Organic Farming Technology in Japan

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Pilot Project for Better Farm Income
By Organic-Based Vegetable Production

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Introduction

In many places of Japan, farmers started trying organic farming approximately 50 years ago. Following developments in the society gave rise to the "organic" movement:

(1) Social background in which organic farming was initiated

a As petrochemical industries developed rapidly, soil and water were contaminated by poisonous chemical substances of many kinds. Human health was endangered by these chemicals in food and drinking water, too.

b Modern farming system heavily dependent on chemicals such as fertilizers, pesticides, etc. created a wide range of problems: Soil fertility was depleted by heavy dependence on chemical fertilizers. Farmers suffered from poisoning by chemicals. Pests and diseases resistant to chemicals emerged, leading to their repeated outbreaks. Overdose of chemical fertilizers polluted water. Increasing volumes of farm products proved to be hazardous to human health.

c Consumer movements became increasingly active, asking for safe farm products.

Photo 1: Seed exchange seminar by the Japan Organic Agriculture Association

As organic farmers gradually increased in number, they tried to organize themselves into a national association. In 1971, a **Japan Organic Agriculture Association** was established. The Association provided an incubating environment, in which dedicated farmers worked together and exchanged their experiences to create, refine and disseminate organic farming technology. (See Photo 1: Seed exchange seminar by the Japan Organic Agriculture Association.)

Organic Farming Technology (OFT) is the fundamental on which farming technology stands. Through basic practices described below, soil becomes rich. Crops grow healthy and resistant to pest and diseases. Qualities of the products are higher: Vegetables are more nutritious, tastier and contain substances good for human health.

(2) Fundamentals of Organic Farming Technology

a Soil is enriched (***"tsuchi-dukuri"*** in Japanese language) by using compost and ***bokashi*** fertilizers, produced by fermenting various organic materials. Soil conditions are improved by using earthworms and microorganisms which decompose organic materials. Improved soil helps crops grow healthy and sturdy.

Materials for soil enrichment are produced by composting locally available materials such as household food wastes, animal wastes, plant residues (dead twigs and fallen leaves), weeds, dead insects, small fish not for human consumption, crop residues, etc.

b Combined planting of different types of crops is practiced in the form of crop rotation and mixed planting. Combination of gramineous and leguminous crops is particularly effective in soil enrichment and creating environments to minimize pest and disease damages.

c In order to reduce pathogenic fungus/bacteria and hazardous insects, one tries to propagate useful creatures which eat them in the fields, such as microorganisms, insects, frogs, lizards, small birds, etc.

OFT reduces production costs by using locally available recourses and minimizing purchased inputs. OFT, at the same time, contributes to environmental conservation: It harmonizes with ecological system of the nature by avoiding the use of synthesized chemical substances. (See Table 1: Ingredients of compost and its chemical contents (example) and Table 2: Ingredients of *bokashi* and its chemical contents (example))

Table 1: Materials of compost and their nutrient contents (%)

Materials	N	P2O5	K2O	CaO	MgO	SiO2	C/N
Rice straw	0.4～0.9	0.1	0.8～1.5	0.3	0.2	5.5	50～ 70
Wheat/barley straw	0.5～0.7	0.1～0.2	0.8～2.0	0.3～0.4	0.1	3.0	60～100
Maize stems and leaves	0.5～1.0	0.4	1.6	0.5	0.2	1.3	60～90
Fallen leaves Sawtooth Oak*1	1.1	0.2	2.0	1.8	0.3	1.5	30～50
Pine needles	0.8	0.1	0.1	0.5	0.1	0.2	
Sasa	0.5	0.1	0.2	0.4	—	6.5	
Dried weeds Mugwort*2	2.5						20～60
Japanese pampas grass*3	0.7						60～70
Weeds	1.2	0.4	1.3				
Soybean stems and leaves	0.8～1.1	0.3	1.5～2.0	0.4	0.4		40～60
Rice hull	0.4～0.6	0.2	0.5				80～90
Saw dust	0.1						500～1000
Cattle dung (60% moisture	0.8	0.9	0.8	0.7	0.4		15～20
Swine dung (60% moisture)	1.2	2.1	0.7	1.5	0.5		8～12
Dried chicken dung (in cages)	3.0	4.5	2.5	4.2～9.0	1.1～1.8		6～10
(on ground)	2.0	2.5～3.0	1.0～1.5				15～20

C／N ratio : Oil cake, fish meal 5 – 6, compost 15 – 25, green manure 18 to 25, vegetable waste 10 -20, tree trimmings 100 – 200, (soil approximately 10, microorganism 5 – 10)

*1 *Quercus acutissima*

*2 *Artemisia princeps* Pampan

*3 *Miscanthus sinensis*

Table 2: Raw materials of ***bokashi*** fertilizer and their nutrient contents (%)

Materials	Guaranteed (Official standards)			Marketed ***bokashi***			Other nutrients		Remarks
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	CaO	MgO	
Dried chicken dung				3.0	4.5	2.5	4.2~9.0	1.1~1.8	
Canola oil cake	6.0	2.0	1.0	5.0~6.0	2.0~2.2	1.0	0.9	0.3	Residues from oil extraction
Rice bran oil cake	2.0	4.0	1.0	2.0~2.6	4.0~6.0	1.0~1.2	0.1	0.7	Residues from oil extraction
Rice bran				1.7~2.1	3.4~3.8	1.3	0.1		
Wheat bran				1.3~2.2	1.1~2.7	0.7~1.5	0.2		
Fish meal	7.0	3.0	—	7.0~8.0	4.0~6.0	~1.0			Boiled fish after oil extraction
Crab/ shrimp shell	4.0	1.0		4.0~5.6	3.0~6.0	0.5~0.8			Powder
Guano (nitric)	12.0	8.0	1.0						Bird dung and corps
Guano (phosphoric)				0.1~0.5	27~30	0.2~1.0			(Bat guano)
Ground shell fossil							20~40	1.0~3	Silicic acid content 20~30%
Wood ash					1 ~2.0	6 ~10		.0	

Source: "Handbook of Organic Fertilizers and Microbiological materials" (Nobunkyo Press) and others

Practices of Major Importance for Organic Farming

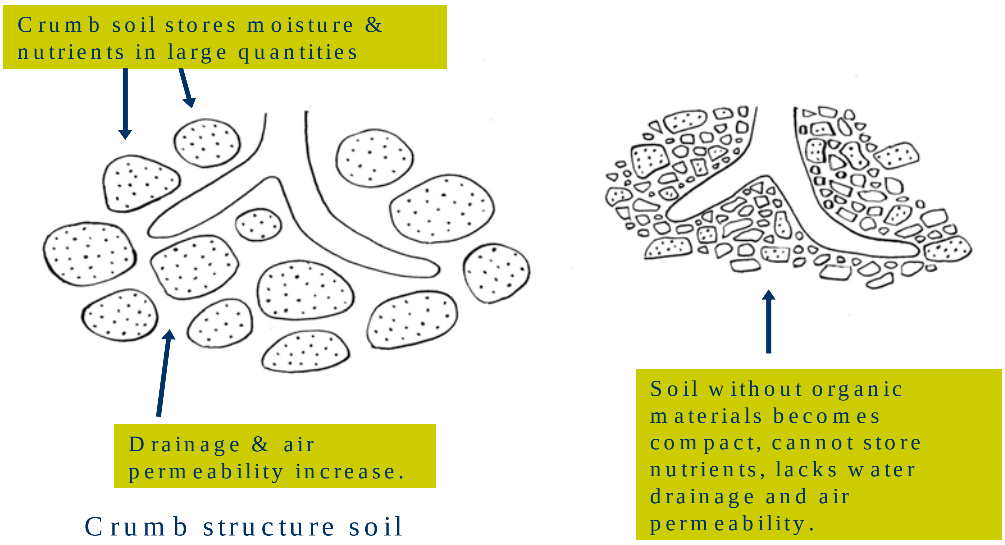
1. Soil Enrichment (*tsuchi-dukuri*)

Soil enrichment (***tsuchi-dukuri)*** is a combination of technical practices designed to maintain and enhance the natural recycling system of organic materials and wide varieties of creatures living in and around the soil. The practices are intended to maintain the natural environment. They consist of the following:

(1) Soil productivity (richness)

The fundamental approach is to increase the productive capacity of the soil. It is productive capacity of soil, not fertilizers, that raises crops. Compost and ***bokashi*** fertilizers input to soil are intended to provide nutrition to earthworms and microorganisms and store the nutrition in the soil, rather than to provide nutrition to crops directly. In other words, we enrich the soil through activities of earthworms and microorganisms. (See Chart 1: Tsuchi-dukuri: Provide organic) materials to create crump soil structure

Chart 1: Tsuchi-Dukuri: Provide organic materials to create **crumb soil structure**



(2) Compost and *bokashi* fertilizer

Activities of varied lives (especially those digesting organic materials) are utilized by providing compost and ***bokashi*** fertilizers to the soil. Organic materials are fermented and decomposed to a certain extent and used so that these microorganisms may easily digest them.

a Raw materials of compost and *bokashi* fertilizers

Following materials are used to increase soil richness: Crop residues (rice straw, straws of wheat and barleys, rice hull, stems and leaves to beans and maize, vegetable and fruit residues, rice bran, etc.), organic materials of plant origin around farm fields (cut grass, fallen leaves, dead twigs, saw dust, wood ash, etc.), animal wastes (from cattle, pigs, chickens and other domestic animals), oil cakes (from canola, soybeans, fish, etc.), food processing residues (bagasse, coffee grounds, fish processing wastes, crumbs, food leftovers, shell powder, etc.) and mineral resources of natural origin without industrial processing (rock salt, phosphate rocks, guano, fossil shell, etc.). (See Photo 2 Organic resources forest such as fallen leaves and twigs and Photo 3 Compost is produced using animal manure and food processing wastes.)

Photo 2: Organic resources from forest such as fallen leaves and twigs

Photo3: Compost is produced using animal manure and food processing wastes

b How to produce and use compost

i. Neutralizing compost

Heaps of compost generate a large quantity of organic acids at the initial stage of disintegration, and show strong acidity. During its maturing process, organic acids are decomposed into neutral substances. When you use the compost in the pre-mature stages, it is advisable to mix wood ash, lime powder, shell fish powder, etc. into compost. Materials of high C/N ratio must be stacked in a heap for a long time period before composted. Hence, neutralization is not necessary

ii Providing air and water

When materials are stack up first, their optimal moisture content is judged with the following way: Clasp the material tightly by hand, then, water seeps out. It contains 50 -60% moisture. When materials are dry, pour water or animal urine over the stack until water seeps out from the bottom. Raw grass, household garbage, vegetable wastes, fresh animal dung, etc. contain 80-90% moisture, which is too high. Moisture has to be reduced by mixing dry materials.

Aerobic bacteria do not propagate in stack when air is not supplied. Be careful not to stamp on/ press the stack too hard and not to supply water too much. Cut open and mix the heap (**turning**) periodically to supply air inside the stack. When mixing, materials inside are brought to surface of the stack, and *vice versa*.

iii Stack of materials

The stack must be roofed where it rains much. It may be covered lightly by old plastic films. Dried straw or pampas grass may be used to cover the heap in such a way the cover is slanted so that rain water may run down to the side.

Materials are mixed or sandwiched so that easily decomposable materials and those hard to decompose are stacked alternately. Ideally, the heap is build so that surface be hard and inside soft.

The heap has to be turned at least two or three times. First turning takes place 2 to 3 weeks (or more) after the beginning. Reconstitute the stack so that materials inside in the original stack may be brought to surface of the new stack, and *vice versa*. When it is dry, add water. Second turning should take place 4 – 5 weeks later. In case of using slowly decomposing materials, turn the stack every one or two months. （See Chart 2 How to Build Heap of Compost Materials.）

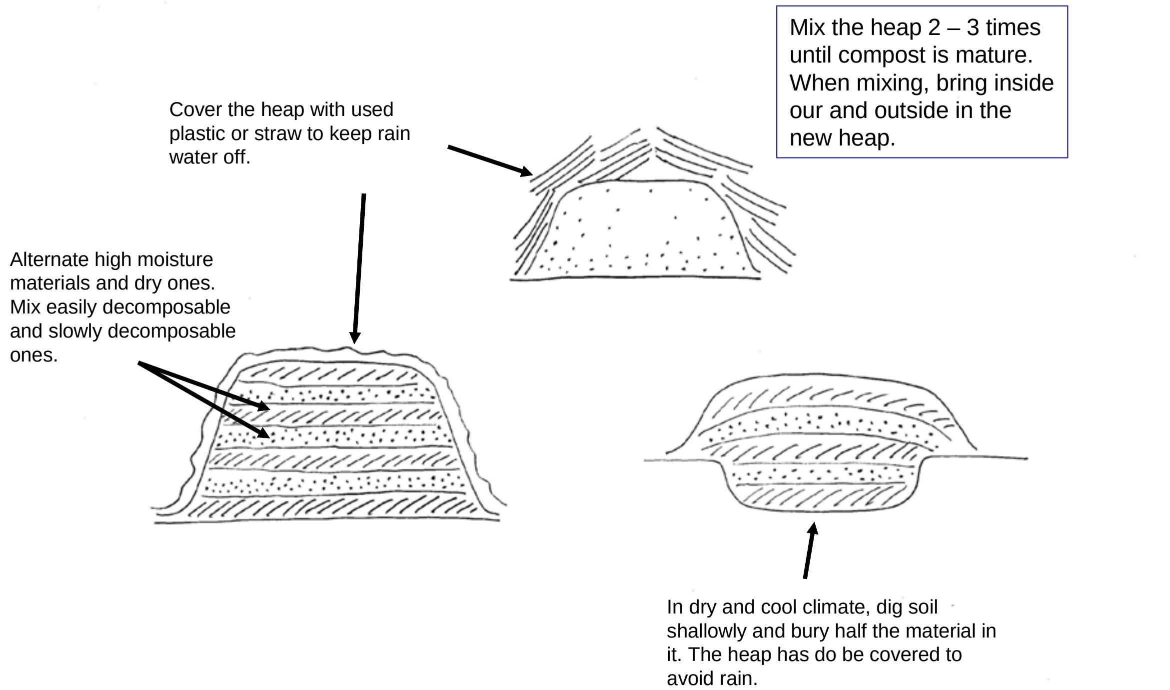


Chart 2: How to Build Heap of Compost Materials

iv Humification process

Inside the stack in which materials with C/N ratio 30 – 40 is used, decomposition process by microorganisms comes to near halt after the second turning. Color of materials gradually turns black. Himification has already started. White hyphae are seen inside.

Photo 4: Compost made of rice straw and rice bran

Compost is complete when the materials become crumbly and brown to black color. It occurs 4 – 5 week after the 2nd or 3rd turning. Hard fiber can be easily cut by hand. Its volume is half the original size. Its surface is dry but its inside is slightly moist with 40-50% moisture. Water does not come out when you clasp it tightly by hand. (See Photo 4: Compost made of rice straw and rice bran.)

v Time necessary for compost production

Animal manure mixed with rice straw takes 6 – 7 weeks and the one with wheat straw, 8 – 10 weeks to complete turning into compost. When saw dust or rice hull is mixed with animal wastes, it takes 4 to 6 months to get mature compost. When wood chips and bark is to be used, these materials must be left outdoors (under the sun and rain) for a half to one year. Then, mix with nitrogen-rich materials, stack, and leave more than 6 months.

c How to produce and use *bokashi* fertilizers

There are two different types of ***bokashi***. On is aerobic ***bokashi***, produced by high-temperature fermentation with air supply. The other is anaerobic ***bokashi,*** fermented under low temperature in closed containers. Normally, aerobic ***bokashi*** is used. However, anaerobic ***bokashi*** using "EM" is produced by practitioners of "Natural Agriculture"

i Materials of aerobic bokashi

Aerobic ***bokashi:*** is produced in the following way: Chicken dung, oil cake, fish meal, rice bran, wheat bran, fish meal, kitchen garbage, leaf mold, oyster shell powder, etc. are mixed; water is added, stacked and fermented. The stack is turned from time to time.

Photo 5: *Bokashi* prepared by a farmer

(Fermentation fungi are seen as white threads.)

ii How to prepare aerobic *bokashi*?

Detailed description of aerobic ***bokashi*** is as follows:

① Keep it under cover – do not expose it to ultra-violet ray or rain.

② Process it on the ground soil (no concrete) – small amount of ***bokashi*** is left on ground and bacteria remain in soil.

③ Proper moisture content – clasp hard and get a clod but it crumbles when pushed.

④ Stack is not higher than 50 cm high and keep temperature not higher than 60℃; Spread on the ground when temperature gets high.

⑤ Turn 2 – 3 times for uniform fermentation

⑥ When materials get dry and white and temperature goes down to normal, it is complete. (See Photo 5: *Bokashi* prepared by a farmer and Photo 6: Turning *bokashi* fertilizer.)

Photo 6: Turning *bokashi* fertilizer

iii Effectiveness of *bokashi*

Bokashi has two useful features: One is fertilization. Another is that microorganism propagated through fermentation process enhances activities of plant roots. Microorganisms involved in fermentation include *Rhyzopus*, Koji mold (*Asperllus orizae*), *Bacillus natto*, *Bacillus subtilis,* Lactic acid bacilli, Yeast, *Actinomycetes*, etc. They generate organic acids, amino acids, vitamins, plant hormones; and activate enzymes and minerals. These actions are believed to enhance healthy crop growth. Microorganisms propagated in ***bokashi*** discourage activities of pathogenic fungi, bacteria and nematodes.

iv How to increase effectiveness of *bokashi*?

In some cases soil from mountain is mixed (approximately 30%) with ***bokashi*** materials so that volatile ammonium may be adsorbed. Carbonated rice hull may also be mixed (10 – 20%). When crab shell powder is added, chitin contained in the shell enhances growth of Actinomycetes. The latter inhibits actions of pathogenic microbes. Hard fallen leaves from evergreen trees contain chitin in a large quantity and hence leaf molds are also effective in enhancing Actinomycetes. Organic materials in ***bokashi*** are already contained in the microorganisms. Therefore, explosive decomposition does not take place after being applied to the field and damages to young plants are minimized. Therefore, it can be both base-dressed and top-dressed. ***Bokashi*** is primarily intended to enrich microbiological activities in plants' rhizosphere and hence, its application near the plant (in planting ditches or planting holes) is more effective both in base- and top-dressing.

v Quantity to *bokashi* used

Normally, quantities of ***bokashi*** applied to the fields are as follows: spinach and turnip 200-300g per square meters; cabbage, squash and tomato 300-500g; eggplant and chili 500-600g (base + top dressing). Be aware that nutrient contents of ***bokashi*** differ, depending on materials used. Farmers have to adjust the quantities based on experience.

(3) Organic nutrients

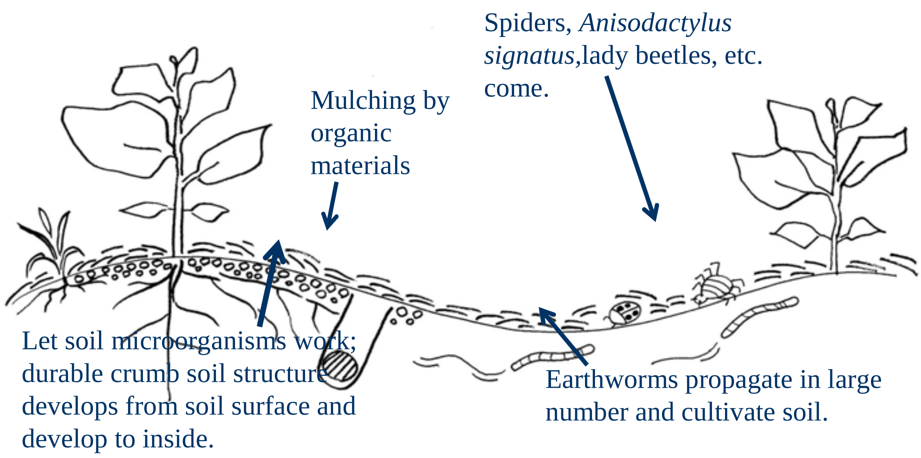
Compost and ***bokashi*** fertilizers enhance healthy growth of crops, which is not achieved by synthesized inorganic fertilizers. Organic nutrients include sugars, organic acids, amino acids, nucleic acids, vitamins, enzymes of varied types, plant hormones, etc. Organic nutrients are generated in the soil through the digestion process of organic materials by microorganisms.

(4) Microbiological antagonism

Earthworms and majority of microorganisms digesting organic materials demonstrate antagonistic behavior towards pathogenic microorganisms and insect pests attacking plants. Hence, we try to create favorable environment for these antagonistic microorganisms to propagate in soil or on soil surface. This is achieved by applying compost and ***bokashi*** fertilizers, mulching by organic materials, minimizing frequency of plowing and tilling. (See Chart 3: Minimum tillage by humans.)

What we call “**antagonism**” includes the following actions of earthworms and useful microorganisms: (a) kill other microorganisms using decomposition enzymes (chitinase, cellulase, etc.); (b) prevent propagation of other microorganisms by substances and acids harmful to them; (c) propagate around plant roots in order to feed on root excretion and keep other microorganisms off the root; and (d) live on other microorganisms as parasite.

Chart 3:Tsuchi-Dukuri: Minimize tillage by humans. Let **EARTHWORM** and **MICROORGANISMS** do the job.



Organic Mulching (cover soil surface by straw, fallen leaves, etc) & **Low grass cover**:

Grass cover enhances earthworm & microorganism propagation, improving soil conditions from the surface.

Photo7: Winter wheat as planted for green manure

(5) Use of gramineous, leguminous and tree plants

Sustainable and productive soil is created by (a) providing compost made of organic materials originating from grasses and trees (fallen leaves, dead twigs, saw dust, etc.) and (b) introducing leguminous plans in the rotational system for propagating nitrogen-fixing bacteria. Through the practices, soil fertility and sustainability is enhanced.

Gramineous plants and materials of tree-origin contain **LIGNIN**. Lignin lets organic materials in soil stay longer and improves physical and chemical conditions of soil. Silicic acid contained in gramineous plants lets the crops be resistant to pests and diseases. Some species of nitrogen-fixing bacteria propagate around roots of not only leguminous crops but also gramineous ones.

Photo 8: *Makomo,* Graminous plant growing in swamp (good material for compost)

Gramineous plants to be used for this purpose include maize, sorghum, upland rice, wheat and barley, rice hull and some weeds (***yoshi and susuki***). These plants may be composted or plowed into soil as they are (green manure). (See Photo7: Winter wheat as planted for green manure.)

Leguminous plants such as soybeans and groundnuts are included in crop rotation. Forage crops such as clover, Chinese milk vetch, alfalfa, hairy vetch, etc. may be used as green manure.

Photo 8-2: Makomo, taller than 2 meters, provides a large volume of compost material.

2. Rotated and mixed planting of varied plant types

When kidney beans are planted repeatedly on a field, their growth becomes weaker year by year. In the end, it may die. Same is true with cabbages, eggplants, cucumbers and watermelons. They suffer from various damages caused by continuous cropping. Diseases and insect damages also increase on these crops.

"Injuries from continuous cropping" are caused by (a) nutritional problems continuous mono-cropping creates by exhausting certain types of nutrients in the soil, (b) pests and diseases coming from soil-born fungi and bacteria whose propagation was accelerated by continuous crop planting, (c) self-poisoning of the plants by harmful excretion from plant roots, etc. Farm fields of single crop tend to be damaged more badly because certain types of insects propagate quickly but the number of natural enemies is limited.

Different types of crops are rotated or mixed in the field. Rotation and mixed planting are intended to avoid imbalance in distribution of soil nutrients and to control damages caused by outbreaks of pests and diseases. They are effective means of producing healthy organic vegetables with good quality.

Photo 9: Clover is planted between rows of Chinese cabbage (Wide range of usefulness: soil fertility increases; soil drying is avoided; natural enemies are attracted; weeds do not grow, etc.)

(1) Crop rotation: To rotate planting of different types of crops instead of planting the same types repeatedly.

(2) Mixed cropping: To plant plural types of crops simultaneously in one patch of field. Different crops may be planted on alternate rows. A different type of crop may be planted between rows of another crop. Seeds of different crops may be mixed and put on the field. (See Photo 9: Clover is planted between rows of Chinese cabbage.)

Major considerations necessary to be kept in mind when planning rotation and mixed cropping are as follows:

- **Crops of different families**

  Crop rotation and mixed cropping should combine crops of different families in order to avoid nutrient deficiency and propagation of plant pathogen/ pests originating from same-family cropping. (See Table 3 "List of crops by family: for crop selection in rotated and mixed cropping".)

  Examples of rotation: Tomato (*Solanaceae*) => soybean (*Fabaceae*) => cabbage (*Brassicaceae*) => onion (*Liliaceae*) => okra (*Malvaceae*) => eggplant (*Solanaceae*) => etc.

  Mixed cropping: Cultivate these different types of crops on a field simultaneously.

Table 3. List of crops by family: for crop selection in rotated and mixed cropping

Family	Species
Gourd family *(Cucurbitaceae)*	Cucumber, squash, bottle gourd (*Lagenaria siceraria* var. *Hispida),* ***shirouri***, oriental melon (*Cucumis melo* var.*makuwa),* bitter melon (bitter gourd), watermelon
Potato Family *(Solanaceae)*	Eggplant, tomato, bell pepper, chili, potato
Brassicaceae	Cabbage, Chinese cabbage, broccoli, turnip, radish, ***Komatsuna*** (*Brassica rapa* var. *Perviridis)*, leaf mustard, mustard spinach, white celery mustard
Apiaceae	Celery, parsley, Japanese parsley (*Oenanthe javanica*), carrot, Japanese honeywort (*Cryptotaenia japonica*)
Asteraceae	Lettuce, *Chrysanthemum coronarium*, Jerusalem artichoke (*Helianthus tuberosus*), yacon, edible burdock (*Arctium lappa* L), chicory, ***Fuki*** **(***Petasites japonicus)*
Liliaceae	Green onion, onion, garlic, garlic chives, ***Rakkyo*** (*Allium chinense* G.Don), asparagus, lily bulb
Fabaceae	Soybean, garden pea, common bean, broad bean, cowpea, groundnut, (green manure crops of fabaceae)
Poaceae (Gramineae)	Upland rice, wheat, barley, maize (oat, rye and sorghum as green manure crop)
Others	Okla. Spinach, ginger, taro, sweet potato, ***red shiso*** (*Perilla frutescens* var. *crispa*), Molokheiya

- **Gramineous and leguminous crops**

  It is necessary/ desirable to combine gramineous and leguminous crops (including forage crops) in the crop mix. (Ref. 1 (6))

Photo 10-1: Multiple cropping 1

- **Multiple-type cropping**

  On upland fields, it is desirable to plant (simultaneously or with time differentials) as many types of crops as the economic conditions permit. (See Photos 10-1 & 10-2.)

Photo 10-2 Multiple cropping 2 (Onions and green onions inhibit soil-born diseases infesting on Gourd Family and Potato Family plants.)

3. Controlling pests and diseases

(1) To propagate antagonistic microorganisms

Microorganisms antagonistic to pathogenic ones may be propagated and stay in and around plants (both under- and above-ground). A group of "fermentation bacteria" propagating in compost and ***bokashi*** are antagonistic microorganisms. They reduce activities of pathogenic microorganisms.

Most effective practices are as follows: Underground, fermented organic materials such as compost and bokashi fertilizers are provided. Above ground, mulching with organic materials and mixed cropping of multiple types

Organic mulching is to cover soil surface between rows or around plants with fallen leaves, rice straw, etc. Rice hull, dead twigs, vegetable wastes may be used too. Compost may be spread over soil surface without mixing with soil. One may use coffee grounds, waste of fruit juice extraction and so on. In the rainy season, organic cover may be rotten and attract pathogenic microorganisms and pests. One should use materials not easily rotten such as fallen leaves, rice hull and saw dust. In the dry season, organic mulching maintains soil moisture and prevents soil drying. (See Photo 11: Rice straw mulching over soil around eggplants and Table 4: Antagonistic microorganisms to pest and diseases)

Photo 11: Rice straw mulching over soil around eggplants (Prevents soil drying, inhibits weed propagation and attract natural enemies.)

Table 4: Antagonistic microorganisms to pest and diseases

Functions	Types	Methods of application	Propagation※
Generate antimicrobial (antibacterial) substances	*Bacillus* (bacteria)	Locally existent varieties feed on easily decomposable organic materials. Can be added to many different types of micro organic materials.	○
	Pseudomonas (b)	Green onions and garlic chives may be intercropped. Seed coating.	×
	Agrobacterium (b)	Marketed as material to control *Agrobacterium tamefaciens*	×
	Streptomyces (Actinomycetes)	Can be added to many different types of micro organic materials. Propagation is enhanced by crab-shell (chitin) application.	○
Antibaterial substances are generated in fermentation process.	Lactic acid bacilli (b)	Can be added to many different types of micro-organic materials. Can be obtained from "nukamiso" (Japanse pickle bed of rice bran) and youghurt.	○
	Yeast (fungus)	Added to most micro-organic materials of fermentation type Locally available varieties feed on organic materials rich in nutrients.	○
	Aspergillus (f)	Koji mold: added to many micro organic materials. Locally available varieties are activated by adding rice bran.	○
	Penicillium (f)	Added to micro organic materials of fermentation type	○
	Rhizopus (f)	Added to many micro organic materials. Activated by cellulose-rich organic materials (ex. Rice staw).	○

Parasitic on pathogenic fungi	*Trichoderma* (f)	Added to many micro organic materials. Marketed as a farm chemical.	○
Symbiosis with plants and induce resistible capacityto pathogens.	*Glomeromycota* (VA mycorrhizal fungi)	Activated by soybean – maize rotation and charcoal application	×
	Xanthomonas (b)	Inoculated	×

※ Microorganisms marked ○ can be propagated in compost and bokashi fertilizers.

Source: Added to Toshio Kimura 1992.)

(2) Disease and pest control effect of rotated and mixed cropping

Rotated and mixed cropping of different types avoids depletion of specific nutrients, lets plants grow stronger and inhibits outbreaks of specific pathogenic fungi/bacteria and noxious insects. Example: Gramineous crops intercropped with vegetables reduce Powdery Mildew damage. (See Photo 12.)

Photo 12: Squash planted after wheat is cut (Wheat straw and young shoots of wheat prevent weeds to emerge and inhibit powdery mildew to propagate.)

(3) Attracting natural enemies

Natural enemies are encouraged to grow around crops to avoid insect damages.

Animals to be used as natural enemies are: insects such as ladybug, spiders, lizards, small birds, etc.

Means of attracting natural enemies are varied. They include mixed cropping; planting of low weeds, leguminous plants, herbs and wheat/barley (**banker plants**) between vegetable rows; organic mulching of fallen leaves, dried weeds, and rice straw. Natural enemies of various kinds come to banker plants and organic mulching on the ground, looking for food.

Photo 13-1 Oats are planted between vegetable rows. (Aphides are controlled by natural enemy insects attracted by oats.)

Herbal plants of certain families have strong smell which Heteroptera and *Henosepilachna vigintioctopunctata* dislike. Hence, these plants intercropped with vegetables reduce insect damage.

When oats and sorghum are intercropped with vegetables, these gramineous crops attract spiders and ladybugs, which in turn reduce aphids attacking vegetables. (See Photo 13: Banker plants for natural enemies (two photos) and Photo 14: ***Komayu-bachi* (*Cotesia glomerata*),** a natural enemy of green caterpillars (two photos) on next page.)

Photo 13-2 : A ladybug coming to oat leave.

(4) Insect barriers

Physical barriers against pests may be built. For example, tall glasses such as maize and sorghum are planted around crops to keep insects off. In several places in the field, tall crops or climbing/ trailing crops supported by poles may be planted and let insect-feeding animals live there, such as mantises, spiders, green lacewing, etc.

Photo 14-1: Cocoons of Komayu-bachi (small winged insects living on caterpillers*).* Green caterpillar is dead after being sucked by the small insects.

Photo 14-2: Adult komayu-bachi (*Cotesia glomerata)* emerged from a cocoon.

(5) Propagating natural enemies

Certain microorganisms function as parasites against noxious insects (natural enemies). They are propagated in and around soil by applying organic materials to soil and mulching soil surface by organic materials.

If dead green caterpillars are found and their bodies are covered with fungi, they are collected, ground and diluted by water to spray to vegetables on the fields. It will enhance propagation of parasitic fungus to these insects. (See Photo 15: Dead tobacco cutworm **(*Spodoptera litura)*.**)

(6) Other methods of pest and disease control

Photo 15: Dead tobacco cutworm (*Spodoptera litura*). White powder particles are spores of parasitic fungi, *Beauveria bassiana*

Other means of controlling pests includes: light traps; yellow sticky boards; and biological chemicals (insect-killing or repellant substances extracted from poisonous plants). In Asia, ***Neem*** (see note) is widely used. (See Chart 4: Light trap catches insects and fragrance trap attracts them by smell.)

<<Note>> Neem

English mame: Chinaberry

Latin name: Melia azedarach Linn.

Fruits contain poisonous "meliatoxin", which is toxic to insects. Care must be taken when using it because it is also poisonous against human beings and animals.

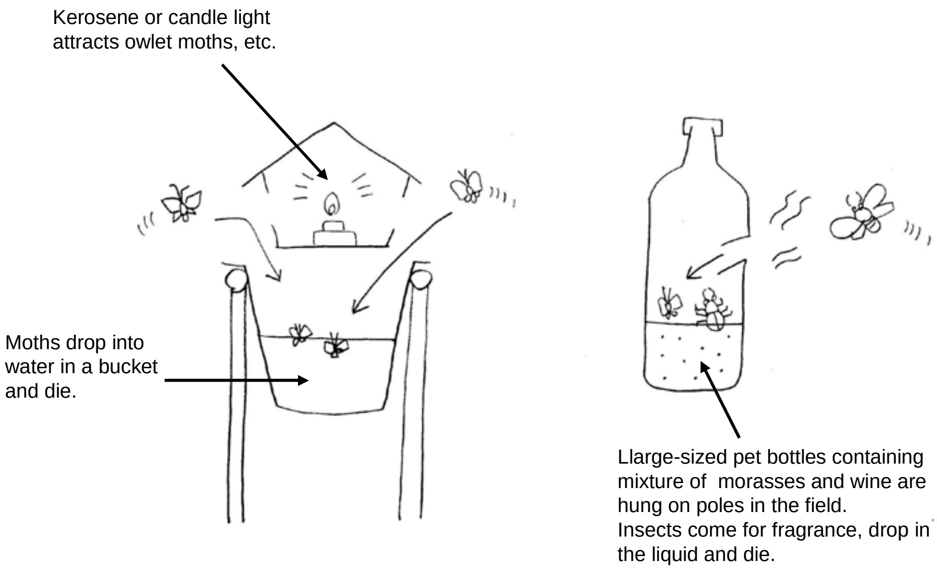


Chart 4 Light trap catches insects and fragrance trap attracts them by smell.

4. Weed control

(1) Removing weeds

Weeds must be removed physically, by hand or lightly cultivating soil surface between crop rows while weeds are still small.

(2) Preventing weed germination and growth

Many means are used to prevent weeds from growing. Colored film (light does not go through it) is used for mulching. Organic mulching is also used. Continued application of organic mulching and physical weeding gradually reduce weed population. Organic mulching also contributes to soil enrichment. Weeds removed from the soil are dried and used for mulching.

5. Conservation of natural environment

(1) Avoid overdose of fertilizers

Nitrogen and phosphate run-offs from soil may pollute underground water and rivers. It occurs by continuous overdose of compost and ***bokashi*** fertilizers, too. One should limit their application to proper quantities sufficient to support healthy crop growth. For example, compost of plant origin (grass and fallen leaves) containing 0.5 – 1.0% of nitrogen may be applied to the soil at the rate of 2 – 3 kg per square meter. On the other hand, quantity should be reduced to 1 – 2 kg per square meter for compost made of animal wastes containing 1 to 2% of nitrogen.

Bokashi fertilizers produced from rice bran, chicken manure, oil cake, small dried fish, garbage, etc. contain 2 to 3% of nitrogen. Rate of application should be around 0.3 – 0.5kg per square meters. Even organic fertilizers make vegetables susceptible to pests and diseases when they are supplied too much.

(2) Efficient use of irrigation water

Excessive water use for irrigation may cause unwanted effects on environments in nearby areas. Quantity of irrigation water should be minimized. This is effectively realized by preventing soil to get dry by way of organic mulching and covering field by leguminous plants, etc.

6. Resource recycling and cost reduction in farming

Following measures are important to attain resource saving, which is one objective of organic farming.

(1) Integrated farming: combination of crops and aminals

Animal wastes from within the farm or from neighboring farms are valuable organic resources and should be utilized. Combination of crop farming and animal husbandry is called "integrated farming with animal". In this model, animal feeds are obtained within the farm (grasses from waste land and forage crops sown to the field) and animal dung and urine are turned to compost to feed to the soil. (See Photo 16: Chicken kept on ground in a handmade pen, Chart 5: Chicken kept on Pigs kept on ground and use of fermentation bed.)

Photo 16-1 Chicken kept on ground in a handmade pen. (Ventilation is important.)

Photo16-2: Fermentation bed of chickens Rice hull, saw dust, fallen leaves are spread on ground. Chicken dung drops and ferments in it. The product may be used as *bokashi*)

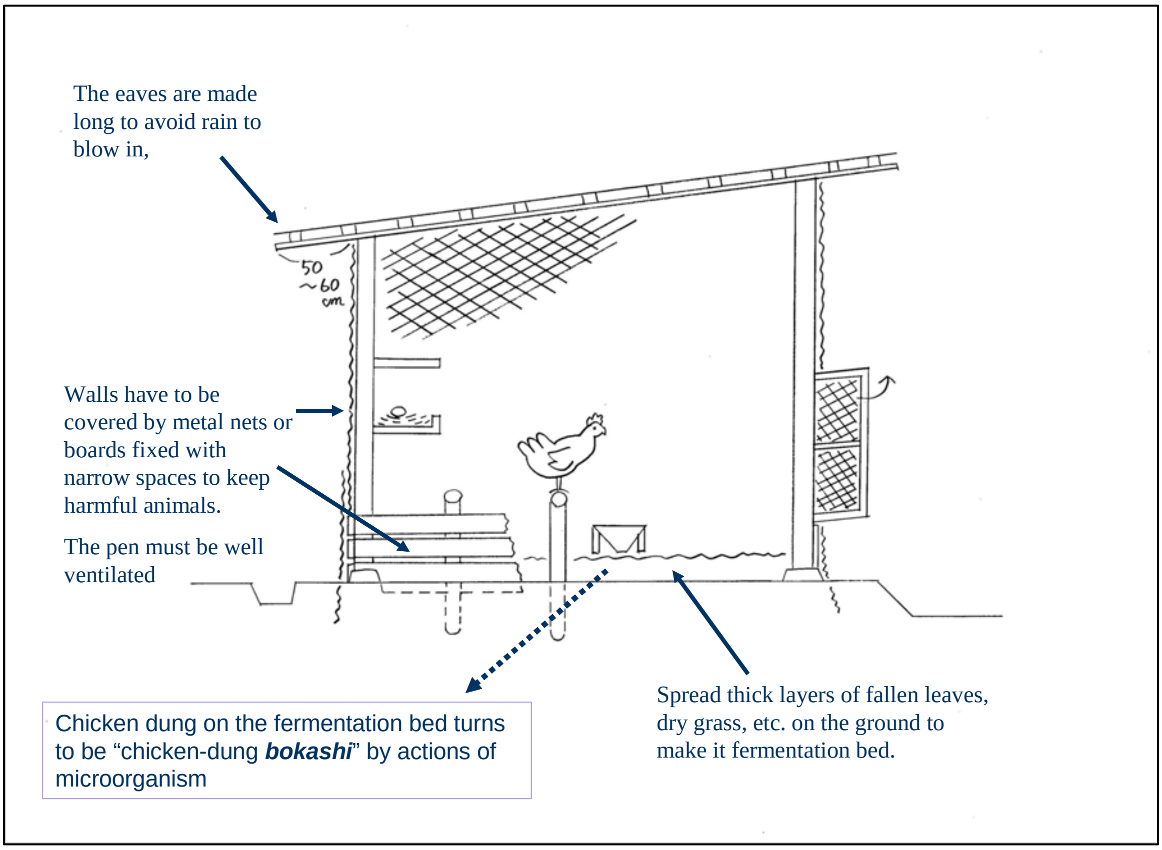


Chart 5: Chicken kept on ground and use of fermentation bed

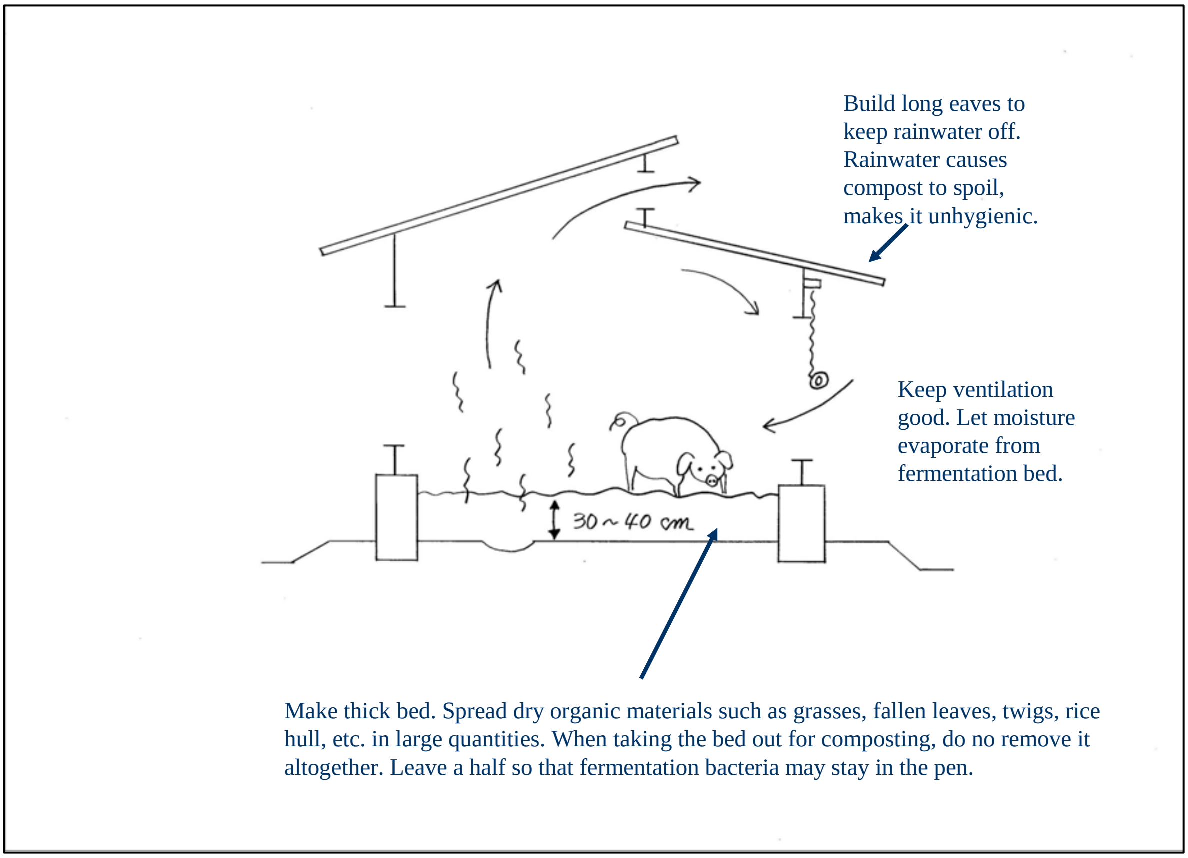


Chart 6: Pigs kept on ground and use of fermentation bed

(2) Use of locally available materials

OFT is based on utilization of locally available resources and enables <u>low-cost farming</u> by minimizing purchased inputs. Soil enrichment (***tsuchi dukuri***) using farm wastes, food wastes, grasses and trees around the farm, animal wastes, locally available fish and shellfish removes necessity for purchased fertilizers. Pest and disease control techniques by way of multi-crop planting also make purchasing chemicals, chemically synthesized films etc. unnecessary. (See Table 5: Organic resources to be utilized.)

Table 5: Organic resources to be utilized

Group	Source	Resources
Vegetal materials	Crops	Rice straw, wheat/barley straw, rice hull, vegetable wastes (trimming), bran, screenings (rice, wheat, barley, soybeans), discarded fruits
	Green manure crops	maize, sorghum, rye, oat, clover, vetch, Chinese milk vetch, sunflower, Indian mustard
	Weeds	Weeds around farm fields, weeds in roadside and riverside, weeds under trees
	Wood	Fallen leaves and twigs, saw dust, tree trimmings, forest thinning lumber
	Others	Seaweed wastes
Animal materials	Animal	Animal excretion (horse, cattle, swine, goat, chicken, etc.)
	Others	Fish meal, shellfish fossil powder, egg shell powder
Wastes	Households	Garbage
	Food processing	Food wastes from restaurants, oil cake, ***sake*** lees, brewer's grains (beer), bagasse, fruit refuse after juice extraction, green-tea refuse, sludge of drained water, rice cake refuse, bread crumbs, waste edible oil
Others	Wood	Charcoal, carbonated rice hull, ashes (grass, wood)

(3) Minimum tillage

Cropping by minimum tillage (sod seeding, partial tillage, etc.) reduces farm labor and let organic substances stays longer in soil. Frequent tillage accelerates nitrogen loss from soil (denitrification) and increases fertilizer requirement. Reduced tillage results in reduced fertilizer requirement. Tilling soil disturbs, though temporarily, useful bio-system in the soil (earth worms and microorganisms antagonistic to hazardous creatures). Non-tillage tends to reduce diseases causing problems in continuous monoculture. (See Chart 7: Minimum tillage helps soil maintain fertility longer.)

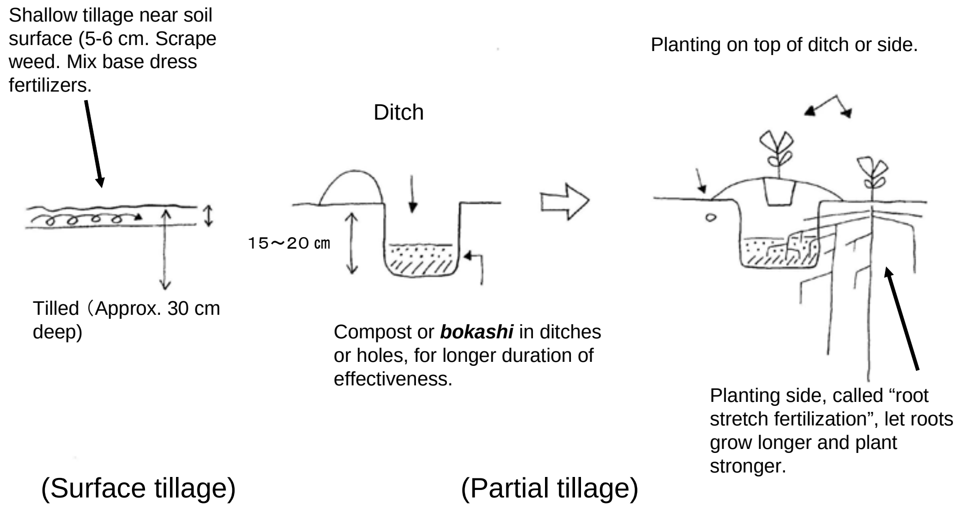


Chart 7: Minimum tillage helps soil maintain fertility longer. Partial tillage is effective.

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