 20.35 | 32.65 | 53 |
| PBW 154 | 14.95 | 22.46 | 37.41 |
| Navdanya No.2 | 25.54 | 39.20 | 64.74 |
| Baroth | 16.29 | 45.37 | 61.66 |
| DW 22 | 14.90 | 24.22 | 39.12 |
| W 75 | 20.26 | 28.92 | 49.18 |
| Safed Gehun | 19.38 | 32.50 | 51.88 |
| Ukhdi | 12.75 | 21.45 | 34.2 |
| DW 23 | 14.53 | 22.60 | 37.13 |
| W 15 | 12.75 | 22.55 | 35.3 |
| RR 21 | 25.54 | 46.25 | 71.79 |
| Desi Gehun Abdullapur | 20.70 | 29.35 | 50.05 |
| **Oats:** | | | |
| Oat I | 9.50 | 11.35 | 20.85 |
| Oat II | 14.55 | 23.65 | 38.2 |
| Masoor | 6.16 | 11.95 | 18.11 |
| **Rai:** | | | |
| Rai I field | 4.40 | 13.50 | 17.9 |
| Rai II field | 4.85 | 16.75 | 21.6 |
| Rai III field | 22.05 | 12.45 | 34.5 |

| Name | Yield /Acre | Straw /Acre | Total Biomass/Acre |
|---|---|---|---|
| **Barley:** | | | |
| Barley 3 | 11.50 | 26.43 | 37.93 |
| Barley 2 | 9.25 | 16.25 | 25.5 |
| Barley 4 | 9.25 | 12.77 | 22.02 |
| Barley 7 | 7.48 | 14.06 | 21.54 |
| Barley 1 | 14.53 | 14.96 | 29.49 |
| Barley 3 | 10.57 | 18.1 | 28.67 |
| Barley 10 | 16.50 | 22.55 | 39.05 |
| Barley 5 | 7.85 | 12.45 | 20.3 |
| Barley 8 | 13.65 | 21.45 | 35.1 |
| **Coriander** | 3.52 | 8.8.1 | 12.32 |
| **Gobhi Rai** | 3.96 | 13.21 | 17.17 |

The conservation of the seed is of paramount importance. Farmers are custodians of agricultural biodiversity. Seed conservation has been their primary duty. Sharing of the seeds exemplifies a way of life, which views with reverence all forms of life. All farming activities are thus geared towards the conservation of agro-biodiversity, in the form of seed. The major activity of seed conservation is the in-situ seed conservation.

Crop genetic resources, in the form of landraces, or farmers' varieties, are passed from generation to generation of farmers, with the associated knowledge base, and are subject to the selection pressures of the farming systems where they are grown.

**Table 10.2 Some high yielding rice varieties grown in Navdanya farm**

| S. N. | Name of the paddy | Length (cm) | Grain yield (Qt./ha) | Straw yield (Qt./ha) | Total biomass (Qt./ ha) |
|---|---|---|---|---|---|
| 1. | Ageti Chaina | 127.5 | 71.58 | 109.68 | 181.26 |
| 2. | Agyatu Naj | 127.5 | 74.88 | 103.16 | 178.04 |
| 3. | Anjana | 107.5 | 38.54 | 13215 | 141.04 |
| 4. | Barik Jiri | 85 | 66.07 | 102.15 | 168.22 |
| 5. | Barik Naj | 145 | 47.35 | 106.64 | 153.99 |
| 6. | Barik Sati Maletha | 82.5 | 44.05 | 110.12 | 154.17 |
| 7. | Bhura Kisalya | 135 | 53.96 | 99.50 | 153.46 |
| 8. | Biju | 97.5 | 71.58 | 115.18 | 186.76 |
| 9. | Chakhulya | 162.5 | 66.07 | 112.75 | 178.82 |
| 10. | Chakhuri | 137.5 | 38.54 | 110.50 | 149.04 |
| 11. | Chamya Naj | 125 | 66.07 | 88.10 | 154.17 |
| 12. | Chardhan | 115 | 77.87 | 102.85 | 180.72 |
| 13. | Dharkotya | 125 | 38.54 | 110.12 | 148.66 |
| 14. | Dhunu Dhan | 115 | 60.56 | 112.75 | 173.31 |

| S. N. | Name of the paddy | Length (cm) | Grain yield (Qt./ha) | Straw yield (Qt./ha) | Total biomass (Qt./ ha) |
|---|---|---|---|---|---|
| 15. | Dusalya | 150 | 55.06 | 102.50 | 157.56 |
| 16. | Gorakhpuri lal dhan | 117.5 | 66.07 | 124.44 | 190.51 |
| 17. | Gwaphlya | 117.5 | 55.06 | 114.75 | 169.81 |
| 18. | Jhumkya mota | 80 | 77.08 | 106.20 | 183.28 |
| 19. | Jhumkya Mota | 152.5 | 44.05 | 110.50 | 154.55 |
| 20. | Jiri Ukhdi | 155 | 55.06 | 110.50 | 165.56 |
| 21. | Khushamati | 145 | 77.08 | 10620 | 183.28 |
| 22. | Kurjhanya | 135 | 66.07 | 103.25 | 169.32 |
| 23. | Lambu Naj | 125 | 60.56 | 110.25 | 170.81 |
| 24. | Nagin Sati | 127.5 | 44.05 | 137.63 | 181.68 |
| 25. | Parmal Barik | 95 | 66.07 | 102.15 | 168.22 |
| 26. | Parmal Bonya | 95 | 60.56 | 112.15 | 172.71 |
| 27. | Timlya Bonya | 67.5 | 62.77 | 88.10 | 150.87 |
| 28. | Udisiyali | 120 | 55.06 | 110.12 | 165.18 |
| 29. | Ukhdi Chaina | 125 | 51.75 | 82.59 | 134.34 |
| 30. | Ukhdi dhan | 110 | 57.26 | 93.65 | 150.91 |

### *10.6.2 Seed storage*

The purpose of seed storage are as follows:

- To save carry over seeds from harvest to the following planting season
- Safeguarding against famine
- Protection from unfavorable environmental conditions
- For long term genetic conservation

Factors affecting the storage life of seeds

- Genetic constitution
- Seed structure and composition
- Seed maturity
- Seed size
- Vigour and vitality
- Moisture, temperature and oxygen availability

*Navdanya's Seed Bank*

#### *10.6.2.1 Traditional seed storage in India*

Traditional farmers, if possible, always retain some seed stock for security. Farmers usually stores their seeds in various containers like baskets, clay pots, rock hewn mortars, gourds, wicker work containers, earthen jar containers, etc. There are many traditional seed storage methods for different crops. In the case of cereals like rice and wheat, the dried seeds are stored in wooden boxes, containers made of woven straw, cane bamboo or in earthen storage urns. Wooden boxes are the most commonly used containers for storing paddy.

In Garhwal region seeds and food grains are traditionally stored in woven bamboo (ringal) baskets or in wooden seed stores called "Datiya kulhar". The local biodiversity plays an important role in the preservation of the stored food grains, the leaves and seeds of various local trees are used to line the storage baskets as they prevent pest attacks. The seeds and the leaves of Timmu tree (*Zanthoxylum indica*), the leaves of the Daikan- the mountain Neem (*Melia azadirach*), and the leaves of walnut (*Juglans regia*) are used to prevent the stored grain from being eaten up by rodents and insects. Using farmer's knowledge and farmer's seeds, Navdanya has initiated a farmer-based seed supply system, which is also an in-situ biodiversity conservation programme.

> ***One effective and natural method of storing rice***
>
> The best strategy here is to sun dry the seeds before storage. Sun drying should never continue after 3 in the afternoon. Sun drying should also only be carried out in winter, as this is the season of least air moisture. Before storage the grains should be soaked in neem oil, as this helps keep away storage pests.

***Working areas of Navdanya in Uttaranchal***

**Dist. Garhwal**

Dugadda Block

**Dhar Area**

1. Balli
2. Charekh
3. Dhooratal
4. Githala
5. Ieeda Gweerala
6. Katal
7. Kaintogi
8. Kandai
9. Mathiana
10. Mundla
11. Pulinda
12. Ramdi
13. Umraila
14. Utircha
15. Syaling
16. Tachyali

**Danda Mandi Area**

17. Bedgaon
18. Chapda
19. Chondli
20. Dabrana
21. Dhargaon

22. Dhoora
23. Juva
24. Kweer Khal
25. Manyani
26. Modai
27. Pali
28. Saruda
29. Sor

**Dist. Rudrapryag**

**Mandakini Valley**

1. Maniguha
2. Bhatwari
3. Malkhi
4. Aenta
5. Badeth
6. Uthid
7. Nala
8. Pailing
9. Supri
10. Satera
11. Khatena
12. Syud
13. Nari
14. Dungri
15. Kotheda
16. Pathalidhar
17. Rudrapur
18. Vadashu
19. Devshal
20. Kurshan
21. Jandola
22. Dharkot
23. Nagali
24. Damkar

**Chopra Valley**

25. Devlekh
26. Sangu
27. Queeli
28. Pali

**Chamoli Garhwal**

29. Salna
30. Vishal
31. Kimotha
32. Dungar

**Dist. Uttarkashi**

**Purola Area**

1. Kuruda
2. Chhara
3. Sreekot
4. Sonali
5. Ghudada

**Jakhol Area**

6. Jakhol
7. Dhara
8. Pawn Talla
9. Pawn Malla
10. Sunkundi

**Sankri Area**

11. Sankri
12. Sour
13. Sindri
14. Kotgaon
15. Moutar

**Dewara Area**

16. Dewara
17. Gaichan gaon
18. Naitwar

19. Dangan gaon
20. Haltari

**Doni-Bhitri Area**

21. Doni
22. Bhitri
23. Khnyasini
24. Saturi
25. Pujeli

**Dist. Dehradun**

**Sahaspur Block**

**Villages**

1. Sabhawala
2. Ramgarh/Shishambara
3. Bhoodpur
4. Palio
5. Nayagaon
6. Singhniwala
7. Sherpur
8. Malachand
9. Aonli wala (Kalyanpur)
10. Tipar pur
11. Ganeshpur
12. Ratanpur
13. Gorkha Karbari
14. Karbari
15. Badon wala
16. Parbal
17. Parbal Nawa
18. Malhan

**Chaprauli, U.P.**

1. Barnala
2. Serpur Luhara
3. Badarkha
4. Mukandpur
5. Nangal
6. Kurdi
7. Boda
8. Chandanhedi
9. Sabga
10. Silana
11. Radhora
12. Halal Pur
13. Jiwani
14. Khedi
15. Chaprauli
16. Suha
17. Malakpur
18. Loomb
19. Heva
20. Mukundpur
21. Tada
22. Kakor
23. Halalpur
24. Nagnal
25. Kurdi
26. Sherpur

Chapter XI

# Agro-Ecology for Sustainability: *Food Security and Livelihood Security*

## 11.1 Livelihood security for small farmers

***Example from Brazil:***

In Brazil there are about 4.8 million farmers (about 85% of the total number of farmers) that occupy 30% of the total agricultural land of the country. Such family farms control about 33% of the area sown to maize, 61% of that under beans, and 64% of that under beans, and 64% of all beans. In addition to family farms, about 4 million landless families live in the rural areas of Brazil many of which are now turning to agro-ecology given new initiatives encouraged by the directives of MST (Landless movement).

For the most part, those farmers gained very little from the green revolution. Many analysts have pointed out that the new technologies were not scale-neutral. The farmers with the larger and better-endowed lands gained the most, whereas farmers with fewer resources often lost, and income disparities were often accentuated (Shiva, 1991). Not only were technologies inappropriate for poor farmers, but peasants were excluded from access to credit, information, technical support and other services that would have helped them use and adapt these new inputs if they so desired. Although subsequent studies have shown that the spread of high-yielding varieties among small farmers occurred in green revolution areas where they had access to irrigation and subsidized agro-chemicals, inequities remain (Lipton and Longhurst, 1989).

Clearly, the historical challenge of new Brazilian government and non-governmental agricultural research community is to refocus its efforts on family farmers and assume responsibility for the welfare of their agriculture. In fact this will be a key intervention to break the vicious cycle of hunger. Many analysts agree that in order to enhance food security the additional food production will have to come from agricultural systems located in areas where the additional people will live in and especially where the majority of the poor people are concentrate. Brazil is no exception.

In order to benefit small farmers more directly, the new agricultural agenda must directly and simultaneously tackle the following objectives through strategic partnerships:

- Poverty alleviation
- Food security and self reliance
- Ecological management of productive resources
- Empowerment of rural communities
- Establishment of supportive policies

Such agricultural strategy must be applicable under the highly heterogeneous and diverse conditions in which smallholders live, it must be environmentally sustainable and based on the use of local resources and indigenous knowledge (Table). The emphasis should be on improving whole farming systems at the field or watershed level rather than the yield of specific commodities. Technological generation should be a demand driven process meaning that research priorities should be based on the socio-economic needs and environmental circumstances of resource-poor farmers (Blauert and Zadek, 1998).

The urgent need to combat rural poverty and to conserve and regenerate the deteriorated resource base of small farms requires an active search for new kinds of agricultural research and resource management strategies. NGOs have long argued that a sustainable agricultural development strategy that is environmentally enhancing must be based on agroecological principles and on a more participatory approach for technology development and dissemination, as many agree that this may be the most sensible avenue for solving the problems of poverty, food insecurity and environmental degradation.

## 11.2 Agroecology for sustainability

Natural resource problems experienced by poor farmers are not amenable to the research approaches previously used by the academic research community. In most

**Table 11.1 Technological requirements for resource-poor farmers**

| ***Innovation characteristics important to poor farmers*** | ***Criteria for developing technology for poor farmers*** |
|---|---|
| • Input saving and cost reducing<br>• Risk reducing<br>• Expanding toward marginal-fragile lands<br>• Congruent with peasant farming systems<br>• Nutrition, health and environment improving | • Based on indigenous knowledge or rationale<br>• Economically viable, accessible and based on local resources<br>• Environmentally sound, socially and culturally sensitive<br>• Risk averse, adapted to farmer circumstances<br>• Enhance total farm productivity and stability |

organizations, research has been commodity oriented with the goal of improving yields of particular food crops and livestock, but generally without adequately understanding the needs and options of the poor, nor the ecological context of the systems being addressed.

Most scientists use a disciplinary approach, often resulting in recommendations for specific domains and failing to equip farmers with appropriate technologies or empower them to make informed choices between available options. This is a major problem because despite the significant advances in understanding the links between components of the biotic community and agricultural productivity, agrobiodiversity is still treated as a "black-box" in agricultural research (Swift and Anderson, 1993). This calls for the need that crop, soil, water and pest management aspects be addressed simultaneously at the field or watershed level. Such integrated approach to agroecosystem management can allow the definition of a range of different strategies that can potentially offer farmers a choice of options or capacity to manipulate their systems according to their socio-economic constraints and requirements.

A case in point has been the evolution of integrated pest management (IPM) and integrated soil fertility management (ISFM) which have proceeded separately without realising that low-input agroecosytems rely on synergies of plant diversity and the continuing function of the soil microbial community, and its relationship with organic matter to maintain the integrity of the agroecosystem. It is crucial for scientists to understand that most pest management methods used by farmers can also be considered soil fertility management strategies and that there are positive interactions between soils and pests that once identified, can provide guidelines for optimizing total agroecosystem function. Increasingly, research is showing that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. Soils with high organic matter and active soil biological activity generally exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infection. On the other hand, farming practices that cause nutrition imbalances can lower pest resistance.

A wider understanding of the agricultural context requires the study between agriculture, the global environment and social systems given that agricultural development results from the complex interaction of a multitude of factors. It is through this deeper understanding of the ecology of agricultural systems that doors will open to new management options more in tune with the objectives of a truly sustainable agriculture. The science of agro-ecology, which is defined as the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems, provides a framework to assess the complexity of agro-ecosystems. The idea of agro-ecology is to go beyond the use of alternative practices and to develop agro-ecosystems with the minimal dependence on high agrochemical and energy inputs, emphasizing complex agricultural systems in which ecological interactions and synergisms between biological components provide the mechanisms for the systems to sponsor their own soil fertility, productivity and crop protection.

## 11.3 Agro-ecology as a fundamental scientific basis for natural resource management (NRM)

In trying to improve agricultural production, most scientists have disregarded a key point in the development of more self-sufficient and sustaining agriculture: a deep understanding of the nature of agro-ecosystems and the principles by which they function. Given this limitation, agro-ecology has emerged as the discipline that provides the basis ecological principles for how to study, design and manage agro-ecosystems that are both productive and natural resource conserving, and that are also culturally sensitive, socially just and economically viable.

Agro-ecology goes beyond a one-dimensional view of agro-ecosystems- their genetics, agronomy, edaphology, and so on, - to embrace an understanding of ecological and social levels of co-evolution, structure and function. Instead of focusing on one particular component of the agro-ecosystem, agro-ecology emphasizes the interrelatedness of all agro-ecosystem components and the complex dynamics of ecological processes.

Agro-ecosystems are communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing. Agro-ecology is the holistic study of agro-ecosystems, including all environmental and human elements. It focuses on the form, dynamics and functions of their interrelationships and the processes in which they are involved. An area used for agricultural production, e.g. a field, is seen as a complex system in which ecological processes found under natural conditions also occur, e. g. nutrient cycling, predator/prey interactions, competition, symbiosis, sucessional changes, etc. (Gliessman, 1998).

Implicit in agroecological research is the idea that, by understanding these ecological relationships and processes, agro-ecosystems can be manipulated to improve production and to produce more sustainability, with fewer negative environmental or social impacts and fewer external inputs (Gliessman, 1998).

Ecological concepts are utilized to favor natural processes and biological interactions that optimize synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity. By assembling crops, animals, trees, soils and other factors in spatial/temporal diversified schemes, several processes are optimized. Such processes are crucial in determining the sustainability of agricultural systems.

## 11.4 Agro-ecology for food security

Since the early 1980s, hundreds of agro-ecologically-based projects have been promoted by NGOs throughout the developing world, which incorporate elements of both traditional knowledge and modern agricultural science. In Brazil, a variety of projects exist featuring resource-conserving yet highly productive systems, such as polycultures, agro-forestry, and the integration of crops and livestock, etc. Such alternative approaches can be described as low-input technologies, but this designation refers to the external inputs required. The amount of labor, skills, and management that are required as inputs to make land and other factors of production most productive is quite substantial. So rather than focus on what is not being utilized, it is better to focus on what is most important to increase food output-labor, knowledge and management (Uphoff and Altieri, 1999).

Agroecological alternative approaches are based on using locally available resources as much as possible, though they do not totally reject the use of external inputs. However, farmers, cannot benefit from technologies that are not available, affordable, or appropriate to their conditions. Purchased inputs present special problems and risks for less-secure farmers, particularly where supplies and the credit to facilitate purchases are inadequate.

The analysis of dozens of NGO-led agroecological projects support the fact that agroecological system are not limited to producing low inputs, as some critics have asserted. Increases in production of 50 to 100 per cent are fairly common with most alternative production methods. In some of these systems, yields for crops that the poor rely on most- rice, beans, maize, cassava, potatoes, barley- have been increased by several-fold, relying on labor and know-how more than on expensive purchased inputs, and capitalizing on processes of intensification and synergy.

In a recent study of 208 agroecologically based projects and/or initiatives, Pretty and Hine, 2000 documented clear increases in food production over some 29 million hectares, with nearly 9 million households benefiting from increased food diversity and security. Promoted sustainable agriculture practices led to 50-100% increases in per hectare food production (about 1.71 tonnes per year per household) in rain-fed areas typical of small farmers living in marginal environments; that is an area of about 3.58 million hectares, cultivated by about 4.42 million farmers. Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions.

## 11.5 Mainstreaming sustainable agriculture

The evidence shows that sustainable agricultural systems can be both economically, environmentally and socially viable, and contribute positively to local livelihoods (Uphoff and Altieri, 1999). But without appropriate policy suport, they are likely to remain localized in extent. Therefore, a major challenge for the future entails promoting institutional and policy changes to realize the potential of the alternative approaches. Necessary changes include:

- Increasing public investments in agroecological – participatory methods.
- Changes in policies to stop subsidies of conventional technologies and to provide support for agroecological approaches.
- Improvement of infrastructure for poor and marginal areas.
- Appropriate equitable market opportunities including fair market access and market information to small farmers.

- Security of tenure and progressive decentralization processes.
- Change in attitudes and philosophy among decision-makers, scientists, and others to acknowledge and promote alternatives.
- Strategies of institutions encouraging equitable partnerships with local NGOs and farmers; replace top down transfer of technology model with participatory technology development and farmer centered research and extension.

Opportunities for scaling up exist, including the systematization and application of approaches that have met with success at local levels, and the removal of constraining factors. Thus scaling up strategies must capitalize on mechanisms conducive to the spread of knowledge and techniques, such as:

- Strengthening of producer's organizations through alternative marketing channels. The main idea is to evaluate whether the promotion of alternative farmer-led markets constitute a mechanism to enhance the economic viability of the agroecological approach and thus provide the basis for the scaling up process.
- Develop methods for rescuing/collecting/evaluating promising agroecological technologies generated by experimenting farmers and making them known to other farmers for wide adoption in various areas. Mechanisms to disseminate technologies with high potential may involve farmer exchange visits, regional-national farmer conferences, and publication of manuals that explain the technologies for the use by technicians involved in agroecological development programs.
- Training government research and extension agencies on agroecology in order for these organizations to include agroecological principles in their extension programs, a step taken by EMATER in Rio Grande do Sul where agroecology is an integral part of public agricultural policy.
- Develop working linkages between NGOs and farmers organizations. Such alliances between technicians and farmers are critical for the dissemination of successful agroecological production systems emphasizing biodiversity management and rational use of natural resources.

The evidence is conclusive: new approaches and technologies spearheaded by farmers, NGOs and some local governments around the world are already making a sufficient contribution to food security at the household, national and regional levels. A variety of agroecological and participatory approaches in many countries including Brazil show very positive outcomes even under adverse conditions. Potentials, include: raising cereal yields from 50 to 200 per cent, increasing stability of production through diversification, improving diets and income, contributing to national food security and even to exports and conservation of the natural resource base and agrobiodiversity (Pretty, 1995; Uphoff and Altieri, 1999; Pretty and Hine, 2000).

Whether the potential and spread of these thousands of local agroecological innovations is realized depends on several factors and actions. First, proposed NRM strategies have to deliberately target the poor, and not only aim at increasing production and conserving natural resources, but also create employment, provide access to local inputs and output markets.

Second, researchers and rural development practitioners will need to translate general ecological principles and natural resource management concepts into practical advice directly relevant to the needs and circumstances of small-holders. The new pro-poor technological agenda must incorporate agroecological perspectives. A focus on resource conserving technologies, that uses labor efficiently, and on diversified farming systems based on natural ecosystem processes will be essential. Technological solutions will be location specific and information intensive rather than capital intensive. The many existing examples of traditional and NGO-led methods of natural resource management provide opportunities to explore the potential of combining local farmer knowledge and skills with those of external agents to develop and/or adapt appropriate farming techniques.

Any serious attempt at developing sustainable agricultural technologies must bring to bear local knowledge and skills on the research process (Toledo, 2000). Particular emphasis must be given to involving farmers directly in the formulation of the research agenda and on their active participation in the process of technological innovation and dissemination. The focus should be in strengthening local research and problem-solving capacities. Organizing local people around NRM projects that make effective use of traditional skills and knowledge provides a launching pad for additional learning and organizing, thus improving prospects for community empowerment and self-reliant development.

Third, major changes must be made in policies, institutions, and research and development to make sure that agroecological alternatives are adopted, made equitably and broadly accessible, and multiplied so that their full benefit for sustainable food security can be realized. Existing subsidies and policy incentives for conventional chemical approaches must be dismantled. Corporate control over the food system must also be challenged. The strengthening of local institutional capacity and widening access of farmers to support services that facilitate use of technologies will be critical Governments and international public organizations must encourage and support effective partnerships between NGOs, local universities, and farmer organizations in order to assist and empower poor farmers to achieve food security, income generation, and natural resource conservation.

There is also need to increase rural incomes through interventions other than enhancing yields, such as complementary marketing and processing activities. Therefore, equitable market opportunities should also be developed, emphasizing fair trade and other mechanisms that link farmers and consumers more directly. The ultimate challenge is to increase investment and research in agroecology and scale up projects that have already proven successful to thousands of other farmers. This will generate a meaningful impact on the income, food security, and environmental well being of the millions of poor farmers yet untouched by modern agricultural technology.

CHAPTER XII

# Water Conservation Through Organic Farming

Destruction of water resources through water waste is one of the biggest environmental costs of industrial agriculture and the green revolution. Large-scale intensive irrigation is not related to good agriculture or more food availability. It is often forgotten that 75% agriculture is under rain fed conditions and only about 25% is irrigated. It is estimated that even if all the available water resources were developed for irrigation, about 55 per cent of the cultivated area would still continue to be rain fed. Irrigation itself can be protective. Intensive organic agriculture or indigenous agriculture depends on protective irrigation. Chemical farming/industrial agriculture and green revolution are based on intensive irrigation and non-sustainable water use.

## 12.1 Crop diversity a major instrument for water conservation

Diversity of crops and mixed cropping conserves moisture by reducing evaporation and improving water use efficiency. The table depicts that mixed cropping has higher water use efficiency as compared to monocrops.

**Table 12.1 Comparision of water use efficency in mixed and mono crop farms**

| *Crop* | *Water used (cm)* | *Yield (Q/Ha)* | *WUE* |
|---|---|---|---|
| Gram (monocropping) | 12.51 | 10.68 | 0.85 |
| Barley (monocropping) | 14.91 | 16.41 | 1.85 |
| Gram +Barley (mixed cropping) | 15.89 | 17.92 | 1.91 |

Gram alone used 12.51 cm of water and gave 10.68 Q/ha with water use efficiency of 0.85, and barley alone used 14.91 cum of water and gave 16.41Q/ha with water use efficiency of 1.85 a mixture of barley and grain used 15.89 cum of water, yielded 17.92 Q/ha and grain used and increased water use efficiency to 1.91.

In case of monocultures it has been seen that incidence of soil erosion is higher in farm fields were the mixed crops have been replaced by monocultures. The International Institute for Tropical Agriculture has shown that soil erosion and run–off losses are proportionately lower from mixed as compared to monocropping systems, as can be inferred from Table 12.1.

**Table12.2 Soil loss and run-off with monoculture (cassava) and mixed cropping (cassava with maize)**

| *Slope* | *Soil loss (tonnes/ha/annum* | | *Run-off (%)* | |
|---|---|---|---|---|
| *Monoculture* | *Mixed cropping* | *Monoculture* | *Mixed cropping* | |
| 1 | 2.7 | 2.5 | 1 | 14 |
| 5 | 87.4 | 49.9 | 43 | 33 |
| 10 | 125.1 | 5.5 | 20 | 1 |
| 15 | 221.1 | 137.3 | 30 | 19 |

Mixed cropping especially with leguminous associates of cereals, also enhances soil fertility and soil moisture. The mixing of cereals and pulses, as is the traditional practice in India, tends to help both crops and soils. Traditional cropping patterns are always based on production of organic matter which increases the soil moisture by binding soil particles.

It has been proved that green revolution varieties need much more water than indigenous varieties. High yielding varieties of wheat, need about three times as much irrigation as traditional varieties. Thus, while indigenous wheat varieties need 12 inches of irrigation, the HYV's require at least 36 inches. The comparative yields of native wheat varieties and the HYV varieties are 3,291 and 4,690 kg/ha respectively in Punjab. The productivity with respect to water use is therefore 620.90 and 293.1 kg/ha / cm respectively.

From the perspective of water use, the shift to the new wheat varieties, and the replacement of traditional crops such as millets and maize by rice has therefore led to a decrease in productivity. In addition, the shift has induced processes of social and ecological disruption. Social considerations of equity favour the extensive use of irrigation water, which assures a protective dose of water to crops over as large an area as possible. The intensive use of irrigation as part of the green revolution package limits the provisioning of irrigation to a smaller region. Thus a shift from millets to paddy amounts to a restriction of irrigation from 3 ha to 1 ha.

## 12.2 Crop selection vis-a-vis water use efficency

It has been observed that the HYVs propelled by green revolution has a high water consumption. Some of the data that is presented as under reveals the extent of the water consumed in growing of the so called 'high yielding crops' as compared to the indigenous crops. It has been recorded that high yielding wheat use five times more water than indigenous wheat, soybean and bajra needs 500 mm: while rice needs 1200 mm and sugarcane 2200 mm. The Tables 12.3 to 12.6 depicts the water use and water use efficiency for different crops. Water requirement per hectare per tonne for sugarcane, rice, and millet are also shown in the following tables.

Table 12.3 Average Water use (cm) of some important crops of India

| *Crop* | *Water Requirement (cm)* |
|---|---|
| Paddy | 1756 |
| Millets | 521 |
| Groundnut | 750 |
| Turmeric | 1200 |
| Sugarcane | 3200 |
| Ginger | 250 |

Table 12.4 Water use efficiency of different crops

| *Crop* | *Water Requirement* | *Yield kg/ha* | *Water Use Efficiency (WUE) per m of water* |
|---|---|---|---|
| Rice | 1200 | 4500 | 3.7 |
| Sorghum | 500 | 4500 | 9.0 |
| Bajra | 500 | 4000 | 8.0 |
| Maize | 625 | 5000 | 8.0 |
| Wheat | 400 | 5000 | 12.5 |

Table 12.5 Water requirement for small millet, sugarcane and rice

| *Crop* | *Water requirement* | |
|---|---|---|
| | Cubic m/ha | Cubic/m/t |
| Millet | 1000 | 1190.40 |
| Sugarcane | 30000 | 400 |
| Rice | 14000 | 6264 |

Table 12.6 Comparison of WUE and food security – rice, sugarcane and millet

| *Crop* | *Production million tonnes 2000 AD* | *Area million hectares 2000 AD* | *Water million cubic meters* | *Millet production for same water use* | |
|---|---|---|---|---|---|
| Sugarcane | 300 | 4.0 | 120000 | 100.84 | 120 |
| Rice | 89.40 | 40.0 | 560000 | 470.58 | 560 |

Let us review the ill effects of green revolution's on the water resources

- Green revolution agriculture thus, destroys water resources and hydrological balance at many strata.
- Green revolution varieties and hybrid seeds are all thirsty; water demanding varieties, which lead to high water withdrawals from rivers and underground aquifers.
- Green revolution varieties are dwarf varieties bred to have lower biomass in terms of straw, which deprives the soil of organic matter, and hence reduces soil moisture conservation, including drought and desertification.

- Green revolution monocultures and industrial farming reduce crop cover, lead to higher soil and water loss higher erosion, and higher evaporation.

The agrochemicals necessary for green revolution go to pollute ground water and surface water. Recent studies carried out by CSE have shown that all bottled water, which is withdrawn from ground water sources, contaminate pesticide residues. The same has been detailed earlier in section 2.2.2 of chapter II.

Besides depleting and destroying water through over use and pollution commercially driven agriculture also destroys water resources by inducing a shift from water conserving crops, for food security to water wasteful cash crops. Ground water resources of Maharashtra have been destroyed because of the World Bank induced shift from jowar and bajra to sugarcane. Ground water resources of Warangal are being destroyed because of the corporate driven shift from staples such as ragi, tur to hybrid cotton.

Food insecurity and water insecurity therefore go hand in hand whereas food security and water security reinforce each other. The dominant industrial agriculture paradigm has reduced labour inputs and increased chemical and water inputs, with respect to water, agricultural productivity has actually declined. Water conservation demands that we measure productivity with respect to water use. Once we focus on conserving water, organic farming is more productive than industrial agriculture, millets are more productive than rice, and farmers breeding are more efficiency than the green revolution.

Briefly, it is more than suffice to say that Food and Water are our most basic needs. Without water, food production is not possible. Traditionally, food cultures evolved in response to the water possibilities surrounding them. Water-prudent crops emerged in water-scarce regions and water-demanding ones evolved in water-rich regions.

The water-use efficiency of crops is influenced by their genetic variation. Maize, sorghum, and millet convert water into biological matter most efficiently. Millet not only requires less water than rice, it is also drought-resistant, withstanding up to 75 percent soil moisture depletion. The roots of pulses and legumes allow efficient soil moisture utilization.

Industrial agriculture has pushed food production to use methods by which the water retention of soil is reduced and the demand for water is increased. By failing to recognize water as a limiting factor in food production, industrial agriculture has promoted waste. The shifts from organic fertilizers to chemical fertilizers and the substitution of water-prudent crops by water-thirsty ones have been recipes for water famines, desertification, water logging, and salinization.

## 12.3 Green revolution: The harbinger of monocrop cycling

The advent of the Green Revolution pushed Third World agriculture toward wheat and rice production. The new crops demanded more water than millet and consumed three times more water than the indigenous varieties of wheat and rice. The introduction of wheat and rice has also had social and ecological costs. Their dramatic increase in water use has led to the instability of regional water balances. Massive irrigation projects and water-intensive farming, by adding more water to an ecosystem than its natural drainage system can accommodate, have led to water logging, salinization, and desertification. The recent study that was carried out by Navdanya has reported the ill effects of the imbalances in the use of water in the agro-ecosystem. In its publication ***Corporate Hijack of Water;*** it describes how World Bank, IMF and GATS- WTO rules are forcing water privatization and adversely affecting the livelihoods of the people.

In the Krishna basin, water logging at the Malaprabha irrigation project led to farmer rebellions. Before the introduction of the irrigation project, the semi arid had produced water-prudent crops such as *jowar* and *pulses*. The sudden climatic change, the intensive irrigation, and the cultivation of water-demanding cotton aggravated the problem. Intensive irrigation of black cotton soils, whose water retention capacity is very high, quickly created wastelands. While irrigation has been viewed as a means to improve land productivity, in the Malaprabha area, it has had the opposite effect.

The shift from rainfed food crops to irrigated cash crops like cotton in Andhra Pradesh was expected to improve the prosperity of farmers. Instead, it has led to debt. Farmers borrowed money from banks for land development and for the purchase of seeds, chemical fertilizers and pesticides. While farmers were struggling with unproductive land, banks were making payment demands. At the same time, irrigation authorities levied a development tax on water, known as a betterment levy. The latter increased from 38 cents to 63 cents per acre for *jowar*, and from 38 cents to over a dollar per acre for cotton. A fixed tax of 20 cents per acre was effective with or without water use.

Like wise, the Aral sea, the world's fourth-largest freshwater body, has been ruined by unsustainable agricultural activity. Rivers that recharge the lake are increasingly diverted toward the irrigation of 7.5 million hectares of cotton, fruit, vegetables, and rice fields. Over the past few decades, two-thirds of the water has been drained away, salinity has gone up six fold, and water levels have dropped by 20 meters. Between 1974 and 1986, the Syr Darya river never reached the Aral sea.

Many of the solutions proposed to be problem of agricultural water waste deny water for food production altogether. Industrial shrimp farming is a case in point. The most obvious and important impacts of industrial aquaculture are land and water salinization and drinking water depletion. Paddy fields once fertile and productive are turning into what local people call graveyards. This is true not just in India. In Bangladesh, too, where shrimp farming is widespread, the amount of rice production has dropped considerably. In 1976, the country produced 40,000 metric tons of rice; by 1986, production had plummeted to 36 metric tons. Thai farmers report similar losses, harvesting 150sacks of rice per year instead of the 300 sacks they were harvesting before the introduction of shrimp farms to the region.

The argument that genetic engineering will resolve the water crisis obscures two important points. First, peasants in drought-prone regions had bred thousands of drought-resistant crops, which were eventually displaced by the Green revolution. Second, drought resistance is a complex, multi-trait, and genetic engineers have so far not been successful in engineering plants that posses it. In fact, the GM crops currently in the field or in labs will aggravate the water crisis in agriculture. For instance, Monsanto's herbicide-resistant crops, such as its Round-Up ready soybeans or corn, have led to soil erosion. When all cover crops are killed by Monsanto's herbicide Round Up, rows of soya and corn leave soils exposed to tropical sun and rain.

Similarly, the heavily advertised Vitamin A- rich golden rice increases water abuse in agriculture. Navdanya has carried an in-depth study about the facts of the claims made by the multinationals. In their publication ***Vitamin A Deficiency:*** **Green Solutions vs Golden Rice** it was revealed that golden rice contains 30 micrograms of vitamin A per 100 grams of rice. On the other hand, greens such as amaranth and coriander contain 500 times more vitamin A, while using a fraction of the water needed by golden rice. In terms of water use, genetically engineered rice is 1,500 times less efficient in providing children with vitamin A, a necessary vitamin for blindness prevention. The golden rice promise is infact "a blind approach to blindness prevention."

The myth of water solution by way of GM crops obscures the hidden cost of the biotech industry – the denial of fundamental rights of food and water to the poor. Investing in indigenous breeding knowledge and protecting the rights of local communities are more equitable and sustainable ways to ensure access to water and food to all.

## 12.4 Navdanya's contribution in water conservation

Efforts are already on in the Navdanya's agro-ecological farm that aims to increase status of organic matter in soil agro-ecosystems. Their intiative may be described point wise as under:

- Soil organic matter is a storehouse of plant nutrients and a binding agent that influences soil erodibility and moisture holding capacity. Efforts are on to develop the soil organic matter base in the farms by using composting
- Crop residues on the soil surface helps in preventing excessive evaporation during early crop growth. The amount of water conserved in this way is directly related to the amount of residue present on the soil surface. This effort is being augemented by the process of mulching
- Increased infiltration of rainfall occurs when crop residue remains at or near soil surface. This process is being facilitated by green manuring and mulching.
- Most evaporation from soil occurs when the soil is wet. The presence of crop residues by tilling the straw of the previous crop protects the soil moisture
- Trees acts as a windbreak to reduce evaporation. For this farm forestry is being taken up in the bunds of farm fields.
- Earthworms are beneficial because they speed up recycling of crop nutrients from

surface residue and create large soil pores that help to improve water infiltration rates. For this vermi-composting unit is established on farm and the manure is periodically applied to the farm soil

- Preventing water loss by cultural practices such as bunds and soil working so that water collects into the water harvesting structures
- Division of land into compartments for easy workability and water harvesting.
- Land shaping, leveling according to slope.
- Adopting water harvesting for in situ conservation and by collecting water in the run-off tanks for future use.

## 12.5 Building the soil as a water reservoir by enhancing the water holding capacity of the soil

A scientific analysis of the soil in a study carried out in the Navdanya agro-ecological farm has validated the claim that moisture regime of a agroecosystem can be enhanced by organic farming practices. The experiment concentrated the build up of water holding capacity of the soil.

### *12.5.1 Water holding capacity (WHC %)*

The results of the study carried out in organically managed Navdanya farm showed 46% increase in water holding capacity in organic soil of Navdanya. The data showed that in chemical farming system WHC ranged from 28-33% whereas, in Navdanya farm it ranged from 42-47% refer Fig 12.1. The enhanced WHC is due to the presence of a beneficial microorganism as the soil has high organic matter in it signifying a healthy soil. The soils of chemicalised farming have a high fertilizer and pesticide concentration resulting in low build up of organic matter. This in turn has an adverse effect on the native soil flora and fauna, therefore showing a dry sandy soil with lesser ability to retain moisture.

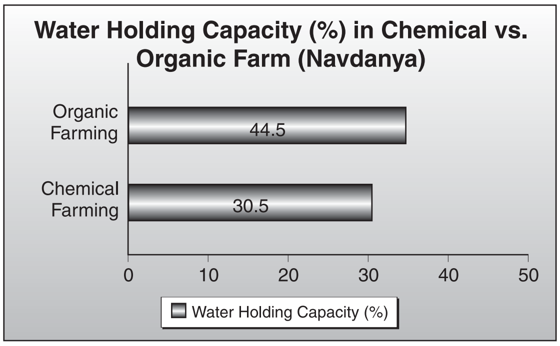



*Figure 12.1 Projected WHC values of soils of organic farm and chemicalised farms*

## 12.6 Traditional water harvesting system - mainstay in conservation of water

Traditional water conservation systems including Khadin and Johads in Rajasthan, Ahars and Pynes in Bihar, eris in Tamil Nadu, have given water security to agriculture in spite of rain as low as 167 mm in Rajasthan 200-600 mm in the semi arid Deccan.

### *12.6.1 The indigenous culture of water conservation*

Water is the basis of life. For the survival and sustenance of the farmer, the selection of crops should be strictly in accordance to the prevailing hydro-geo climatic regime of the region. The crops should be grown keeping in mind the water use efficiency and the resultant biomass production.

In ancient India, the rural people were very careful on the use of water. Water harvesting was a intrinsic part and parcel of Indian way of life. The very first sources of water for irrigation were canals. Canal irrigation existed in all parts of the country. In Punjab in particular the system of irrigation made the cultivation of wheat possible. It exists even today in many river basins and goes by various names: Nalas, Bandharas, and Kaluves. Cultivation using floodwaters were also developed. In Kerala, these floodwaters bring in prawns, which are cultivated along with the rice as a second crop.

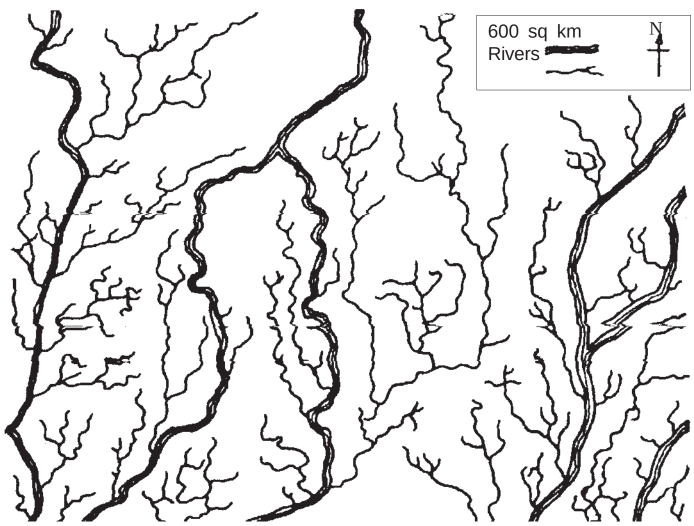
### *12.6.2 Wells*

They are also equally important sources of irrigation. They are the principle source of irrigation in many parts of the country such as in Uttar Pradesh. Nowadays, we can find wells that have been made by simple kachcha earth to have soils having heavy loam. These wells are lined with thick cables of straw and twigs, and could be constructed cheaply as the farmer got his material from the farm and available natural resources. The wells were worked with either by human or animal labour.

### *12.6.3 Ahars and Pynes of Bihar*

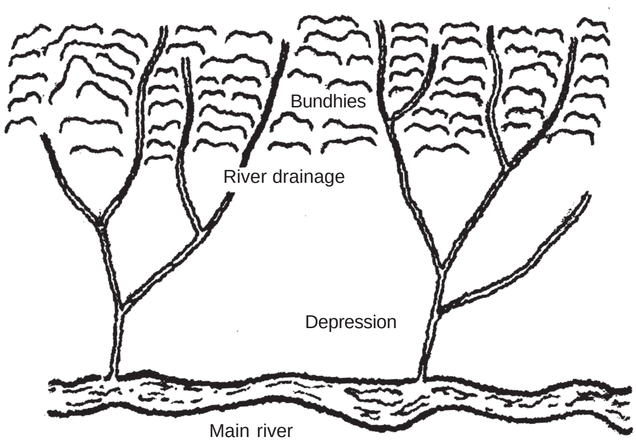
An example of indigenous water use was the widespread system of 'ahars' and 'pynes' used for irrigation of paddy fields in South Bihar as reported by Sengupta. An 'ahar' is constructed by erecting embankment 1 or 2 metres in height on the lower ground.

From the two extremes of this embankment two other embankment are constructed so as to project towards the higher ground, gradually diminishing in height as the ground level rises and ultimately ending at the ground level. Ahars were built on drainage rivulets to collect water.



The Pyne System

'Pynes' on the other hand were systems devised for utilizing the water, which flows through hilly rivers running from south to north and intersection the whole country, 'pynes' were laid off from



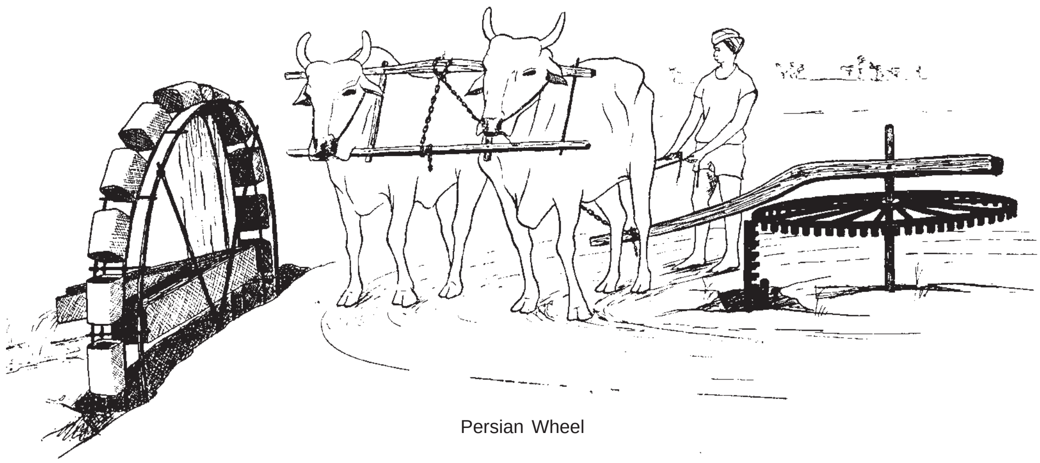

the rivers to carry water to agricultural fields.

### *12.6.4 Bundhies*

The Bundhies of Madhya Pradesh are built generally in a series and therefore capture every possible drop of rainwater. If there is a surplus, a waste weir is provided. There will generally be a sluice at the deepest part of the bundhies. The crop, which is grown in the bundhies after the water is drained, need not be irrigated till harvest.

### *12.6.5 Water lifting devices*

The various irrigation systems in turn led to the development of equally various water lifting devices. Water wheels were designed for better management of hydraulic resources – the araghatta or araghattaghatika, the Persian wheel.



Persian Wheel

Variations of the Persian wheel are found practically all over the world. In India, these devices are found predominantly in Punjab and in the western parts of the country. Constructions cost is very low. Wood being the principal material for the construction of the Persian wheel, each village had artisans who had thoroughly mastered the device.

In many areas, water is lifted from wells and canals using human energy. One such device used for raising water to a height less than one metre is the swing scoop or basket with two ropes on either side. Two or four persons hold the ropes on each side of the basket and swing it.

Water was a precious commodity and the whole community regarded it as a sacred entity.

## 12.7 Community management of water resources

Water is being a precious resource, has been kept in the public domain since time immemorial. The careful husbandry of water was the key to the survival of agricultural communities, and no one person was given the complete authority to oversee its maintenance and distribution. They were, instead managed by a variety of social organisations within the village community. Usually, the structure of such organisations included a collective of all the beneficiaries of irrigation works, and was headed by a leader.

In Maharashtra districts of the basis, such water committees managed the bandharas. In South Bihar, both the constructions and maintenance of water systems was collectively managed. In South India these practice was know as 'kudimarammath'.

### *12.7.1 The role of the community in deciding the cropping pattern*

The panchayats or other leaders of the tank irrigation committee have traditionally played an important part in agricultural production, including deciding what crops are to be planted. In the Panchayat-operated tanks of Karnataka, the panchayat decides at the beginning of the agricultural season, what crop will be grown in the entire command area by each and every farmer, irrespective of social or political status, so that the water requirements of the beneficiaries are fairly equal.

Again, in Talaku, the panchayat has insisted upon jowar and groundnut in the kharif season and pulses as the rabi crop.

But with the advent of British raj, manufacture and trade being high on their priorities led to the erosion of these traditional water harvesting structure that led to the downfall of Indian and the Indian farming system.

It is now the times to wake up from the slumber and stop exploitation of the scarce natural resources. The overexploitation and wasteful method of water usage can cause severe conditions like drought and famine. Water management and prudence in use is therefore is a survival imperative. In agriculture this prudence includes water use efficiency - Crops of water high water use, shifting towards water prudence, water harvesting structures.

CHAPTER XIII

# Prosperity Through Organic Farming

Organic farming is economically viable because:

- Reduction in the use of external inputs and increase in on farm organic inputs with the greatest potential to benefit the health of farmers and consumers
- More productivity through the incorporation of natural processes as nutrient cycles, nitrogen fixation, and pest-predator relationships into the agricultural production process
- Greater productive use of the biological and genetic potential of plant and animal species
- Improvement of the match between cropping patterns and the productive potential and physical limitations of agricultural lands to ensure long term sustainability of current production levels and
- Profitable and efficient production with emphasis on improved management and conservation of soil, water and energy, and biological resources.

During the past years, farmers have shown steadily increasing interest in organic farming. Many farmers who adopted organic farming methods early in this period were motivated by reasons relating to the health and safety of their families, consumers, and livestock, and by idealistic convictions about soil and land stewardship. More recently, as costs of chemicals and credit have increased and commodity prices have stagnated, thousands of conventional farmers have begun to search for ways to decrease input costs. "Low input farming" is the new, socially acceptable term for organic farming, and economic survival is the motivation for many newcomers.

A study by Roberts *et al.,* (1979) compared data from 15 organic farms in the western Corn Belt with USDA data on representative conventional farms in the same area. In most cases the net returns were greater on the organic farms. Both studies showed that production costs were longer on the organic farms.

Navdanya has done a study in the year 2002, on the cost benefit analysis of rice and Wheat in organic and chemical farming practices. The studies showed that net profits were higher in the organic farming system as compared to chemical farming. The data are presented below:

**Table 13.1 Cost benefit analysis of rice per acre in organic frming vs. chemical farming, dehradun (uttaranchal)**

| S.N. | *Activities (organic farming)* | *Cost (Rs.)* | *Activities (chemical faming)* | *Cost (Rs.)* |
|---|---|---|---|---|
| 1. | Nursery raising | 150 | Nursery raising | 160 |
| 2. | Land Management | 200 | Land Management | |
| | | | 2 disc harrow @ Rs. 150/acre | 300 |
| | | | 1 Leveler | 80 |
| | | | 1 Cultivator | 130 |
| | | | 1 Leveler | 80 |
| | | | Puddling | 200 |
| 3. | Transplantation cost | 450 | Transplantation cost | 450 |
| 4. | Fertilizer | - | Fertilizers | 200 |
| | | | 1.5 bag SSP | |
| | | | Urea 2 bags @ Rs. 225 | 450 |
| 5. | Weeding (Two Times) | 400 | Weedicide | 250 |
| 6. | Pesticides | - | Pesticides 3 Spray | 420 |
| 7. | Irrigation cost (3) @ Rs 40/hr for 8 hrs | 320 x 3 = 960 | Irrigation (4) @ Rs 40/hr for 8 hrs | 320 x 4 =1280 |
| 8. | Extra labour cost | 200 | Extra labour cost | 200 |
| 9. | Harvesting | 500 | Harvesting + Threshing | 400 |
| 10. | Threshing | 300 | | |
| 11. | Transportation | 200 | Transportation | 300 |
| 12. | Total Expanses | 3360 | Total Expenses | 4900 |
| 13. | Total Yield = 15 Qtl. Price @ Rs. 700 | 10,500 | Total Yield = 20 Qtl.Price @ Rs. 560 | 11200 |
| 14. | Straw Production 5 Qtl. Price @ Rs. 200/bigha | 1000 | Straw Production | Na |
| 15. | Total Income | 11,500 | Total Income | 11200 |
| 16. | Net Profit | 8140 | Net Profit | 6300 |

**Table 13.2 Cost benefit analysis of wheat per acre in organic farming vs. chemical farming, dehradun, uttaranchal**

| S.N. | *Activities (organic farming)* | *Cost (Rs.)* | *Activities (chemical farming)* | *Cost (Rs.)* |
|---|---|---|---|---|
| 1. | Land Management | | Land Management | 450 |
| | 2 cultivator @ Rs. | | 3 disc harrow @ Rs. 150/acre | 240 |
| | 200/acre | 400 | 3 leveler @ Rs. 80/acre | |
| 2. | Seeds 50 kg @ Rs. 6 | 300 | Seeds 45 kg @ Rs. 12 | 540 |
| 3. | Sowing cost | 200 | Drilling/sowing @ Rs. 120/acre | 120 |
| 4. | Fertilizer FYM | 1000 | Fertilizers DAP @ Rs. 425 | 425 |
| | | | Urea 2 bags @ Rs. 225 | 450 |
| 5. | Weeding manually (labour cost) | 200 | Weedicide | 350 |

| S.N. | Activities (organic farming) | Cost (Rs.) | Activities (chemical farming) | Cost (Rs.) |
|---|---|---|---|---|
| 6. | Pesticides | - | Pesticides | 400 |
| 7. | Irrigation cost | 160 x 2 = 320 | Irrigation 4 @ Rs 40/hr for 4 hrs | 160 x 4 = 640 |
| 8. | Extra labour cost | 200 | Total Labour cost | 200 |
| 9. | Harvesting + Threshing | 1200 | Harvesting + Threshing | 400 |
| 10. | Transportation | 200 | Transportation | 200 |
| 11. | Total Expenses | 4020 | Total Expenses | 4415 |
| 12. | Total Yield = 12 Qtl.<br>Price @ Rs. 875 | 10,500 | Total Yield = 18 Qtl.<br>Price @ Rs. 600 | 10,800 |
| 13. | Straw Production 12 Qtl.<br>Price @ Rs. 125/Qtl. | 1500 | Straw Production | Not used |
| 14. | Total income | 12000 | Total income | 10,800 |
| 15. | Net Profit | 7980 | Net Profit | 6385 |

**Table 13.3 Cost benefit analysis of wheat per acre in organic farming vs. chemical farming Place: Agra, U.P.**

| S.N. | Activities (organic farming) | Cost (Rs.) | Activities (chemical farming) | Cost (Rs.) |
|---|---|---|---|---|
| 1. | Land Management | | Land Management | |
| | In dry field 2 harrow | 300 | In dry field 2 harrow | 300 |
| | 2 cultivator | 280 | 2 cultivator | 280 |
| | 1 leveler | 140 | 1 leveler | 140 |
| 2. | Seeds 80 kg @ Rs. 7 | 560 | Seeds (hybrid) 80 kg @ Rs. 12 | 960 |
| 3. | Sowing | 180 | Sowing | 180 |
| 4. | Fertilizer | - | Fertilizer | |
| | | | I. Urea – 100 kg | 450 |
| | | | II. Zinc – 20 kg | 200 |
| 5. | Pesticides | - | Pesticides | 50 |
| 6. | Irrigation | 3000 | Irrigation | 3000 |
| 7. | Total Labour cost | 1500 | Total Labour cost | 1500 |
| 8. | Threshing | 1600 | Threshing | 1600 |
| 9. | Transportation | 200 | Transportation | 200 |
| 12. | Total Expenses | 7760 | Total Expenses | 8,860 |
| 13. | Total Yield = 20 Qtl.<br>Price @ Rs. 650 | 13,000 | Total Yield = 25 Qtl.<br>Price @ Rs. 600 | 15,000 |
| 14. | Straw Production 30 Qtl.<br>Price – @ Rs. 200/Qtl. | 6,000 | Straw Production 2.5 Qtl.<br>Price – @ Rs. 200 | 500 |
| 15. | Total Income | 19,000 | Total Income | 15,500 |
| 16. | Net Profit | 11240 | Net Profit | 6640 |

**Table 13.4 Cost benefit analysis of wheat per acre in organic farming vs. chemical farming Place: Lakhisarai, Bihar**

| *S.N.* | *Activities (organic farming)* | *Cost (Rs.)* | *Activities (chemical farming)* | *Cost (Rs.)* |
|---|---|---|---|---|
| 1. | **Land management (plough)** | Land management | | |
| | **2 Days @ Rs. 150** | 300 | **I. 3 harrow** | 450 |
| | | | **II. 2 leveler** | 220 |
| | | | **III. 1 cultivator** | 120 |
| 2. | Seeds 50 kg @ Rs. 6 | 300 | Seeds (hybrid) 50 kg @ Rs. 12 | 600 |
| 3. | Sowing | 200 | Sowing (Drill) | 130 |
| 4. | Fertilizer (Compost) | 1000 | Fertilizer | |
| | | | I. Urea (2 bags ) | 440 |
| | | | II. DAP (2 bags) | 425 |
| 5. | Pesticides | - | Pesticides | 70 |
| 6. | Weedicides | - | Weedicides | 200 |
| 7. | Irrigation | 200 | Irrigation | 200 |
| 8 | Total Labour cost | 450 | Total Labour cost | 700 |
| 9 | Harvesting + Threshing | 800 | Harvesting | 300 |
| 10. | Transportation | 200 | Transportation | 200 |
| 11. | Total Expenses | 3450 | Total Expenses | 4055 |
| 12. | Total Yield = 14 Qtl. | | | |
| | Price @ Rs. 900 | 12,600 | Total Income | 12,000 |
| 13. | Straw Production 14 Qtl. | | | |
| | Price – @ Rs. 200/Qtl. | 2800 | Net Profit | 7,945 |
| 15. | Total Income | 15,400 | | |
| 16. | Net Profit | 11950 | | |

**Table 13.5 Cost benefit analysis of wheat per acre in organic farming vs. chemical farming Place: Moradabad (U.P.)**

| *S.N.* | *Activities (organic farming)* | *Cost (Rs.)* | *Activities (chemical farming)* | *Cost (Rs.)* |
|---|---|---|---|---|
| 1. | Land management | 150 x 3 = 450 | Land management | |
| | 3 cultivator @ Rs. 150 | | I. 3 disc harrow @ Rs. 150/acre | 450 |
| | | | II. 3 leveler @ Rs. 80/acre | 240 |
| | | | III. 1 cultivator + 1 | |
| | | | leveler 130+80 | 210 |
| 2. | Seeds (deshi) | | Seeds 45 kg | |
| | 50 kg @ Rs. 6 | 300 | @ Rs. 12 | 540 |
| 3. | Sowing | 200 | Drilling @ Rs. 120/acre | 120 |
| 4. | Fertilizers Compost | 1000 | Fertilizers | |
| | | | **I. DAP @ Rs. 425** | 425 |
| | | | Urea 2 bags @ Rs. 225 | 450 |
| 5. | Weedicide | - | Weedicide (2-4-D, Isoproton) | 200 |

| S.N. | Activities (organic farming) | Cost (Rs.) | Activities (chemical farming) | Cost (Rs.) |
|---|---|---|---|---|
| 6. | Pesticides | - | Pesticides (Monocrotophos) | 50 |
| 7. | Irrigation | 600 | Irrigation | 1200 |
| 8. | Extra Labour cost | 400 | Extra Labour cost | 400 |
| 9. | Harvesting | 600 | Harvesting | 400 |
| 10. | Transportation | 200 | Transportation | 200 |
| 11. | Total Expenses | 3750 | Total Expenses | 4885 |
| 12. | Total Yield = 10 Qtl.Price @ Rs. 700 | 7000 | Total Yield = 18 Qtl. Price @ Rs. 600 | 10,800 |
| 13. | Straw | 1000 | Straw | - |
| 14. | Total Income | 8000 | Total Income | 10,800 |
| 15. | Net Profit | 4250 | Net Profit | 5915 |

**Table 13.6 Cost benefit analysis of rice per acre in organic farming vs. chemical farming Place: Moradabad (U.P.)**

| S.N. | Activities (organic farming) | Cost (Rs.) | Activities (chemical farming) | Cost (Rs.) |
|---|---|---|---|---|
| 1. | Nursery | 160 | Nursery | 160 |
| 2. | Land Management | 600 | Land Management | |
| | | | 2 disc harrow @ Rs. 150/acre | 300 |
| | | | 1 leveler @ Rs. 80/acre | 80 |
| | | | 1 cultivator | 130 |
| | | | 1 leveler | 80 |
| | | | 1 puddler | 300 |
| 3. | Transplantation | 550 | Transplantation | 600 |
| 4. | Fertilizers | - | Fertilizers **SSP 1.5 bags** | 300 |
| | | | Urea 2 bags @ Rs. 225 | 450 |
| 5. | Weeding | 500 | Weedicide | 180 |
| 6. | Pesticides | - | Pesticides | 420 |
| 7. | Irrigation (3) @ Rs. 40/hr for 15 hrs. | 1800 | Irrigation (4) @ Rs. 40/hr for 20 hrs | 3200 |
| 8. | Extra Labour cost | 400 | Extra Labour cost | 400 |
| 9. | Harvesting | 700 | Harvesting | 500 |
| 10. | Transportation | 200 | Transportation | 200 |
| 11. | Total Expenses | 4910 | Total Expenses | 7300 |
| 12. | Total Yield = 12 Qtl. Price @ Rs. 700 | 8400 | Total Yield = 18 Qtl. Price @ Rs. 600 | 10,800 |
| 13. | Straw | 600 | Straw | - |
| 14. | Total Income | 9000 | Total Income | 10,800 |
| 15. | Net Profit | 4090 | Net Profit | 3500 |

## 13.1 Recent evidence from certified and non-certified organic systems in developing countries

The University of Essex, in the United Kingdom, recently completed an audit of progress towards agricultural sustainability in 208 projects in 52 developing countries (Pretty *et al.,* 2002). These projects included both integrated and near-organic systems (179 cases), and certified and non-certified organic systems (29 cases). These organic cases comprised a mix of food, fibre and beverage based systems of agriculture, with 154-742 households farming 106 197 hectares (Table 13.7). The average area per household is small (0.7 ha), as many of the projects involve small-scale organic vegetable production.

This audit indicated that promising improvements in food production are occurring through one or more of four mechanisms:

- Intensification of a single component of the farm system - such as home-garden intensification with vegetables and trees.
- Addition of a new productive element to a farm system - such as fish in paddy rice - that boosts the farm's total food production, income, or both but that does not necessarily affect cereal productivity.
- Better use of natural capital to increase total farm production, especially water (by water harvesting and irrigation scheduling) and land (by reclamation of degraded land), enabling growth of additional new dryland crops, increased supply of water for irrigated crops, or both.
- Improvements in per-hectare yields of staples through introduction of new regenerative elements into farm systems (for example, integrated pest management) or locally appropriate crop varieties and animal breeds.

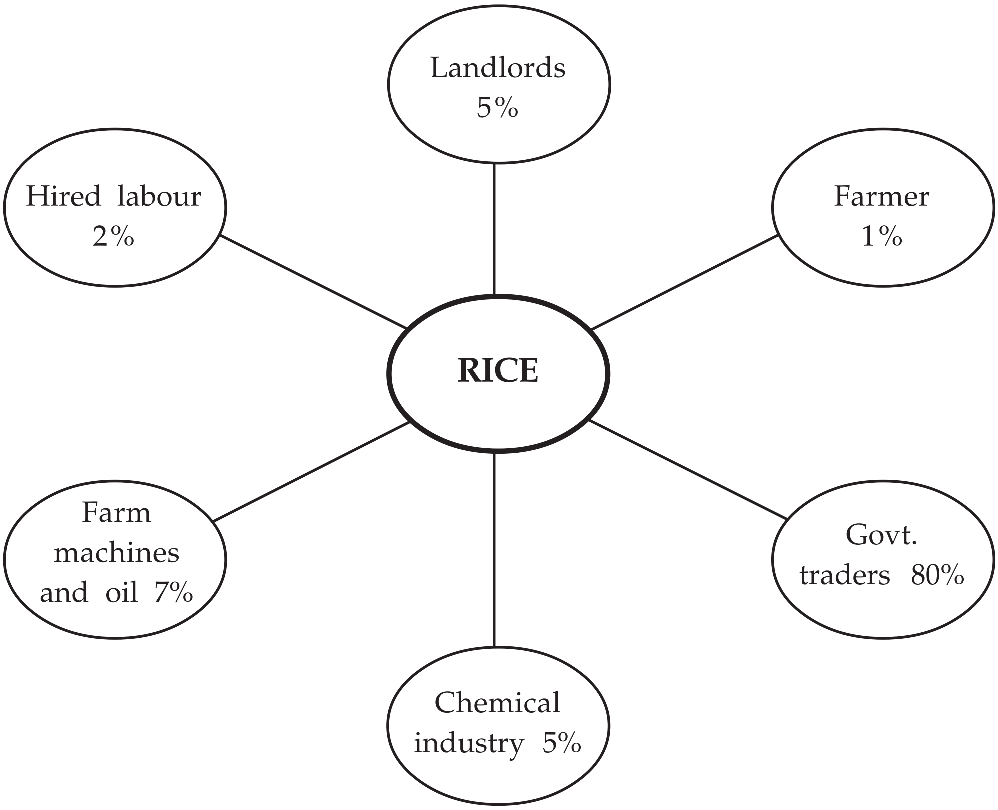
In all cases where reliable data has been reported, increases in per hectare productivity for food crops and maintenance of existing yields for fibre have been shown. This is counter to the popular myth that organic agriculture cannot increase agricultural productivity (Borlaug, 1994a, b; Avery, 1995), though what we do not yet know is whether a transition to organic agriculture, delivering greater benefits at the scale occurring in these projects, will result in enough food to meet the current food needs in developing countries, let alone the future needs after continued population growth and adoption of more urban and meat-rich diets. But what we are seeing is highly promising. There is also scope for additional confidence, as evidence indicates that productivity can grow over time if natural, social and human assets are accumulated. These findings are similar to those of McNeely and Scherr (2001b) and Parrot and Marsden (2002) whose recent review of eco-agriculture in both developing and industrialised countries has also indicated that there are novel ways both to feed the world and to save biodiversity.

**Table 13.7 Summary of scale and impacts of certified and non-certified organic projects and initiatives**

| | *Country* | *Project* | *Number of farm households* | *Area under organic agriculture (ha)* | *Changes in productivity* |
|---|---|---|---|---|---|
| 1. | Bolivia | Prodinpo integrated development programme | 2000 | 1000 | Potato yields from 4 to 10-15 t/ha |
| 2. | Brazil | AS-PTA alternative agriculture | 15000 | 60000 | Bean yields up 50-100% |
| 3. | Brazil | Agroecology in Zona da Mata | 215 | 50 | Coffee - nd |
| 4. | Cameroon | Macefcoop organic coffee | 600 | 300 | Coffee - nd |
| 5. | Chile | CET organic vegetable gardens | 10 | 5 | Vegetables, 20-30 kg per month |
| 6. | Cuba | Organic urban gardens | 26000 | 8000 | Total production up from 4000 to 700000 t/yr |
| 7. | Dominican Republic | Plan Sierra soil conservation | 2000 | 1000 | Maize - nd |
| 8. | Egypt | SEKEM biodynamic cotton | 150 | 2000 | Cotton from 2.25 to 3.0/t ha |
| 9. | Ethiopia | FAO Freedom Hunger | 2300 | 2150 | Sweet potato yields up from 6 to 30 t/ha |
| 10. | Ethiopia | Cheha integrated rural development | 12500 | 5000 | Cereal yields up 60% |
| 11. | Guatemala | San Jose Poacil ADECCA | 1450 | 1260 | Mixed crops - nd |
| 12. | India | SPEECH, Tamil Nadu | 500 | 409 | New rice crop in dry season |
| 13. | Kenya | Manor House Agriculture Centre | 70000 | 7000 | Maize yields from 2.25 to 9 t/ha; new vegetable crops |
| 14. | Kenya | C-MAD programme | 500 | 1000 | Maize from 2 t/ha to 4 t/ha |
| 15. | Kenya | Mumias Education for Empowerment project | 2069 | 217 | Beans/groundnut yields from 300 to 600 kg/ha |
| 16. | Kenya | Push-pull pest management | 300 | 150 | Maize yields up 60% |
| 17. | Lesotho | Machobane farming systems | 2000 | 1000 | Whole system productivity improved |
| 18. | Malawi | Small-scale aquaculture | 200 | 10 | New fish crops |
| 19. | Mexico | ISMAM organic coffee | 1200 | 1000 | Coffee - nd |
| 20. | Mexico | UCIRI fair trade and organic coffee | 4800 | 5000 | Coffee yields from 300-600 kg/ha to 601-1200 kg/ha |
| 21. | Nepal | Community welfare and development | 600 | 250 | Maize and rice yields up citrus up from 1.2 to 1.6 t/ha |
| 22. | Nepal | Jajarkot permaculture Programme | 580 | 350 | Maize and rice yields up (nd), new vegetable crops |
| 23. | Pakistan | Sindh Rural Women's Uplift Group | 5000 | 2500 | Mango yields from 7.5 to 22.5 t/ha; citrus up from 12 to 30 t/ha |
| 24. | Senegal | Rodale Regenerative Agriculture Research Centre | 2000 | 2000 | Millet/sorghum yields from 0.34 to 0.6-1.0 t/ha |
| 25. | Senegal | ENDA organic cotton | 523 | 233 | Cotton yields - no change at 300 kg/ha |
| 26. | Tanzania | GTZ organic cotton | 134 | 778 | Cotton yields - no change at 300 kg/ha |
| 27. | Zimbabwe | Chivi Food Security Project | 500 | 600 | Sorghum/millet yields doubled; new vegetable crops |
| 28. | Zimbabwe | Silveira House | 1211 | 735 | New vegetable crops |
| 29. | Zimbabwe | Zambezi Valley organic cotton | 400 | 2000 | Cotton - nd |
| | | Total | 154742 | 106 197 | |

(nd = no confirmed data on yields)

## 13.2 Chemical farming: The losing economy




Lockeretz et at. (1978) compared the economic performance of 14 organic crop/ livestock farm in the Midwest with that of 14 conventional farms. The study farms were paired on the basis of physical characteristics and types of farm enterprises. The market value of crops produced per unit area was 11 percent less on the organic farms. But since the cost of production was also less, the net income per unit area was comparable for both systems. Berardi (1979) compared 10 organic and 10 conventional farms in New York and Pennsylvania for returns from wheat (*Triticum aestivum*) production only. When cash operating costs alone were included, the returns were higher on the organic farms.

A 1984 survey of the members of the Regenerative Agriculture Association offered further information on the economic performance of organic methods compared to conventional methods. Of 213 respondents, 88 percent said their net income either stayed the same or increased when they began farming with fewer purchased inputs, while 12 percent said net income declined.

A Nebraska study (Helmers *et al.*, 1984) attempted to measure the performance of a fully organic system, so the first three years of data, which represented a conversion period from conventional to organic practices, were excluded from the analysis. Animal manure was available, but other aspects of the livestock operation were excluded from the economic analysis. Six possible cropping systems were considered three organic rotations, two conventional rotations, and continuous corn (*Zea mays*). The organic systems had the lowest costs of production, and all rotational systems performed better than continuous corn. The scenario most representative of an organic farm assumed that straw was sold and that the cost of manure was equal to application costs only. With this scenario, the returns were comparable to those from the conventional rotations.

During the conversion period, organically produced crops are vulnerable to weeds and nitrogen deficiences. However, once organic practices are established, the crops are often less vulnerable to drought and other natural disasters than conventionally grown crops. Organically farmed soils absorb more of the available rainfall, providing protection from drought (Cacek, 1984). Because organic farmers grow a greater diversity of crops, the entire production on a farm is not vulnerable to the same pests or seasonal weather events. If there is a total crop failure, organic farmers suffer fewer economic losses because they have invested less in purchased inputs.

**Table 13.8 Inputs of technologies used in traditional and "modern" conventional farming systems**

| | *Traditional agriculture* | *Modern agriculture* |
|---|---|---|
| **Land** | Small (<1-5 ha) | Large (10-100 ha or more) |
| **Tools** | Simple | Complex: tractors and imple meets, threshers, combine harvesters, etc. |
| **Crops** | Many species (5-80), land races, no genetic improvement, wide genetic base | Few species (1-3), improved narrow genetic base |
| **Animals** | Several species (2-5) | Usually 1 or 2 species |
| **Labour** | Manual, human energy, or animal power | Mechanical, petroleum fuels, electrical energy |
| **Soil fertility maintenance** | Fallows, ash, organic manures | Inorganic fertilizers, sometimes manures, soil amendments, e.g. lime and gypsum |
| **Weed control** | Manual, cultural | Mechanical, chemicals (herbicides and petroleum-based products) |
| **Pest and disease management** | Physical/cultural | Mainly mechanical, chemicals, insecticides, fungicides, bactericides, nematocides, rodenticides |
| **Crop management** | Manual | Growth regulators for defoliation, control of flowering, fruit drop, etc. |
| **Harvesting** | Manual or with simple tools | Mechanical, tractors plus implements: pickers, balers, threshers, combine harvesters |
| **Post-harvest handling and drying** | Simple sun-drying and over fires | Mechanical forced-air artificial drying using petroleum fuels, sometimes refrigeration |

***Source:*** *Okigbo (1988). Okigbo, B.N. 1986. Cropping systems and land degradation in the tropics. Ibadan: IITA. Mimeo.*

The diversity of crops on organic farms can have other economic benefits. Diversity provides some protection from adverse price changes in a single commodity. Diversified farming also provides a better seasonal distribution of inputs.

Organic farmers need to borrow less money than conventional farmers for two reasons. First, organic farmers buy less input such as fertilizer and pesticides. Second, costs and income are more evenly distributed throughout the year on diversified organic farms.

## 13.3 Future trends

The relative economic performance of organic farming and conventional farming is sensitive to the ratio of input costs to the value of outputs. Both organic and conventional farmers are vulnerable to fluctuations in both input and output prices, but the effect of a given change will differ between the two farming systems.

Volatile changes in commodity prices can be expected to have greater impacts on conventional than organic farmers. Even where conventional producers have higher average yields; assuming constant production costs, price increases will increase the net returns of conventional farmers by a greater proportion than those of organic farmers. Conversely, price decreases will decrease conventional returns by a greater proportion than organic returns. Differential price changes (increases in some commodity prices and decreases in others) would also tend to have effects of greater magnitude, whether positive or negative, on conventional farmers, since they depend on fewer crops for their income. Because organic systems are more diversified, the effects of differential price changes on income would partially offset each other.

Increases in the cost of variable inputs would be less damaging to organic farmers because they purchase less input. The most likely price increases in the near future will be for energy, with consequent increases in the price of synthetic nitrogen fertilizers. Organic farmers use less energy than conventional farmers, primarily because they use less synthetic nitrogen. In the Lockeretz (1978) study the organic farmers used 60 percent less energy per unit of value of production. The Berardi (1978) study showed that conventional wheat farmers use 48 percent more energy for 29 percent higher yields.

Chemical agriculture goes hand in hand with monocultures. Most chemical agriculture is under 7 globally traded crops. The price farmers are receiving for these crops are dramatically declining because of globalization. Organic agriculture brings price stability for farmers by diversifying crops. In 2003, farmers of M.P. were encouraged to grow potatoes. The cost of cultivation was Rs. 255/Qtl. The price farmers received were Rs. 40/Qtl. leading to a loss of Rs. 200 per Qtl. and debts of 4-5 lakh per acre. Farmers with diversified cropping patterns are not vulnerable to such price collapses.

Chapter XIV

# Beyond Monocultures of the Mind:
## *From false Diversification to real Freedom*

The green revolution and Industrial Agriculture are based on monocultures. Monocultures are an ecological and economic disaster. Monocultures destroy the soil and water, they are a recipe for the spread of pests and diseaes. And economically monocultures push prices downwards through a combination of market dependency on monopolies buyers, and creation of artiicial surpluses in the monoculture commodity (while there is a real scarcity in other farm produce, including food that farm families need for household food security). Monocultures are anti nature, anti farmers. They serve only the interests of commercial interests.

The green revolution monocultures were kept financially viable for farmers in the short run through subsidies for inputs, and minimum support price (MSP) for guaranteed government procurement. Globalization and trade liberalisations are dismantling both the input support and market support. Meantime, the globalizaion led new agriculture policy, which promotes corporatisation of agriculture, is replacing green revolution monoculture of wheat and rice with monocultures of cash crops such as vegetables and cotton aimed at experts. While shift from food staples to export crops is justified in the name of "diversification", monoculture of tomatoes or potatoes or gheekinis is not "diversification". It is a false diversification because it does not introduce biodiversity in farming and it does not diversify farmer's options. It replaces monocultures of wheat or rice with monocultures of tomatoes and potatoes. It perpetuates the mentality of the "monoculture of the mind", while adding new vulnerabilities and new risks for ecosystems and rural producers. Firstly, wheat and rice provide staple foods, can be consumed by farm families and can be stored tomatoes and potatoes do not ensure food security for farming households or the country. Unlike food grains they are perishable and hence reduce the producers more vulnerable to a downward push of prices by trading interests.

(New agriculture policy – Special Export Zones. Myth: Export benefits Third World Producers).

### Subsidies in 2002-2003 budget:

- Seeds
- Cold Storage

- Agroprocessing
- Transport
- Export

## Real diversification

1. Biodiversity
   a. Conservation and Ecological security
   b. Food security
   c. Income security
   d. Livlihood security

Real diversification, unlike the false diversification of cash crop monocultures, brings back diversity into farming systems. Biodiversity is the basis of ecological security, food security and income and livlihood security. Biodiversity provides internal inputs, saving farmers from debts and suicides. Integrated farming based on develop crops, livestock and agroforestry is more resilient and able to withstand ecological and economical vulnerability.

Real diversification also allows producers to simultaneously increase in ecological security, food security and income and livlihood security. By growing diverse crops, farmers grow what they need for food consumption while also growing crops for marketing. Under real diversification, the producers, under false diversification it is controlled by the trader shape the market. Diversified production increases producer choices and reduces vulnerability to exploitation by traders because the farmers sustenance needs are met by self-production and farmers are not desperate to sell at any price. By not depending on a single crop for marketing, farmers also increase their bargaining power in the market place. Finally, in a diversified internal input system, farmers are free and independent producers. Such a system is characterised by

1. Farmers as corporate seefs
2. High costs of inputs
3. Low price for produce.

This is a recipe for a suicidal economy which is pushing farmers to suicides with increasing debts from rising production costs and declining prices for farm produce, and farmers trapped in cycles of dependency for non renewable seeds, toxic chemicals, intensive irrigation, and closed markets

(Case study of False Diversification, Potatoes in UP, Dr. Vandana Shiva)

(Case study of Real Diversification, Punjab Farmers)

## Conclusion:

Organic farming is a sophisticated alternative agricultural system. Ample data exist to conclude that it can compete economically with convention farming. Further research is needed on the economics of organic farming with vegetables and horticultural crops and in other geographic regions. Particular attention should be given to optimum approaches for conversion to organic farming. Information needs of organic farmers should be surveyed and information delivery systems should be tailored to meet those needs.

Organic farming benefits society substantially by reducing pollution and flooding; conserving energy, soil, nutrients, fish, and wildlife; reducing federal costs for grain price supports; and insuring the supply of food for future generations. Policy makers also need information on the impact of organic farming on international trace, input suppliers, the food marketing chain, and rural communities. In areas where organic farming is known to be economically feasible, policy barriers to conversion should be identified and evaluated. Organic farming is an attractive alternative for both farmers and policy makers. With the development and delivery of better information, both will be able to make the best use of this alternative.

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