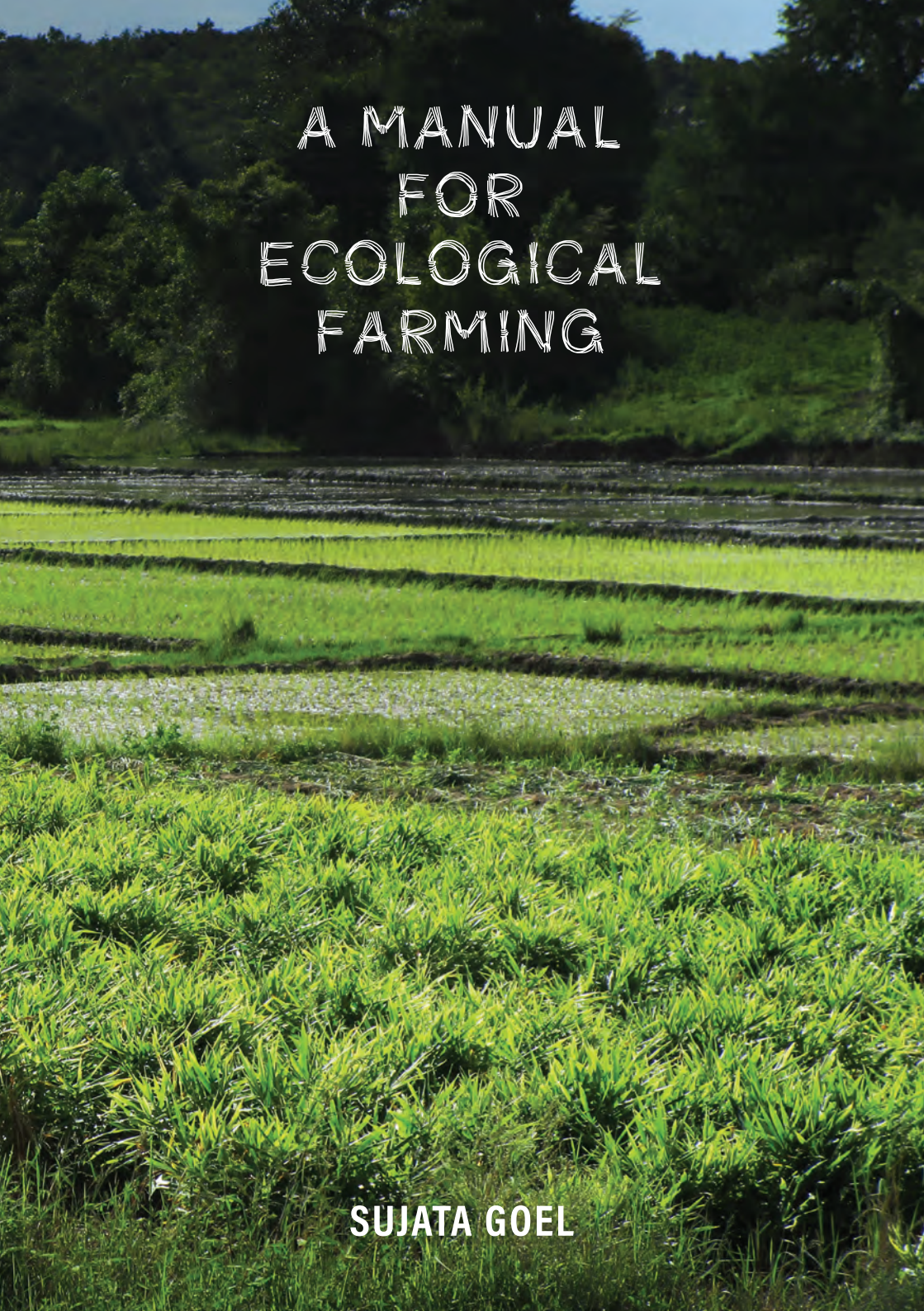

A MANUAL FOR ECOLOGICAL FARMING

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The Manual for Ecological Farming has been prepared as a collaboration between **OFAI, WAPRED and EARTH CoLab**

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Index

1. WHY ORGANIC FARMING?

Organic Farming nurtures living soils. Agricultural practices across the world have impacted the ecology of our planet in such severe and violent ways, that unless we change to a more ecological path, our soils and biodiversity will be irreparably destroyed and lost to world.

Ecological Farming allows for cultivating crops along sustainable principles, regenerating ecosystem services like replenishing soil humus and nutrients, water bodies, and conservation of local biological diversity.

The challenge is to achieve a mainstream productive food system which is both sustainable and regenerative.

2. CRAFTING YOUR LAND AND WORKING WITH IT

Agriculture is the largest human activity, and although its beginnings have been traced back to over 10,000 years, it is during the past 200 years that conventional practices have drastically changed our landscape, water bodies, climate and soil conditions. In many regions, farmers have abandoned their lands on account of desertification, soil erosion, poisoning of water bodies, loss of biodiversity and worst, increasing toxicity to all living beings.

There are thousands of individuals and communities across the world who have moved beyond conventional agriculture to work towards regeneration and conservation through improved soil management practices, reviving habitats, water bodies to improve local biodiversity, restore forests and wetlands to bring safety into our foods again.

REGENERATIVE FARMING AND GOOD AGRONOMIC PRACTICES

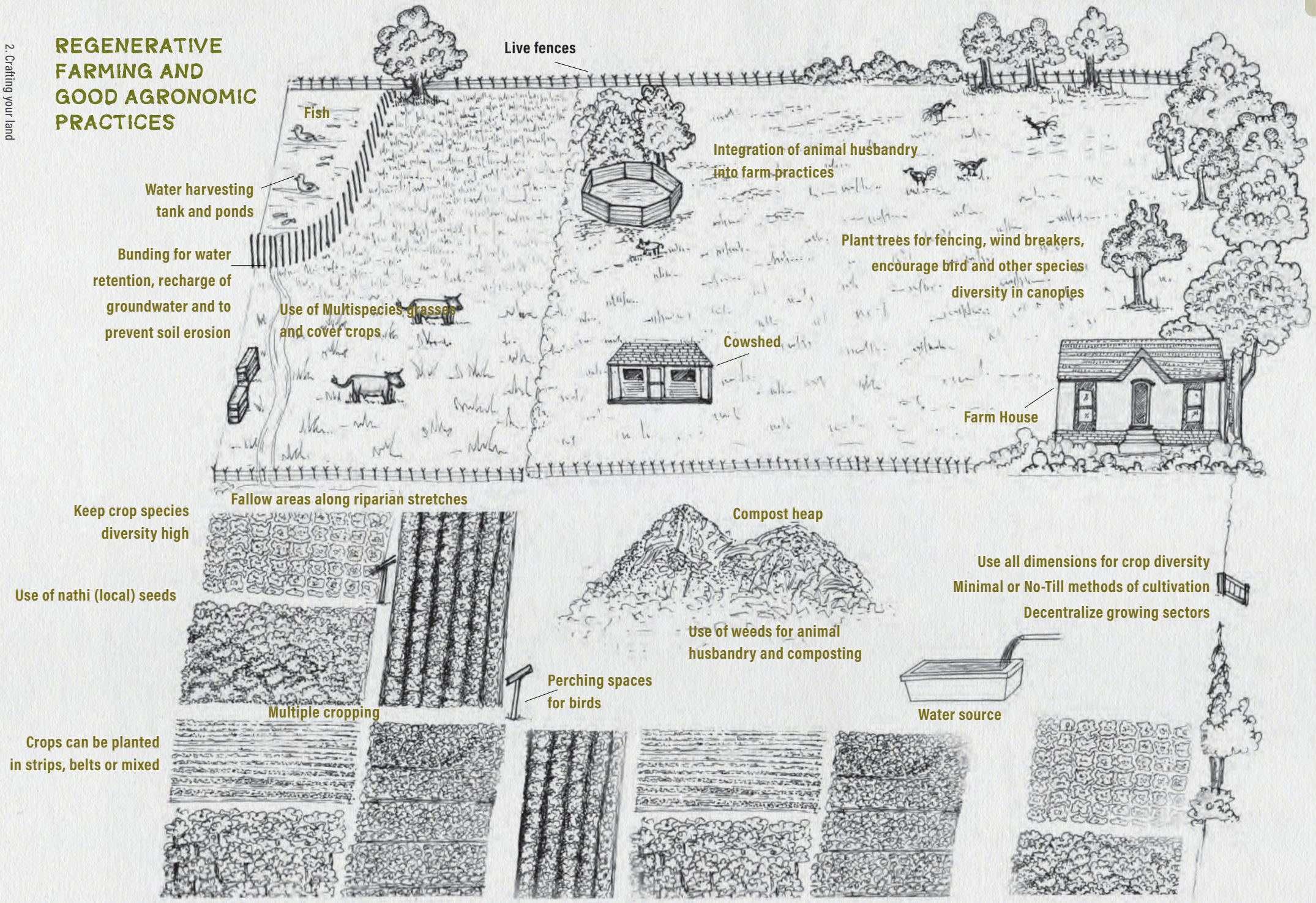


Figure 1: Illustration shows how sustainable agronomic practices can be incorporated into farming ecosystems.

INTEGRATION OF ANIMAL HUSBANDRY

Animals are intrinsic to organic farms. Their gut microbes have evolved to digest green and other organic matter to simpler compounds. Introduction of these microbes through animal waste into the farm composting systems accentuates compost quality and reduces composting time.

Figure 2a: Livestock at Mojo Plantation

Figure 2b: Farm animals contribute far more to the agroecosystem than just providing food and manure; goats graze to keep weeds in check, turkeys are effective waste disposers, chickens work the soil and can convert highly clayey ones into soft friable soils ideal for growing vegetables and other crops. They also feed on grubs which decreases the need for pest control. Geese are vociferous watchdogs and keep the water bodies clean. All together, they add to the functional beauty of any farm.

3. ALL ABOUT COMPOSTING

Composting biomass generated on the farm is the most effective way of returning humus and nutrients to the soil. This is facilitated by soil inhabitants like earthworms, beetles, grubs, etc. followed by bacterial and fungal microbes. Microbes are natural sources of enzymes which can act upon organic matter both in the presence and absence of oxygen, breaking down large complex molecules into simpler compounds that plants can take up.

Figure 3: Humus-enriched soils enable good germination and plant growth

METHODS

Composting can be done anywhere, with any organic matter. It can be done on a small scale for household needs, or scaled up for use on big farms. Microbes release enzymes which breakdown and mineralise big organic fragments into small molecules which add to the soil nutrient pool. There are several methods by which this can be facilitated.

On a farm scale, composting of organic matter requires layering of green manures, wood ash, oil cakes, animal waste (dung from cattle, goats, horses or poultry, fish meal, blood or bone meal from abattoirs, any rich source of protein and nutrients).

Figure 4a: Compost Mixing

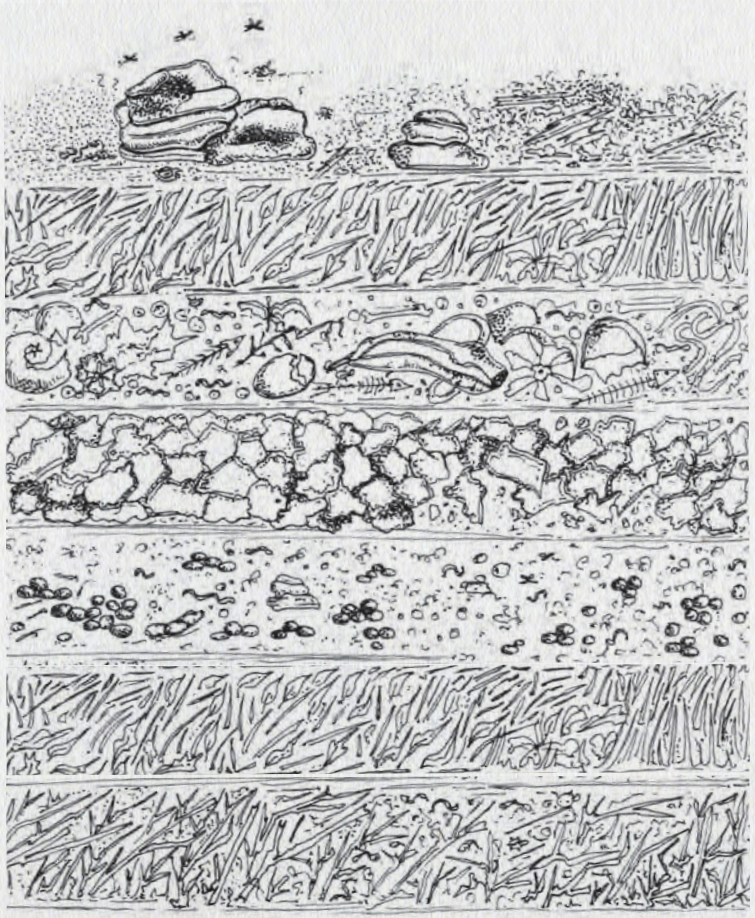


Figure 4b: Expanded compost heap

Addition of agrichemicals to the soils destroy all microbial life, reducing the land to a barren state.

Compost mixing

Ready for application

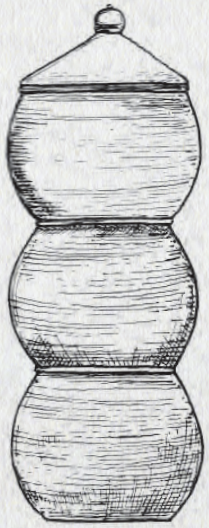
Applying compost to base of cardamom plant, followed by mulching

Mixing wood ash into crop beds (ash is a good source of potash, phosphates, minerals).

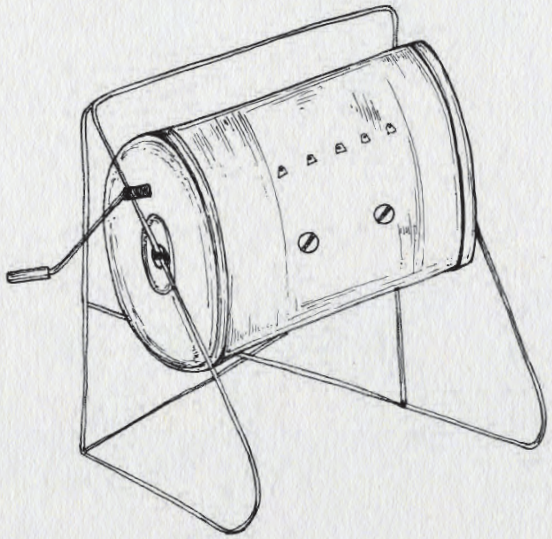
Figure 5a: Applying compost to plants

Figure 5b: Composting cycle

On a small scale, organic waste is introduced into drums, earthen containers, heaped on the ground, or in pits. Drums allow for rotation to accelerate oxygenation thereby speeding up the composting period. Innovative ways to compost are innumerable.



Earthen Pots



Composting Drum

Figure 6:

Bacteria and fungi have a remarkable ability to enzymatically mineralize organic matter, and ecological farming takes maximum advantage of this to contribute to a healthy growing medium for the cropping systems.

ENHANCING COMPOST

The quality of compost can be enhanced through addition of Biochar.

Biochar is made by incomplete combustion (pyrolysis) of waste wood or any biomass in an oxygen-limited environment. It is one of the few carbon-negative forms of energy available today, meaning that it sequesters carbon underground so as to reduce the concentration of greenhouse gases in the atmosphere.

High concentrations of nutrients get adsorbed onto the surface which contributes to enriching the compost. The biochar activated-compost enhances the ion exchange capacity of the soil, improves its porosity and texture, and increase the mycorrhizal populations, resulting in a slow release of nutrients to the plants over time.

Biochar drum is packed with waste wood fragments and lit from top

Biochar is ready in 45 min after ignition under partial oxygen conditions

Biochar is pulverized, soaked in liquid manures to enhance its nutrient absorbing quality, then mixed into compost.

Making biochar in the field without drum

Figure 7: Making Biochar

Biodigesters

Composting of biomass using biodigesters can be used to generate biogas. This is a microbial process under anaerobic conditions, during which a mixture of methane and carbon dioxide are released. The digested slurry, which is a by-product of the process, can be added directly to the field as an excellent manure and soil conditioner. It can also be added to compost to enhance its quality and reduce the composting process as many complex molecules have already been broken down.

Figure 8a: Constructing a biogas dome

Figure 8b: Cowdung for biogas

Figure 8c: Biogas plant

HOW IT WORKS

MYCOMAGICIANS

Unspoilt soils are inhabited by fungi. They are the Mycomagicians of the soil. These may be visible above ground in diverse and beautiful forms. Some are saprophytic and play and important role in releasing nutrients from dead wood, and other decaying matter.

Many fungi send up fruiting bodies described as bracket fungi or mushrooms which bear spores which help spread the fungi across the fields. Fungi grow by means of their mycelium in all directions. This is the "communication network" of the soil.

Figure 9: Fungal mycelium grows in all directions

Bracket fungi are significant detritus feeders which break down woody and other decaying matter

Bracket fungi promote wood decay

Bracket fungi have various forms

Fungal diversity enhances the resilience of the soils and crops

Figure 10: Different forms of Fungi

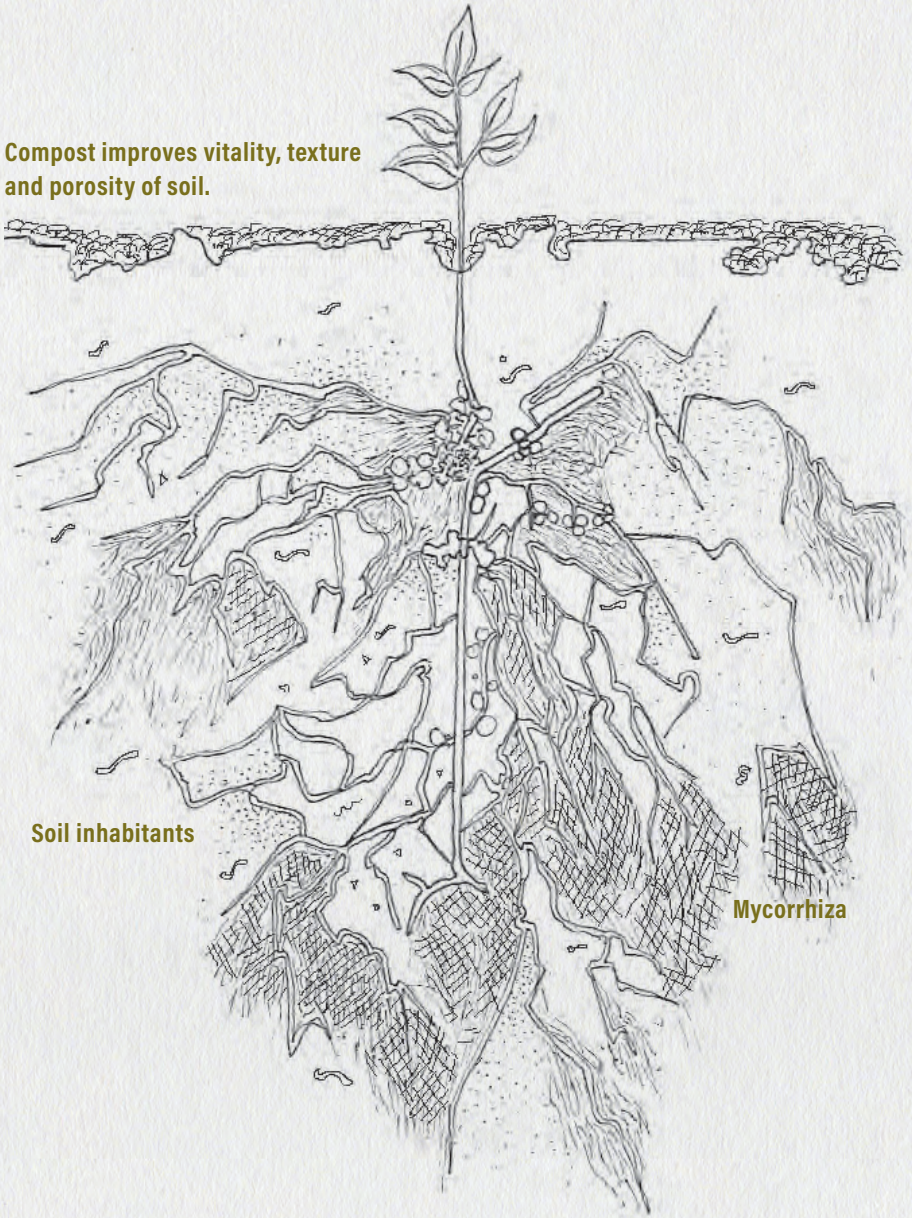


Figure 11: The roots are intimately associated with fungal mycelium

Adding compost enhances the humus and moisture in the soils creating the perfect environment for encouraging microbial and other biodiversity. Fungi multiply and their mycelia get intimately associated with the roots of plants (Fig.11). These are known as Mycorrhiza, and may remain on the surface (ectomycorrhizal) or penetrate the root cells (endomycorrhizal) (Fig 12). Their presence indicates the health of the soil and plays a vital role in nutrient uptake. Both fungi and bacteria secrete enzymes which break the compost down into simpler compounds which add to the soil nutrient pool. Mycelia can also directly transfer (inter-cellular) soluble nutrients to the plant through the root hairs. Some macronutrients essential for optimal plant growth like phosphates and iron are often present in forms unavailable to plants. Mycorrhiza secrete enzymes which solubilize such macronutrients resulting in enhanced uptake by the roots and healthy growth of plants. Some fungal mycelia often harbor nitrogen fixing bacteria which can convert atmospheric nitrogen into forms available for plants to utilize. A few common bacteria are *Acetobacter, Azotobacter, Bradyrhizobium,* and *Rhizobium*. Adding compost to soils results in enhancing such living components which are beneficial to crop productivity and resilience.

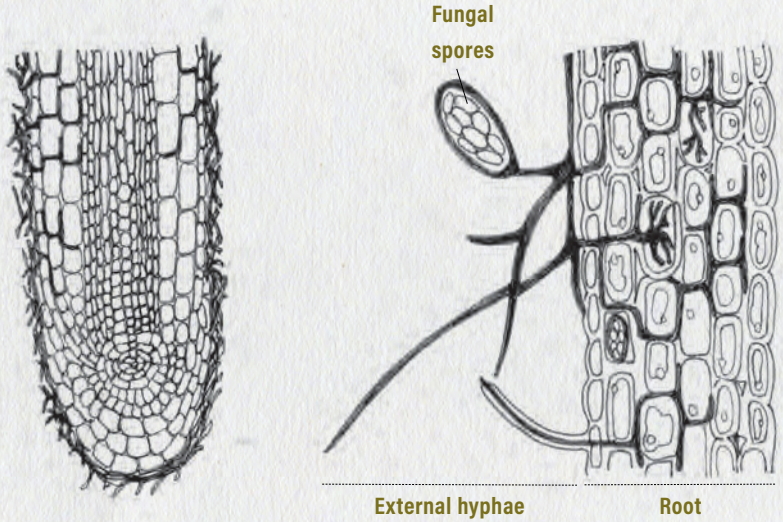


Figure 12: Magnified section of root showing penetrating fungal mycelium

4. MICROBIAL PREPARATIONS

Microbes contribute to humus-enriched soils; they facilitate nutrient uptake and enhance soil micronutrient exchange capacity.

Figure 13: Microbial preparations can be used as a liquid manure and for crop protection

EFFECTIVE MICROORGANISMS (EM)

EM is a mixture of "good" microbes, isolated from soils. It include photosynthetic bacteria, (*Rhodopseudomonas*), lactic acid bacteria (*Lactobacillus*), and various yeasts (*Saccharomyces*), all of which work towards very rapid enzymatic breakdown of large organic molecules into simpler compounds which can be effectively taken up by plants as nutrients. Addition of EM to composts decreases composting time from 6-8 months to 2 months.

Figure 14: Effective Microorganisms (EM)

Preparation:

In a 10 litre carbouy add:

1kg Jaggery (or molasses) + **100 ml EM (culture stock)** + **10 litres Water (chlorine-free)**

- Keep in warm dark place for 4-6 days.

- Fruity smell develops, pH falls to about 2-4, and the liquid becomes turbid indicating microbial growth

- Extended EM is ready for use in 5-7 days

Dilute Extended EM with Water to use:

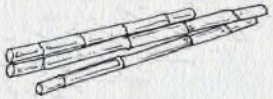
- (1:200) for adding to compost heaps
- (1: 200) Addition to animal and poultry feeds
- (1:500) for washing animals, animal houses, sanitary tanks
- (1:1000) for watering plants to enhance growth and health
- (1:1500) for cleaning water bodies, ponds, polluted tanks, etc.

PANCHAGAVYA

is a traditional preparation made from 5 basic ingredients from the cow:

Cow milk
2 lts

Cow ghee
1/2 kg



Sugarcane juice
3 lts

Cow Urine
3 lts

Ripe Banana
12

Fresh cow dung
5kg

Cow curd
2 lts

Toddy or grape juice
2 lts

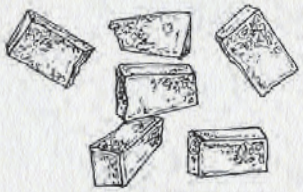
Tender coconut water
3 lts

- Customize by addition of ripe fruits, coconut water, and jaggery to enhance its efficacy.
- Use at dilutions of just 3% has shown significant increase in yields across a range of crops from fruits and vegetables, to cereals and tubers.
- Ferment from 21 to 30 days

Lab analysis of the preparations 15 days into the fermentation period has shown significant increase in concentrations of major and micronutrients, of available nitrogen, phosphorus, potassium, organic carbon, increase in plant growth hormones like gibberellins and auxins and other organic compounds which protect crops against pathogenic attack. Populations of beneficial bacteria like azotobacters, azospirillum, phosphobacteria, pseudomonas also multiply, improving soil quality.

JEEVAMRUTHA

Ingredients (Sufficient for 1 acre)



Jaggery
1-2 kgs

Cow Urine
3-4 lts

Water
200-250 lts

Cow dung
10-15 kgs

- Soil under a tree or un-disturbed location from the same land - 2-3 handfuls.
- Mix all of them and keep them in a shade for 3-4 days.
- Stir the mixture once a day.
- Apply the mixture when the ground is wet for the plants.
- This is an excellent culture for rapidly (3-4 days) increasing the beneficial microbes.

5. DISEASE MANAGEMENT

The first step is to build up biodiversity both above and below ground to enable a healthy and resilient agro-ecosystem. Instead of introducing new species, it is far better to create microhabitats which support biological diversity so that natural populations of microbes including fungi, insects, frogs, birds prevent pestilence from developing in the field.

Figure 15: Fallow stretches encourage biodiversity

Figure 16: Stream with fallow riparian areas

HEALTH AND RESILIENCE

Encouraging Biodiversity: Fallow lands are used to provide native habitats that encourage diversity and enable a constant flow between species, maintaining ecosystem connections between farms. As a result, beneficial micro organisms contribute to a rise in detritus activity of the soil, increased nitrogen fixation, increase in nutrient cycles, and replenishments of depleted nutrients. Areas where grasslands are encouraged, become sponges for harnessing rain water to recharge water tables and aquifiers. Integration of fallow lands into the cultivated also enable pest-predator balances, and attract pollinators with non-crop flowering plants. On organic farms which have no trace of chemicals around, parasitic insects are known to colonize native plant species and play significant roles in controlling pest populations. Such areas also provide breeding space and habitats for bats, birds, reptiles and a range of predatory insects all contributing towards keeping the pest populations in a balanced check. Organic farming practices work with nature, not against it so they enable conservation of a diverse range of plant and animal species by integrating them into the farming ecosystem.

Whistling Thrush

Golden Oriole

Figure 17: Bird diversity: Birds are voracious insect feeders and good at controlling larvae and grubs which feed on plants.

Figure 18: Ants (Weaver ants, *Oecophylla*) are Nature's scavengers removing decaying matter from the habitat.

Figure 19: Praying Mantis and Scorpion (*Heterometrus*) are often nocturnal and feed on live insects like crickets, moths, flies, and caterpillars.

Figure 20: Spiders *(Nephilla)* trap insects into their wide webs; other species may be non-web spiders moving amongst the crops predating even on small insects like aphids and thrips, preventing them from becoming pests.

Figure 21: Wasps forage for caterpillars and other small insects and bring them into their nests for their newly hatched carnivorous larvae.

Figure 22: Termites secrete the enzymes necessary to mineralize wood, releasing nutrients into the soil; they also harbor Nitrogen-fixing bacteria in their guts and enhance soil nitrogen.

Figure 23: Frogs (Malabar gliding frog, *Rhacophorus malabaricus*) are indicators of healthy soils; they feed on insects, and range in their habitats from water tanks to tree canopies.

MAKING BOTANICAL REPELLENTS

Synthetic pesticides have destroyed diverse life forms, polluted soils and water bodies, killing many more species than are the targeted pests. Plant extracts are less toxic, rarely hurt human life and generally degrade rapidly in the soil. If the necessity arises, use of Botanical repellents to contain the spread of pathogens is both effective and has a low impact on the agro-ecosystem. There are several plants growing in the wild which can be used for crop protection.

Figure 24: Mixing plant extracts to prepare an insect repellent

- Neem *(Azadirachta indica)* Azadiractin is an insect antifeedant and growth disrupter
- Karanj *(Pongamia pinnata)* Antifeedant, lowers insect fertility, disrupts oviposition
- Ram phal *(Annona reticulata)* Inhibits larval growth
- Milkweed *(Calotropis procera)* Latex has 2 enzymes chitinase and proteinase which injure insects
- Wild tobacco *(Lobelia nicotianifolia)* Repels insects, impairs digestion
- Wild Tulsi *(Ocimum tenuiflora)* Repels and kills larvae.
- Soapnut *(Sapindus trifoliatus)* Inhibits digestive enzymes, disrupts cellular structure
- Lakkigidda *(Vitex negundo)* Antifeedant
- Lantana *(Lantana camara)* Antifeedant, kills insects

BIOCONTROL AND ROLES OF SOME ORGANISMS

Biocontrol is the use of biological organisms to prevent pests from developing. These may be microbes or fungi, like *Beauveria* and *Trichoderma* which are being used to control pests and pathogens on economical scales in ways which are not harmful to the land.

Trichoderma is a fungus which occurs naturally in many soils and can destroy other disease-causing fungi. The *Trichoderma* release lytic enzymes which result in the rupture of the pathogen invading the plant. Areas with good soil populations of *Trichoderma* have very low disease incidence. It is commercially available now and can be multiplied in compost before it is applied to the field.

Figure 25: *Trichoderma* cultured on a medium in a petridish

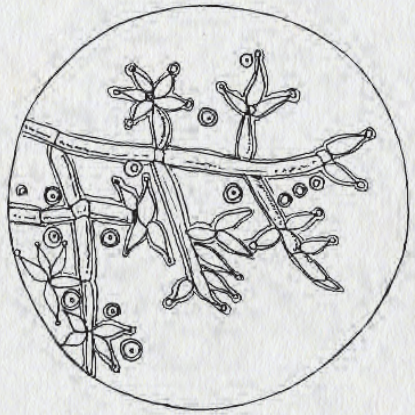


Figure 26: *Trichoderma* mycelium as seen under a microscope

Beauveria is an entomophilous fungus which infects adults and larvae of beetles, moths, whiteflies, thrips and others, eventually killing them. When the fungal spores come into contact with the insect body, they germinate, penetrate the cuticle and grow within, killing the insect in a few days. Later, a white mold emerges, resulting in what is known as white muscardine disease, and produces new spores. This is the asexual phase of the fungus' life cycle. *Cordyceps* is the sexual phase of *Beauveria* and produces spore-containing fruiting bodies which emerge out of the body of the insect, resulting in its death. *Beauveria bassiana* has been used in effective bio-control of coffee berry borers and other pests on a large scale.

Figure 27: Caterpillars infested with *Cordyceps* (sexual phase of *Beauveria*) which results in their death.

PLANTS CAN DEFEND THEMSELVES

We need to recognize that in nature, plants defend themselves through complex mechanisms. Minor injuries result in inducing a cascade of chemistry that finally culminates in synthesis of several compounds which inhibit insects from further causing any damage, and others which can destroy invading bacteria, viruses or fungal pathogens.

Mycorrhiza indicate the health of the soil and play an important role in stimulating the plants' natural defense mechanism. Their association with plants (both cultivated and wild) results in enhanced production of defense-related compounds known as phytoalexins. Phytoalexins are synthesized by plant cells as a defense response to bacterial or fungal attack. They are broad spectrum inhibitors and are chemically diverse (terpenoids, glycosteroids and alkaloids) in different plant species. They inhibit pathogens by damaging cell membrane, disrupting cellular metabolism or inhibiting reproduction.

Ecological Farming is based upon natural principles, it provides a path to mitigate the disastrous effects of global warming, and enables land use balanced with conservation of diverse species. It is a powerful step towards ensuring clean food security and a sustainable future.

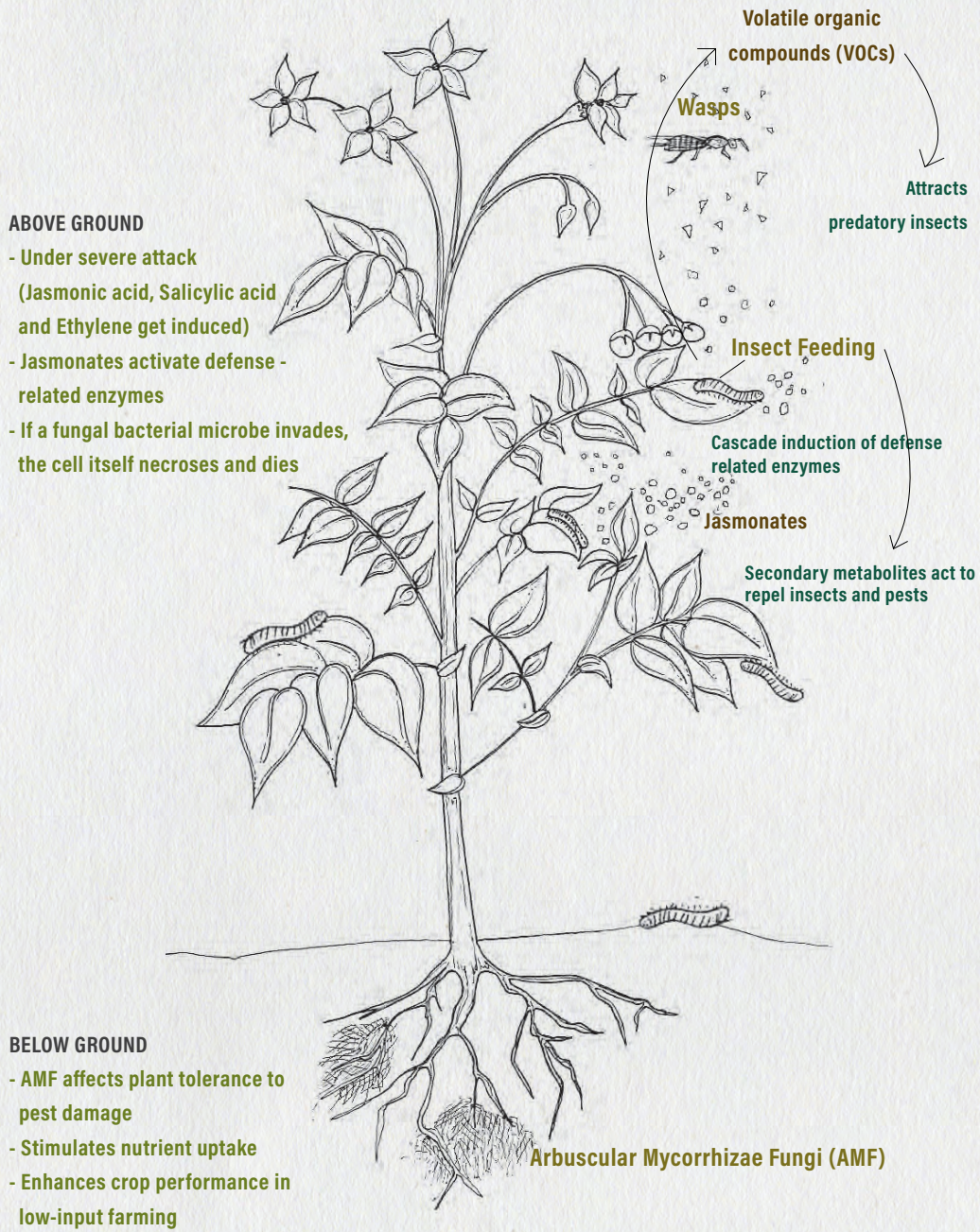


Figure 28: Diagrammatic representation of Plant Defense Action

6. SUGGESTED READINGS

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ABOUT THE AUTHOR

Sujata Goel graduated from University of Delhi with a Ph.D in Plant Biochemistry. She then worked as a Research Scientist at the International Centre for Genetic Engineering and Biotechnology, New Delhi. Relinquishing a promising career in the world of science, she left her life in the city and found a piece of land in the hills of the Western Ghats of Southern India. Mojo Plantation grew out of an idea, and is now a beautiful farm based upon ecologically sustainable principles. She lives there with her daughter, Maya, and husband, Anurag, using it as a platform to encourage organic agriculture in India and overseas.

ABOUT THE DESIGNER

Pooja Gupta is a visual artist with a passion that is inextricably linked to the environment and conservation. She brings thoughts, concepts and stories to life, through the language of video, illustration and graphics. Having graduated in Digital Video Production with core practice in filmmaking, her work has primarily focused on the documentary genre of film while also channelling her combination of interests and expertise in the field of science communication. As an artist, she uses her creative approach and strength in design thinking in project development, education design, mixed-media educational material and user-specific communication.

This manual describes practical methods for farming on an ecological template, and explains the principles which make such practices sustainable. It is a useful guide for gardeners, farmers, and anyone who is interested in following the organic path of cultivation. It has been specially prepared for circulation as part of the Proceedings made available to the delegates of the Organic World Congress 2017.