<u>Control of rice thrips</u>: Organophosphates such as Dimathoate and Malathion are highly effective. Both emulsions and powders can be used and the effects are better with systemic insecticides. The insecticides should be applied to the seedling at the initial stage of rice thrip damage. Emulsions should be diluted 1,000-fold and powders applied in concentrations of 2 - 3 kg/ha. Another method is to remove the damaged stocks and burn them.

Table 6-8 Percentage frequencis of adult colour types of *Nezara viridula* in the world (Kiritani 1972)

Locality	G	O	F	R	No. of specimens examined
Japan, Honshu, Wakayama	86.0	7.3	5.1	1.0	45,455
Shikoku	78.0	12.3	6.5	3.2	2,916
Kyushu	80.7	8.7	7.1	3.5	1,216
Amami Is.	64.0	16.0	16.0	4.0	25
Okinawa	60.9	17.4	8.7	13.0	69
Formosa	77.8	22.2	0	0	9
Philippine Is.	97.3	2.7	0	0	37
Ceylon	100.0	0	0	0	1
India	50.0	50.0	0	0	2
Borneo	84.0	8.0	4.0	4.0	25
New Guinea	100.0	0	0	0	218
Australia	100.0	0	0	yes	7
New Zealand	yes				
Mariana Is.	99.2	0	0.8	0	130
New Hebrides	100.0	0	0	0	2
Hawaii	100.0	0	0	0	109
Samoa	100.0	0	0	0	42
Society Is.	100.0	0	0	0	32
Solomon Is.	100.0	0	0	0	5
U.S.A. Southern part	100.0	0	0	0	59
Honduras	100.0	0	0	0	2
Costa Rica	100.0	0	0	0	4
West Indies	100.0	0	0	0	115
Iraq	100.9	0	0	0	5
Israel	yes				
Ethiopia		yes			
Spain	80.0	20.0	0	0	5

Table 6-9 Some thrips pest of rice (Pathak 1970)

Name	Abundance	Host plant	Distribution
Haplothrips aculeatus Fabricuis	Very common	Polyphagous: grasses, cereals and on many kinds of flowers	India, Thailand Java, Taiwan Philippines, and Japan
Thrip oryzae Williams	Very common	Primarily rice and maize. Also other graminaceous crops and weeds	ibid
Anaphothrips obscurus Muller	Less common	Usually a pest of tobacco. Infests the leaves of rice and other graminaceous plants	Europe, Japan
Chirothrips manicatus Haliday	Less common	Polyphagous	Japan
Frankliniella intosa Trybom	Less common	Flowers of graminaceous and other plants	Taiwan, Europe Japan
Frankliniella tenuicornis Uzel	Less common	Flowers of graminaceous plants	Japan
Aeolothrips fasciatus Linn.	Less common	Polyphagous. Collected from rice crop at all stage	

6-2-3. Group C

(1) Army worms

There are many species of army worms in the tropics but three cause considerable damage to rice: the rice army worm or ear cutting worm, *Pseudaletia separata* Walker; the rice cut worm, *Spodoptera litura* Fabricus; and the rice swarming caterpillar, *Spodoptera maurita*. All of these are nocturnal insects belonging to the genus Noctuidae. Table 6-10 shows the distribution and host plants for army worms.

Table 6-10 Important army worm pests of rice

Name	Common name	Host plants	Distribution
Pseudaletia separata	Rice army worm	Rice, wheat, millet, maize, sugar cane, gramineous forage crop	Throught Asia, Pacific Islands, East Australia, Fiji, New Zealand
Spodotera litura	Rice cut worm	Rice, sweet potato, sugar beet, crucifer, spinach, dasheen, leguminous forage grasses	Australia, India, Indonesia, Malaysia, Philippines, Thailand
Spodotera mauritia	Rice swarming caterpillar	Rice,	Africa, Australia, Ceylon, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand, USA

Ecology and life history of army worms: The life span of adult rice army worms (Photo 23) is three to seven days. The eggs hatch after seven to nine days and one female lays 232 eggs (Photo 24) between the leaf sheaths. The first instar larva is 1.8 mm long and feeds on the soft parts of the leaves. The third to sixth instar larvae (Photo 25) feed on the leaves. From the third instar, the larvae form groups but in the sixth instar, they separate and move individually. The amount eaten by the sixth instar accounts for more than 80% consumed during the entire larva stage. The larva stage lasts a total of 28 days. The pupae remain in the soil and change remarkably in 7 to 30 days. The larvae are nocturnal and remain inside the leaf sheath during the day.

Rice cut worm females each lay 200 to 300 eggs in the leaves. The eggs are laid in masses and are all wrapped in hair. The eggs hatch after three to four days and the first instar larvae (Photo 27) live in groups although subsequent instars gradually become more independent. The larva stage lasts 20 days and the body lengths reach 4 - 5 cm. The pupae form a chamber 6 cm below the soil surface for their metamorphosis. The pupa period lasts 6 - 7 days.

S. maurita lays rather long and narrow egg masses on the leaves and these egg masses are covered by hair. One female lays 200 - 350 eggs which hatch after 5 - 9 days. The first instar larvae form groups and feed on part of the leaves. As the instars progress, the larvae eat more of the leaves and rapidly eat all of the rice in one paddy after which they move on to the next one. The larva stage lasts for 21 - 28 days and the matured larvae spend the pupa stage under the ground. The pupa stage is 10 - 14 days and one generation covers 37 days with each generation in different weeds.

Occurrence and damage of army worms: Army worms suddenly appear in large numbers but the process is still not clear. It has been reported the large outbreaks of army worms appear in wet rice after floods. Rice army worms appear mainly in Aman rice (first crop) and the young instar larvae are scattered about the leaves on which they feed. However, the older larvae tend to congregate in groups and cut through the rice ears so that they cause the most damage and make harvesting impossible.

The worms damage not only rice but also other important crops and there are cases when they cut the seedlings near the ground level.

S. mauritia also causes the greatest amount of damage to seedlings. When the larvae get larger, they form groups and move from plant to plant. In the tropics, they occur from June to August. There have also been reports in some places of the insects occurring in April or October. The larva damage the rice until just before the appearance of the ears.

Control of army worms: Measures to control army worms must be taken while the larva are young. Insecticides are not effective once the larvae have passed the fourth instar stage. Recently, tests have been performed concerning the control of army worms by viruses. Since it is also gradually becoming clear how the occurrence of army worms is suppressed with respect to the behavior of their insect natural enemies, integrated control of army worms combining insecticides and natural enemies should soon be established. The most effective insecticides are DDVP, Sevin and Methoxychlor. Emulsions should be diluted 600 - 800 fold and powders applied in concentrations of 30 - 40 kg/ha.

(2) Rice leaf folders (*Cnaphalocrosis medinalis*)

These species previously caused slight damage but recently they have become a major problem in Southeast Asia, Taiwan, Japan and other regions. The rice case worm, *Nymphula depunctalis*, is also a major pest. The distribution and host plants of these two species are shown in Table 6-11.

Table 6-11 Important pyralid pests of rice

Name	Common name	Host plants	Distribution
Cnaphalocrosis medinalis	Rice leaf roller	Rice, sugar cane	Japan, Korea, Pakistan, India, Malaysia, Thai, Indonesia
Nymphula depunctalis	Rice case worm	Rice	Australia, Southeast Asia

Life history of pyralids: The eggs of rice leaf folders are laid in pairs or individually on young leaves. These eggs are yellow and flat oval in shape. The hatch in four days. The larvae (Phote 28) wrap themselves vertically in the leaves and feed on the leaves from the inside. The larva stage lasts 15 to 25 days and the pupae are formed wrapped in the leaf and the stage lasts six to eight days. One generation covers 25 to 35 days.

The eggs of rice case worms are laid individually on the leaves and hatch after three days. The larvae are semi-aquatic and make their nests from several leaves in the form of cylinders. As the larvae become larger, the size of these cylinders changes. The inside of the cylinders are filled with water and the larva have gills in the form of long thin fibers on both sides of their bodies. Since oxygen is continuously transmitted in to the bodies via the gills, it is necessary that fresh water be supplied inside the cylinders. The larva stage continues for 15 to 30 days and the pupae remain in cylinders neat the base of the plant stalks. The pupa period is four to seven days and one generation lasts for 20 to 40 days.

Damage cause by pyralid pests: Rice leaf folders firmly close both sides of the leaves of comparatively young rice plants and the larvae nest in the leaves while feeding from the inside of the rolled leaves (Photos 29 and 30). The damaged leaves have white blotches which indicates that the larvae feed mostly on chlorophll. The damaged leaves become dry and when the damage is extensive, the entire plant becomes shrivelled. There have been cases where up to 60% of all the rice stocks were damaged.

The larvae of the rice case worms form their nesting cylinders by cutting through the rice leaves. The sizes of the cylinders change to match the size of the larva bodies. The chlorophyll disappears from the damaged leaves and they become white. The leaves are eaten near the stalk parts and the damage is especially great in young rice, the growth of which is often stunted.

Pyralid pest control: The leaves and host plants damaged by rice leaf folders can be removed but this is not effective. Rice case worms can be controlled by draining the damaged paddies for three or four days. The application of 600 - 800 fold dilutions of emulations or 30 - 40 kg/ha of powders of insecticides such as malathion is also effective. In normal years, there are also many cases where these pests are controlled effectively by insect natural enemies.

(3) Rice skippers

This group consists of three species: *Parnara guttata*, *Pelopidas mathias* and *Telicota augias*. Table 6-12 shows the distribution and host plants of rice skippers.

Table 6-12 Important rice skippers of rice

Name	Common name	Host plants	Distribution
Parnara guttata	Rice skipper	Rice	Japan, Himalayas, Indonesia, Celebes, China, India, Thailand
Pelopidas mathias	Rice skipper	Rice	India, Indonesia, China, Thailand, Africa, New Guinea, Malagacy
Telicota augias	Rice skipper	Rice	Philippines, Indonesia, Australia

Ecology and damage of rice skippers: The eggs are laid on the surface of the leaves and hatch after three days. They are light yellow and the larvae are light green (Photo 31). The larvae feed on the leaves from the outer edge to the center so that only the mid-rib remains (Photo 33). The larvae make their nests by binding leaves together. Damage is especially great in young leaves after transplanting. The larvae continue feeding until the ears appear and when there is a high level of damage, the rice plants cannot recover in many cases. The pupa stage (Photo 32) is passed in the leaf tube and lasts for 8 - 10 days. Small outbreaks of rice skippers are common.

Control of rice skippers: Control of skippers is based on the same methods as used for army worms and rice leaf folders.

(4) Leaf beetles

The leaf beetles include one important pest, the rice hispa, *Dicladispa armigera*. This species is distributed throughout Southeast Asia (Thailand, India, Burma, Indonesia and Pakistan), Nepal and the southern part of mainland China. Host plants include rice, *Leersia hexandra* and wild rice.

Ecology and damage of leaf beetles: An adult female lays an average of 55 eggs in the epidermis near the lower edge of the leaf. A black excretion is left in the area where the eggs are laid. The eggs hatch after five days and the larvae feed on the leaves. Damage is confined mainly to the young rice plants due to the feeding of the adults and larvae. Patches of the larvae are in the form of vertical white lines. These white patches run from the tip of the leaves to the base (Photo 34) and the damaged leaves die. The larva stage lasts 7 to 12 days and the pupa stage five days. The pupa stage is spent in the patches of the larva. In India, there are six generations a year and in the southern part of Pakistan, these beetles cause important damage to Aus rice. Rice yields are decreased by 10 to 65% and 150,000 - 200,000 acres of paddy fields are affected annually.

Control of leaf beetles: Insecticides such as Diazinon, Sumithion, Sevin and Dimecron are effective if applied in 1,000 - 2,000 fold dilutions for emulsions and 30 - 40 kg/ha for powders.

Because of lack of space, consideration of leaf scales, grasshoppers, plant weevils, root worms, crane flies and mole crickets have been omitted.

6-3. Literature Cited

CHAPTER SEVEN
RODENT DAMAGE TO RICE PLANTS

Masaru Seki

The severity of rodent damage to agricultural crops needs no particular description.

The tropical area in Asia is no exception. The rodent damage to agricultural crops increases in parallel with the expansion of farm-lands. Although rats are considered omnivorous, most of their food is plants and what is worse, except for toxic plants, there is no vegetable unfit for their diet. This is why almost all agricultural crops suffer rodent damage.

In the monsoon zone of Asia, where the seasons are divided into dry and wet, floods deprive rats of their food and nests during the wet season. This destruction of their living environment acts as a natural selection to cause a considerable reduction of their population. Nevertheless, why isn't there any sign of decline in either their population or the damage they inflict? It is probable that rapid restoration of their population is due to the ample supply of food in the tropical area and their vigorous reproductive potential. With regard to high rodent reproduction, the figures, 20, 155, 392, reprent the accumulated inbreeding population after three years, based on the following assumptions: annual frequency of parturition, 3; litter size, 10, with equal numbers of males and females; and survival rate, 100%. One can imagine how terrible the result would be if 22 rats inhabited a hectare of farm-land, each eating 30 - 50 g of rice a day. In view of the current mounting concern about the world-wide food crisis, greater effort is urged for eradication of the rats.

7-1 RODENT CONTROL

Rodent control on a large-size farm is a most difficult and painstaking operation. The operation should be effectively and economically carried out by an appropriate strategy mapped out on the basis of a knowledge of rodent habits and ecology and the quickest possible prediction of their migration. Some technical information, such as the facts mentioned below, are indispensable to putting a rodent control plan into effective and economical operation.

7-1-1 Determining Rat Species

In carrying out the control operation, the rat species toward which the operation is directed must be known, otherwise the program itself can hardly be established. Identification of a rat species is the first step in rodent control. A rough identification is possible from morphology; however, various features must be accurately memorized because misidentification often results from the possibility that infant rats, and subadults as well, differ from adults in the color of body hair. A method of measuring external features, a basis of identification by morphological forms, measures a rat in the supine position, with the body stretched naturally, as illustrated in Fig. 7-1. The measurement will be easy if drafting dividers are used.

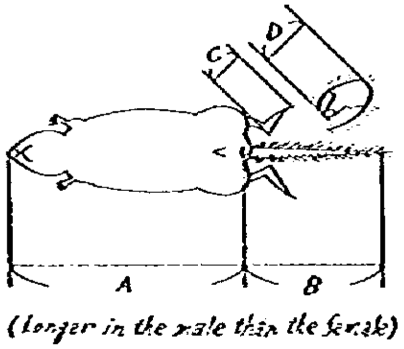


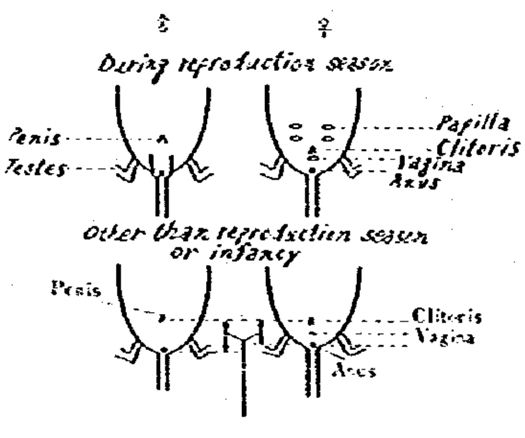
Figure 7-1

A- Length of body: From tip of nose to anus.
B- Length of tail: From anus to tip of tail exclusing hair on tip.
C- Length of hind foot: From heel to tip of longest toe excluding nail.
D- Length of ear: Maximum length from entrace of ear hole to edge excluding hair on edge.

The values thus obtained are important data for classification. Body colors and tail should also be recorded after careful observation. Nearly all species of rats can be classified by the above-mentioned information. However, when it is felt that morphological forms alone are not enough for classification, the rat must be classified by observing the features of its skull and molar teeth. In taking out the skull, the head is first skinned, then boiled in hot water, and then the muscle of the skull is stripped off. This must be done carefully as the skull is easily broken.

The sex of the rat must be known when the measurement of the external features are taken. The identification must be founded on anatomy in order to secure accuracy. The abdominal region is cut open to separate the reproductive organs using a scalpel without injuring the other internal organs. The male can be identified by the testes and the female by the ovary or the uterus. During a season of reproduction, adults can be readily identified from external features because the testes are enlarged and protruding in the male, the vagina is open in the female and the papillas are clearly visible if the rat is pregnant or suckling (Fig. 7-2). The number of papillas sometimes varies with species, another feature for classification. During a season other than that of reproduction or when the rat is in infancy, the testes are not visible from outside as they are inside the abdomen. The female is difficult to distinguish as the vagina shuts completely and the penis and the clitoris look alike. Judgement is, however, usually correct if it is based on the fact that, in rats belonging to the same species, the penis and the anus are separated in males but the clitoris and the anus are close in females.

Figure 7-2



7-1-2 Understanding Rat Ecology

A knowledge of habitats, the way of living and the condition of reproduction of each species is indispensable to efficient extermination. Of the various ways of studying rat ecology, the "Mark and Release Method" is explained here. This method seems quite good for studying the social structure of rodents. In this method, a trapping operation is conducted every day for 5 to 10 days, with traps set in the area at a certain spacing, say, 10, 15 or 20m from one to another, in a checkered pattern. Every captured rat is given a separate mark with which to record sex, the growth of the reproductive organs, suckling, weight, etc. The records on the condition of the reproductive organs include the growth of the testes in males and the state of the opening and closing of the vagina in females. As for the mark, one might think of using a pigment to mark the body of a rat, but this is not useful for a long-term survey because the change in hair will eliminate the pigment. A better way is to cut off toes of a rat and use this for marking. The writer has adopted the method shown in Fig. 7-3. In short, toes are cut off one after another, beginning with the outermost toe of the left fore foot, with the rat in the supine position. Note that the 9th mark is produced by cutting the outside of the left and the right fore foot. The hind feet are handled in a similar manner to have the toes represent the 10th, 20th, 30th, 40th . , . . . 100th mark, beginning with the 1st outermost toe of the left hind foot.

Fore legs· Hind legs

For example, No. 59 is produced by cutting off the outermost toe of both the left and the right fore foot and the 5th outermost toe of the left hind foot.

No. 145 is marked by the amputation of the innermost toe of the right fore foot, the fourth outermost toe of the left hind foot and the innermost toe of the right hind foot.

In cutting toes, care should be taken not to allow the rat to escape. The amputation can be performed by seizing the scruff of the neck when the rat is as small as a mouse, but if it is a *Rattus* or a *Badicota*, an anesthetic should be administered to the rat prior to the amputation for safety because of the danger of being bitten. The writer has been using ether for anesthetic. The rat is put in a large, heavy-duty, transparent vynil bag in which ether-soaked absorbent cotton has been placed. In this bag, the progress of the anesthetic effect can be observed. Extended anesthesia is fatal. Toes are ready for amputation when the rat is found incapable of standing after being turned over on its back outside of the vinyl bag. When there is severe bleeding after the cutting, it should be stopped by covering the cut with the fingers. Application of disinfectant is also good for prevention of suppuration.

The rats marked by this method are released to the area where they were caught. It is desirable to conduct the several-days trapping operation once every month so that the change in population, and the condition of reproduction in the investigating area, can be known.

As for bait to be used for the trapping operation, any rodent's favorite food in the respective areas will do. The writer used sweet potato in Taiwan for a rat investigation in sugar cane fields, but used mud snails in Cambodia for a similar operation in paddy fields. Both achieved good results.

In examining rodent reproduction ecology and population size, "snap-traps" are employed to catch and kill rats so that they can be dissected for observation of the growth of reproductive organs. This method is simple but good enough for checking rat migration in an area if it is applied 4 times a year for about 5 days each. Naturally, locally developed traps can be used instead of the snaptrap. It is advisable to establish a fixed rate between the size of investigation area and the number of traps.

(1) Home Range

A series of investigations using the "Mark and Release Method" will prove that every individual rat has its own range. This is called the home range, a domain of rats for maintaining their life, reproduction, breeding, acquisition of food, etc. The home range contains areas, called territories, which are off-limits to other rats. Unlike the home ranges, the territories will not overlap with one another. The area of a home range varies with species, sex and age; it is wider in *Murinae* than *Microtinae*, male than female, and subadult than adult. It also changes with the seasons and habitats, probably because of dietary conditions. Even when the home range is limited, if it offers the rats easy access to food and a good environment, or if the season provides the same conditions, enough for living, the inhabitant population will increase. On the other hand, an unfavorable situation will widen the home range, reducing the inhabitant population. The area of a home range is estimated with respect to a rat with a record of capture more than 3 times. The method is; plot the spots of capture on a piece of section paper, draw squares with the spots at the center and estimate the total area by means of combining the squares. In practice there are two methods; large enclosure or small enclosure of the area by means of combining the squares with a line. Figure 7-4 shows experimental results in sugar cane fields in Taiwan, using the large enclosure. (See next page.)

Figure 7-4.

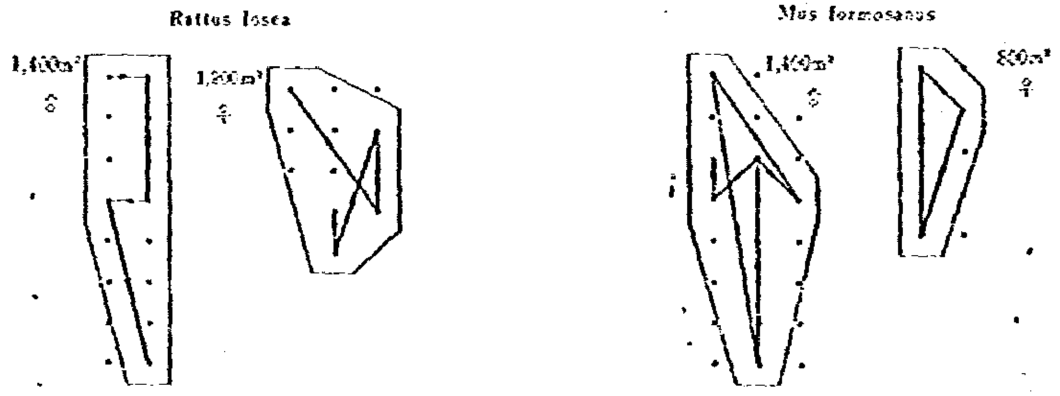
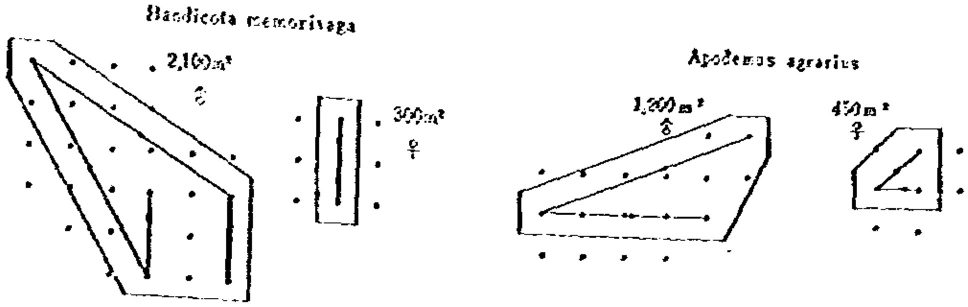


Figure 7-4



(2) Reproduction

The rat is so vigorous in reproductive powers that the early-maturing type of mob *Rattus norvegicus* will be sexually mature and possessed of reproductive powers in 25 days the late-maturing type in 60 days, averaging 35-40 days after birth. The female is in estrus in 50 days on the average, 35 days at the earliest and 90-120 days at the latest. However, 8 to 9 months elapsed before child-birth, said a report on a rearing test in Taiwan. Such being the case, it seems that the existing conditions have a great bearing on this question. The female is in estrus and capable of another conception soon after delivery. The female of *R. norvegicus* may have eight litters yearly, but that of *Bandicota nemorivaga* experimentally reproduced 3 to 4 times annually, four in each litter on the average, according to the rearing test in Taiwan. There is a case in which a *Bandicota indica* of Cambodian origin was found to have a litter of 13 when dissected. The life of rats is estimated at one year or less in nature although survivals of from one to three years have been recorded in laboratory animals.

(3) Eating Habits

A knowledge of rodent foods in the fields will help in deciding what materials should be used for poison bait in rodent control. The rats eat almost all kinds of vegetation although they are omnivorous. Naturally, food intake varies with dietary preference, but their dietary preference is unimportant when there is a shortage of food due to a poor harvest caused by climatic factors, or due to the increase in their population. In such conditions, huge damage will undoubtedly be done to agricultural crops.

The eating habits of rats are learned from an examination of their gastric content through dissection. However, a visual check seems ineffective in identifying the foods by varieties since the contents have been well masticated. Observation under a microscope is necessary to identify the varieties and this is done by mixing the gastric contents with iodine potassium iodide solution, separating a section displaying the so-called iodic reaction, then for identification observing the starch grains contained there under the microscope. Most of the starch grains contained in cells can be identified since those of cereals and potatoes vary in shape with species. Being indigestible, solid protein and chitin leave some part to distinguish them from eating insects. The methods of examining a rodent's eating habits from its gastric contents, though accurate, seem to be unfit for general application. One will be able to know a rodent's eating habits to a certain extent not from the gastric contents but by continuing careful observation in the fields, namely, through evidence of what they have devoured. A little experience will give evidence even of their species. To dig up their burrows and examine food in storage is an another method.

As previously mentioned, rats demonstrate their dietary preference at a low population density. But even at a high population density, the damage they do to crops begins with the crops they prefer. At times it happens that their preference is directed to certain species among several in the same crop. This is not only due to their dietary preference but also to a possible rodent concentration on such species because these species, susceptible to wind and rain, tend to lodge and develop many leaves becoming rodent shelters.

7-2 Rodent Control Technique

How effectively the knowledge in the preceding paragraphs can be put into operation is control technique. In practice there are four methods of control; chemical control using chemical rodenticides, ecological control utilizing a knowledge of rodent ecology, biological control making use of natural enemies and mechanical control using instruments such as traps, etc.

7-2-1 Chemical Control

This is an effective, low-cost, labor-saving method. On the other hand, because the chemicals used have some effect on man and other animals, a full understanding of the characteristics of the chemicals is required if accidents are to be avoided.

(1) Kinds of Rodenticide

. Na-monofluor acetate $CH_2FCOONa$

This is the 1080th chemical compound developed in America during World War II, and for this reason it is designated 1080 (ten-eighty). This is a water-soluble white powder and so toxic that even an extremely small dose will kill animals. The rat poisoned with this first develops paralysis of the motor nerves, then stops moving and dies of the poisoning. Since the time from intake to paralysis is so short that one can spot the carcass easily, this chemical is advantageous in view of the convenience of carcass disposal. On the other hand, strict control must be exercised because the poison is lethal even to carnivorous birds and animals which are the natural enemies of rats, not to mention its terrible toxicity to man. Its lethal dosages to man and various animals are as follows:

LD 50 (mg/kg bw)

Rat	0.3 - 4	Chicken	6 - 7
Dog	0.1 - 0.2	Goat	0.7
Monkey	5 - 5.7	Pig	0.3
Man	*350g (at a body weight of 70kg)		

*Note: The above figure for man is an estimate based on actual cases because experimental results are not available.

Thallium

The use of thallium for rodenticide begain in Germany in 1920. Thallium acetate and thallium sulfate are the available compounds, but the use of the latter is more common although both are equally toxic. Some Cambodian origin *Rattus rattus* were experimentally killed by biscuit-form bait containing thallium sulfate at dosages of 19.4 - 195.7mg/kg in 24-48 hours. A lethal dose for *Rattus norvegicus* is 15.8 ± 0.9mg/kg.

Thallium could cause loss of hair even if it fails to kill the rat, and because the chemical will not neutralize itself in the carcass, care should be taken to prevent secondary accidents to other animals which might eat the carcass.

Red-squill

The toxic ingredient of this chemical is the scilliroside contained in the bulb of *Urginea maritima*, a Liliaceae plant growing wild on the coast of the Mediterranean Sea. Although there are two varieties; white (native to Malta) and red (native to Algeria), only the latter is used for the rodenticide. Lethal dosages for the Norway rat are as follows:

Norway rat	Male	133 10mg/kg
	Female	276 29mg/kg

A limited toxicity to man and animals is a characteristic of this poisonous agent. Acerbity which may cause vomiting in the event of erroneous intake is also one of its characteristics.

Strychnine

This alkaloid, together with brucin and vomicine are contained in *Strychnos nuxvomica* and *Strychnos ignatii* which grow wild in India, Sri Lanka, Indo-China, Australia and so on. The lethal dose for rats is 1 to 10 mg/kg. It is also strongly poisonous to man and animals. The lethal dose for man is estimated to be 0.1g. There was, however, a death from a dose of 0.03g.

Zinc-phosphite

This is a dark-gray powder insoluble in water. It will decompose in acid, producing PH_3 gas of a peculiar odor. When taken by a rat, it dissolves in the acid of the gastric juices and turns into PH_3 gas; it passes out of the body leaving no toxicity. This is why secondary damage will not occur even when natural enemies to rats eat the carcass. This is another feature of the rodenticide. The lethal dose for rats: 40-75 mg/kg (LD=50%).

Coumarin

Once cattle were found dying one after another from hemorrhage of unknown cause when they were continuously fed with bad sweet clover. A study aimed at determining the cause finally discovered a chemical substance which was later named Dicumarol. This led to the discovery of another substance called Walfarin which is 20 to 30 times stronger than Dicumarol. The chemical name of this substance is 3-(α-acetonyl benzyl)-

4-hydroxycoumarin. This toxic agent will cause chronic toxicosis. The rat will experience hemorrhaging in the body 2 to 3 days after beginning the intake of this agent, becomes inactive and loses energy, it will be dead in 5 to 6 days. This toxic agent is ineffective unless the rat eats it every day. The rate of intake of this chemical by rats seems unchanged because other rats do not exercise precautions against those killed by the chemical as death seems to be natural. This chemical is practically harmless to man and other animals.

Since each toxic agent including those mentioned above has merits and demerits and no rodenticide which is safe under every condition has been developed yet, there is no alternative but to go ahead with the preparation and study the application of poisoned bait by putting the characteristics of the existing agents to best use.

(2) Preparation of Poisoned Bait

In preparing poisoned bait, materials preferred by rats must be found. The food habits and dietary preferences of rats vary to some extent with species and habitats. The dietary preference of the rats to which a control operation is directed must be ascertained prior to the preparation of poisoned bait. This is a basic principle of chemical control.

(3) Material and Form of Poisoned Bait

When two kinds of bait, one unhulled rice and the other dumplings made of rice flour, are simultaneously fed to rats, they eat the former at once without taking precautions but a little time is needed before they settle down to start eating the latter. Strongly cautious animals like the rat do not react to natural forms like unhulled rice but they will show what zoopsychology calls the reaction to foreign matter to the dumplings. It is, however, experimentally evident that when filling materials preferred by rats are added to the dumplings, their intake of the dumplings will exceed that of unhulled rice, once they get used to the bait.

Whether a toxic agent is soluble or insoluble in water will not matter to the preparation of dumpling-form poisoned bait, but to coat ordinary rice with a non-water-soluble toxic agent is very difficult. Chemicals must be carefully selected for an area where large, medium and small rats such as *Bandicota*, *Rattus* and *Mus* live together. Suppose the concentration of the toxic agent has been prepared to meet the weight of large rats, the control operation may end in failure because the other rats will avoid taking such bait.

(4) Scattering of Poisoned Bait

In the monsoon zone of Asia, in my experience, it is advisable to scatter poisoned bait three times a year, before and after the rainy season and sometime in January or February in the dry season if rodent control is conducted periodically every year.

As method of scattering bait in natural form, it is advisable to set up bait stations in order to prevent erroneous intake by other birds and animals. It is even desirable that bait in dumpling form be kept in bait boxes.

7-2-2 Ecological Control

This method aims at rodent control by depriving the rats of their habitats and food through destruction of their living environment. In Southeast Asia, picking of the panicle instead of cutting the plant down from near the root seems popular in harvesting rice plants. The author cannot help thinking that this method favors rodent reproduction. The harvesting of rice plants begins sometime during the dry season, unfortunately when rats reach their breeding period. A high rate of shattering can be observed when the panicles are picked. A survey in Cambodia recorded shattering as high as 150kg/ha. The rice plant whose panicle has been picked is left becoming an ideal habitat for rats. When they have food and habitats, the rats will, presumably, enhance their vigorous reproductive potential. Needless to say, this kind of environment must be destroyed. If this is not possible, efforts should be made to reduce the size of the rodent population by different means including the scattering of poisoned bait.

7-2-3 Biological Control

One should conduct rodent control while protecting carnivorous animals. Most rapacious birds catch and eat small animals. In Cambodia I had an opportunity to dissect five hawks. To my surprise, the craw of every bird was full of rodent hair and bones.

7-2-4 Mechanical Control

This method makes use of traps. Since there are many kinds, one may be puzzled about which to select. Hand-made traps designed in various areas are in use. I should say that their value should not be underestimated. They may be superior to mass-produced traps. People should be encouraged to catch as many rats as possible using hand made traps.

Conclusion

The four methods of rat control will demonstrate their effectiveness only when they are used in combination. Effort and perseverance are basic for rodent control.

CHAPTER EIGHT

DRYING AND STORAGE OF PADDY

Shinjiro Takeo

8-1. DRYING OF PADDY IN TROPICAL AREAS

The moisture content of paddy in the harvesting season in tropical areas is 16 to 28%. However, paddy with moisture content of more than 14% is unfit for storage from the viewpoint of minimizing quality deterioration and loss. This demands use of drying to remove such an extra moisture.

Sun drying is popular in tropical areas. This method is simple but effective when carried out properly and when there is good weather during the drying period. Control is a difficulty in effective sun drying. Paddy dries in a few hours in hot and dry weather but in two days or so under cloudy skies in a humid climate. Rainfall at the last stage of drying where the moisture content is about 16% can cause cracked and broken rice.

It is important in sun drying not to overdry a large volume of paddy, and to avoid hasty drying. When the moisture content of the greater part of the paddy is less than 20%, sun drying must be avoided because cement yards in tropical areas are extremely hot in the afternoon. Temperatures above 40°C are dangerous to the quality of paddy. It is however, impossible to avoid such temperatures in hot afternoons.

A study of sun drying has pointed out that successive one-process drying is harmful to paddy as it will increase the occurrent of broken rice in the milled rice. In paddy with a high moisture content it is advisable to dry it until its moisture content is reduced to 16 to 20%, gather and store it in the drying yard, leave it covered for 3 to 4 hours and supply tempering overnight if needed, then spread it and dry it again until 12 to 13% moisture content is reached.

Weather conditions during harvesting in the rainy season are not always favorable for sun drying. There is a danger that a large quantity of paddy will be lost when there is a shortage of sunshine and continuous rainfall. Artificial drying is the only solution to this problem. Even in tropical areas, when a modern harvesting technique such as the use of harvesting combines is adopted in future, a large volume of paddy will have to be artificially dried because the machines do not permit field drying after reaping.

8-2. PRINCIPLES OF DRYING

Drying, the removal of the moisture content of paddy, can be carried out in basically two ways; sun drying and artificial drying. Sun drying is a method of evaporating the moisture content of paddy by the heat of the sun, and natural wind. In sun drying, the drying capacity will increase in relation to an increase in temperature; in air dryness and in wind. A combination of these factors makes fast drying possible. Thus, it is important to control such conditions of the air as temperature, humidity and the rate of air flow properly for drying. These factors can be adjusted by machine, but they are difficult to control when natural drying is used. Heat is a prerequisite to remove moisture from paddy. The moisture in paddy is evaporated by hot air. Air flow will continuously carry away the evaporating moisture, thus drying the paddy. Heat and wind play a major role in paddy drying.

8-2-1. Relation between Drying and Heat

Total evaporation of 1kg of water will usually require 580 to 590kcal at a normal temperature, as shown in Fig. 8-1. The same principle can be generally applied to the removal of 1kg of moisture content from paddy, and roughly 600kcal is required for ordinary drying. But 600kcal is insufficient for actual artificial drying because of various losses, and 1,000 to; 2,000kcal and sometimes even 4,000kcal, are needed. This additional heat is affected by atmospheric conditions. It may be less than 600kcal when the weather is fine and the outdoor temperature is high, but as high as 3,000 to 4,000kcal when the weather is bad and the outdoor temperature is low.

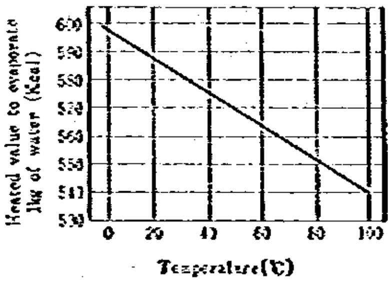


Fig. 8-1 Relation between Temperature and Heated Value for Evaporation

8-2-2. Relation between Drying and Wind

The rate of air flow is represented by m^3/sec. per 100kg of paddy before drying. The greater the rate for two lots of paddy of air flow, the shorter the drying time. This was proved by meaning the time to reach a specified moisture content with two lots under the same air temperature and humidity conditions but with different air flow rates. In short, a greater rate of air flow will quicken drying. However, an imprudent increase in the rate of air flow is practically useless because it does not always induce a proportional increase in drying speed, and the increase in the rate of air flow will consume more fuel and require high horse-power for ventilation. The rate of air flow of dryers in the market is normally 0.02 to 0.2m^3/sec per 100kg of paddy, but in some it is as large 0.6m^3/sec.

8-3. KINDS OF DRYERS

8-3-1. Flat Bed Type Dryer

This is a dryer for farmers' use, simple in structure and cheap for what it can do (Fig. 8-2). A small model of the dryer is capable of accepting approximately 700kg of paddy at a time, and a large model about 1,500kg. In operation, attention must be paid to air temperature. It is inadvisable to raise the temperature too high in view of a possible increase of uneven drying and cracking, although the temperature of the heated air differs with the moisture content at the time of loading. It is advisable to raise the temperature to 5° to 10°C above atmospheric temperature.

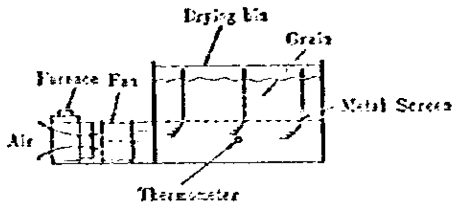


Fig. 8-2 An Example of FlatBed Type Dryer

In drying paddy with a high moisture content, the temperature of heated air is set lower than for paddy with low moisture content. But to reduce the uneven drying without dropping the drying speed too much, the thickness of the pile should be reduced. (For example, reduce the thickness to one half if it is 45cm.)

8-3-2. Upright Type Forced Air Dryer

The upright type dryer whose heater and fan are, in many cases, the same as those of the flat type is shown in Fig. 8-3. The merits of this model compared to the flat type are: (1) capability of automatic throwing and discharging of paddy, (2) small installation area in comparison with its capacity. However, the mechanization does not necessarily result in faster discharging. Discharging may not be easy when the materials contain a lot of straw dust.

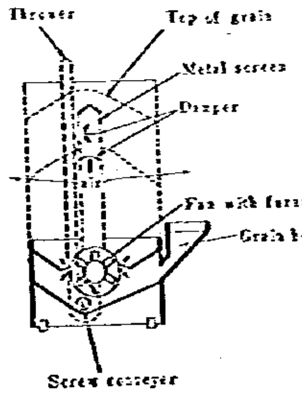


Fig. 8-3 An Example of Upright Type Forced Air Dryer

In the upright type, the position of the paddy must be changed by taking it out from the bottom and putting it back of the top once or several times while it is being dried since the paddy may not be equally exposed to the air flow. Precautions should be taken with paddy of high moisture content. The temperature of heated air applied to the flat type is applicable to this type.

8-3-3. Circulation Dryer

This machine is designed for drying paddy through constant circulation. (Fig. 8-4). Characteristics of this type are; decrease in uneven drying, convenient operation thanks to automatic throwing and discharging of paddy, and small installation area in comparison with its capacity. However, there is the possibility that admixture of a lot of straw dust may cause poor circulation and worsen uneven drying and quality. There are certain varieties in this type ranging from a farmer's model with the holding capacity of about 300kg at a time to one with a capacity of about 1 to 2tons for public facilities. With regard to its capacity, the moisture of the paddy being held can be reduced only 1 to 1.5% every hour. In this type of dryer, paddy is dried while being circulated and the so-called tempering condition is reached, because at the time of a low rate of air flow the paddy near the air inlet is exposed to high temperature, while that near the outlet is exposed to low. This type will produce higher temperature of heated air than that by the bed type dryer.

8-3-4. Continuous Flow Dryer

This type dries the paddy by heated air while the paddy is falling from top to bottom by gravity. The dryer consists of a drying chamber, a fan and a heater. An air planum is connected and a conveyor is provided for throwing and discharging paddy in and out of the dryer. The dryer can be classified into the following three major types according to the structure of the drying chamber. (Fig. 8-5)

(1) Screen Type

In this simple type paddy is thrown between two perforated boards while heated air is supplied to one board and then to the other, with a few places for catching straw dust while circulating the air, thus reducing the clogging problem. However, there may be only one drying when paddy is falling, because the paddy at the inside of the perforated board is hardly circulated at all toward the outside of the board. This might cause uneven drying on both sides of the air inlet and at the outlet of the heated air, but usually this is not a serious problem.

(2) Screen Baffle

The sides of the air inlet in this type in baffle, and generally the outside is perforated sheet iron and the inside is an imbricate-construction door. The reason why the outside is made of perforated sheet iron is that there is the possibility that the admixtures in the paddy may fly out with an increase in the speed of air flow.

This type is characterized by less uneven drying which can be attricuted to stirring by the baffle when paddy is falling. But there may be catching of admixtures, disturbance of smooth flow of the paddy and difficulty in cleaning if the baffle is not properly shaped.

(3) Inverted Troughs Type

This type is named after its shape. The heated air and exhaust pipes are alternatively installed, and the tops of the pipes usually have an inverted shape. Many inverted pipes will alter the path of the paddy when it is falling. Then the paddy is stirred while passing through the dryer. Uneven drying is slight in spite of a rather limited rate of air flow, because of the alternative placement of heated air and exhaust pipes.

The drying method in a country elevator is a multi-pass drying system composed of a continuous conveyor type dryer and a tank for tempering. In the multi-pass drying system, paddy passes through the continuous conveyor type dryer several times to reduce its moisture content little by little, and tempering is applied in the middle of the passage. An example is shown in Table 8-1.

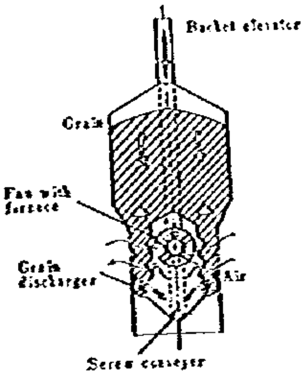


Fig. 8-4 An Example of Circulation Dryer

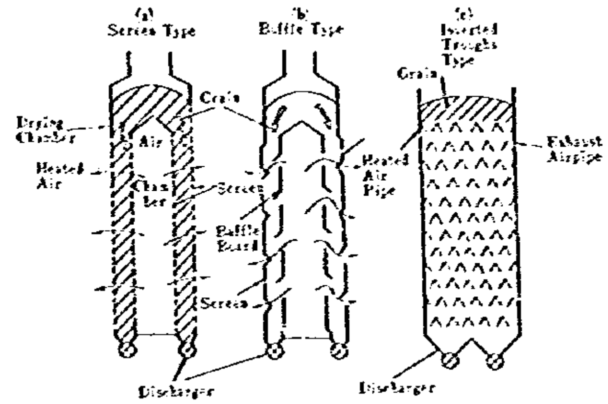


Fig. 8-5 Continuous Flow Dryers

8-4. CRACKING

Cracking is caused by quick drying and rapid absorption of humidity. Usually the rice kernel has almost no moisture gradient. But if a gradient exists, the kernel quickly dries and rapidly absorbs humidity, and cracking of the kernel will occur.

Table 8-1. Examples of Combination in Multi-pass Drying System

Method	Holding time of paddy in dryer	Temperature of heated air	Rate of air flow	Drying speed
A	Short (12~15 min.)	High (about 55°C)	Large (0.3~0.4 m^3/sec per 100 kgs of paddy)	About 2 %/ 12~15 min.
B	Middle (about 30 min.)	Low (about 45°C)	Large (0.2~0.3 m^3/sec per 100 kgs of paddy)	Slower than A Faster than C
C	Long (3 hours, twice, when start from 24% moisture content.)	Comparatively high (there are differences according the flow situation of paddy.)	Small (0.1 m^3/sec per 100 kgs of paddy)	Slowest 4~5%/3 hours

Note. (1) Temperatures of heated air and other figures are not always optimum for all cases.
(2) Tempering times are 3~4 hours or more than 4 hours.

Cracking due to absorption of humidity will develop under the following conditions; before harvesting, while paddy is being dried in the field, and after drying. Before harvesting, cracking may occur when a sudden rainfall or dew with dried paddy. It happends that paddy is generally dried in the field when harvesting is late and if comparatively fine weather continues. Even well-dried paddy in field drying will develop cracking due to showers and dew. And even after drying, the paddy will develop considerable cracking when it absorbs humidity in the air.

Factors related to cracking which occur during drying are:

(1) Initial moisture content of paddy,

(2) Final moisture content,

(3) Temperature and humidity of forced air,

(4) Stirring condition of paddy while drying,

(5) Rate of air flow per unit of paddy,

(6) Continuous or intermittent flow, and

(7) Variety and damage.

In many cases, cracking occurs in parallel with an increase in initial moisture content, also due to continued drying. The rate of cracking occurence will increase with a rise in temperature and drying speed. The following steps are therefore advisable for drying paddy with a high moisture contnet; not to dry to the moisture required for finishing through continuous ventilation, but to stop drying halfway and continue drying after waiting until the moisture gradient in the rice kernel is eliminated. This process is the previously mentioned tempering. Continuous alternative drying and tempering help decrease cracking.

A small rate of air flow per unit of paddy may develop large uneven drying on both sides of the air flow and also at the air outlet. Therefore, in order to avoid cracking as much as possible it is advisable that drying of paddy should be done with the air flow at a low temperature, but in this case drying time is inevitably prolonged. A technique for rapid drying of paddy is to dry it by stirring, keeping in mind that frequent and equal stirring will reduce cracking.

8-5. STORAGE OF RICE IN TROPICAL REGIONS

The major points of emphasis in regard to storing rice in Japan are the insuring of viability of rice, and maintaining suitable conditions of the moisture content of the rice as well as environmental factors such as temperature and humidity, to prevent the deterioration of rice quality and of variously-caused loss of volume. In regions such as Japan where new rice is thought to be highly palatable the relation between the freshness of rice and assuring its viability is more important than in tropical regions where parboiled rice is preferred. In the latter greater attention is paid to the prevention of loss of volume and damage in face of the high temperatures throughout the years and extremely high humidity during the monsoon season.

In general, almost all storage is in the form of paddy and at central markets near centers of consumption the ratio of milled rice is high. Although there is some variation from country to country, aside from rice kept for use on the farm, the storage period is relatively short for rice (paddy) which is sold by farmers to rice jobbers and particularly among smallholders the storage period is short because of economic reasons. Therefore in many instances the storage of paddy and milled rice must be done in the warehouses of brokers and millers; examples of the duration of such storage are given in Table 8-2.

Table 8-2. Duration of Storage

(%)

Duration	Farm level				Central market			
	Philippines	Vietnam*	Thailand	Nepal	Philippines	Vietnam*	Thailand	Nepal
within a month	40		65	40	20	17.5	50	50
1~6 months	60	100	30		75	82.5	50	
6~12 months or more than 12 months			5		5			
Total	100	100	100	—	100	100	100	—

Note: * Except Mekong area.
Source: APO data, Project No. SYP/VI/70 (1970)

Regarding the manner of storage, paddy is stored on farms in bulk, and milled rice is stored at central markets is stored in bags, while at local markets about half of the rice stored is bulk paddy and half is bagged milled rice.

Storage facilities used on farms very often consists of sheds of woven bamboo or sometimes of wood. At central markets a trend toward an increase in the use of corrugated metal sheets may be seen although the situation varies from country to country. Nevertheless, this latter method is not suitable for the storage of rice. In Nepal, considerable use is made of concrete, including some use of the concrete lower portion of roads. All harbor warehouses in Thailand are of concrete or brick. In the Philippines 70% of storage facilities are aluminum bins, 20% are wood, 5% are of stone and 5% are silos.

The floor on which rice is tored on farms in often of plants or logs, and central market and harbor warehouse floors are often of concrete. Roofs of farm storehouses are often of corrugated metal sheets, and thatch roofs are rare. Walls are usually of boards, metal sheets or bamboo on farms, and concrete, brick and mortar are common in central markets. Virtually no use is made of ventilation equipment.

Investigations have been conducted in many countries in recent years of bulk storage of paddy in silos, and beginnings have been made in the use of this method, while tests are still being conducted elsewhere; attention must be given to meteorological conditions, which vary from country to country. Effective use has been made in the United States of aeration of rice stored in bulk but care is required in adopting aeration because of the need to comply with requirements imposed by local meteorological conditions lest the efforts result in failure. For example, in some regions aeration may not function at all during certain seasons.

8-6. Fundamental Factors in Rice Storage

Grains in storage under natural conditions suffer deterioration from inside the grains themselves, plus biological damages from outside by insects and microorganisms. The following can be mentioned as the principal factors involved in deterioration and damage during storage.

Physical Factors	Temperature, humidity
Chemical Factors	Moisture content, enzymatic reaction, oxidation
Physiological Factors	Respiraiton, heating
Biological Factors	Insects, microorganism, rodents

The storage of rice is quite complicated where these factors correlate with one another. The consequence is the occurrence of qualitative damage which causes a substantial change in the rice and quantitative damage mostly resulting in weight loss. Insects and microorganisms also have a part in both kinds of damage. Among the above factors, correct moisture content and temperature are the most fundamental factors in rice storage, not to mention the importance of the soundness of grains themselves.

8-6-1. Moisture Content

Moisture content of rice is the first of various factors to be considered. When moisture content is low, rice withstands fairly poor storage conditions. Humidity during the wet season in tropical areas is the other factor that should not be overlooked. Humidity can be regarded as honogeneous with moisture content, according to the equilibrium mentioned below.

Absorption and desorption of humidity constantly take place between grains in storage and the surrounding atmosphere so that moisture content is exchanged. Through this exchange, moisture content of the grains and humidity of the atmosphere try to reach an equilibrium at all times. Moisture content at this particular time is called equilibrium moisture.

Table 8-3 shows such equilibrium between moisture content of paddy or of various fractions of of grain and humidity, while Fig. 8-6 shows a development through which paddy reaches equilibrium moisture at different humidities. At 25°C, paddy with a moisture content of 18.5% absorbs humidity if this is more than 86% but turns to desorption if it drops to less than 75%.

Table 8-3. Percentage of Moisture of Various Fractions from Artificially Dried and Naturally Dried Paddy in Equilibrium with Atmospheres of Different Ralative Humidities. (25°C)

Description of sample	Relative humidity of atomosphere, %								
	10	20	30	40	50	60	70	80	90
Paddy[1]	4.4	6.5	7.9	9.1	10.4	11.8	13.2	14.8	17.6
Paddy[2]	4.6	6.6	8.0	9.3	10.6	11.6	12.6	13.8	17.0
Paddy[3]	—	7.6	9.0	10.2	11.3	12.6	13.8	15.3	18.1
Polished rice[1]	5.2	7.6	9.2	10.5	12.0	13.4	14.8	16.4	18.8
Undermilled[2]	4.6	7.0	8.6	10.0	11.4	12.8	14.2	15.4	18.4
Bran[1]	5.0	6.4	8.0	9.0	10.0	11.0	12.4	14.8	18.0
Bran[2]	4.6	5.8	6.6	7.4	8.3	9.2	10.6	Moldy	—
Hulls[1]	3.7	5.4	6.8	8.1	9.5	10.8	11.8	12.9	15.3
Hulls[2]	3.7	5.4	6.8	7.9	9.1	10.1	10.8	11.6	14.0
Polish[1]	5.3	7.0	8.2	9.2	10.1	11.0	12.4	14.5	18.0

[1] Field-dried paddy.
[2] Rice which had been artificially drid prior to receipt at mill.
[3] Data of Coleman and Fellows converted to wet basis.

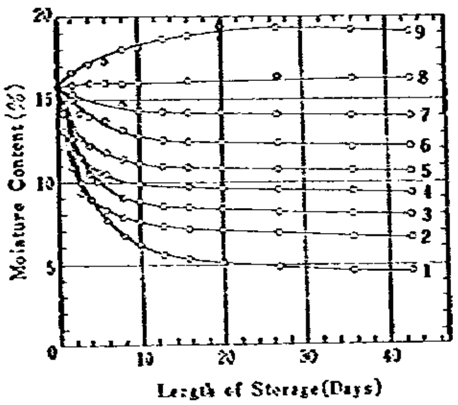


Fig. 8-6 Effect of Length of Storage at Constant Relative Humidity on the Moisture Content of Naturally Dried Paddy.
Relative humidiy are : (1) 11.1%; (2) 22.5%; (3) 32.5%; (4) 43.7%; (5) 53.3%; (6) 64.4%; (7) 75.4%; (8) 86.4% and (9) 92.5%

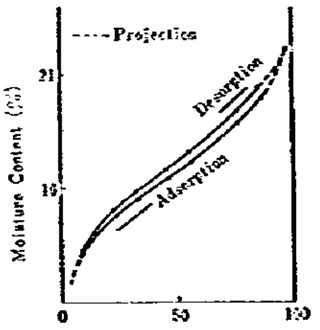


Fig. 8-7 Isotherms for Husked Rice at 20°C

Price arrives at an equilibrium moisture by absorption or desorption of humidity at a given temperature following the S-shape curves shown in Fig. 8-7. There is no coincidence of figure between absorption and desorption. The phenomenon by which desorption and absorption take different developments like this is called hysterisis, which, it is said, indicates a coherence of moisture content of rice with chemical factors.

Safety of storage depends on moisture content and many other factors. To set a single safety limit to moisture content is difficult because of the differences in the equilibrium moisture of rice. However, it is desirable for moisture content to be less than 14%, to protect the rice from development of microorganisms, a problem demanding utmost attention.

8-6-2. Temperature

Fundamentally, temperature is as important as moisture content and humidity. A relative humidity in equilibrium with the moisture content of rice varies with temperature. Low temperatures are more suitable for storage of rice than high temperatures. Weather conditions in tropical areas are disadvantageous on this point because the higher the temperature, the faster the speed of chemical reaction of rice grains becomes, thus activating the respiration and fermentation of the grains themselves or of parasitic micro-organisms. The increase in temperature of rice is chiefly caused by a rise in atmospheric temperature and partly by the respiration and heat generation of rice itself.

When the temperature of rice exceeds 20°C, noxious insects and micro-organisms begin to propagate, the rice activates its respiration and damage occurs. The temperature of rice is closely related to its moisture content. Although low temperature is favorable to storage, the temperature of rice need not be too low when the moisture content of rice is small. After all, it is also important for the tropical area to reduce the moisture content of rice as far as possible.

8-7. PROTECTION AGAINST BIOLOGICAL DAMAGE

In tropical areas, losses during storage are the highest at the farm level, lowest in central markets and intermediate in local markets. Damage from rodents is high as shown in Table 8-4. Damages from birds and insects are comparable with each other. Losses caused by moisture content and heat are high in some countries.

Parboiled rice has long been prepared in India, Burma, etc. as a precaution against damage from insects. There is a primitive method in which the paddy is soaked in water, heated in a pot, exposed to sunshine for drying and then milled. Even an indust-

Table 8-4. Percentage Distribution of Damages during Storage by cause

(%)

	Philippines	Vietnam (Local market)	Thailand (Farm level)	India
Rodents	43	40	50	42
Birds	1	25	33	17
Insects	12	10	8	33
Molds	3			
Moisture	17			8
Heat	18			
Spillage	2	25	8	
Total	100	100	99	100

Note : Sum does not come of 100 percent because of rounding.
Source : APO data, Project No. SYP/VI/70 (1970)

rialized type of this method where steam is used for steaming paddy still makes use of the process of soaking, steaming, drying and milling. This treatment is advantageous since it not only gelatinizes rice grains to harden them and prevent insect attacks but also helps produce a vitamin B-rich, highly nutritional milled rice by the transfer of vitamin B which exists in the germ and the bran layer to the endosperm, not to mention the advantage of less broken rice at the time of milling.

The use of grain protectants, fumigants and rodenticides varies from country to country. They are widely used in some countries but little applied in others. Typical chemicals being used in Japan are described below for reference. PGP (phyrenon grain protectatnt) and DDVP (dimethyl-clichloro vinylphosphate) are serving as grain protectants. PGP is the compound of pyrethrin, an ingredient of the pyrethrin flower, and puper-rounyl butoxide, a stabilizer. It is effective for protection against insects when sprayed on packages of husked rice. A 0.2% mixture of it in husked rice is the other usage. However, the spraying should be done two or three times a year because of the short life of the compound. DDVP is soaked in plastic strips. When left hanging in a storehouse, these strips will gradually generate a gas which kills noxious insects. A sheet of the strip is used for every $100m^3$ of the internal capacity of the storehouse.

Methyl bromide and phosphine are used as fumigants. With a low boiling point (4.5°C), the former evaporates. It is also characterized by economy and absence of erosive action because of its small gas absorption. Phosphine is a tablet whose main ingredient is aluminum phosphide. On absorbing atmospheric moisture, it begins to decompose to generate hydrogen phosphide gas gradually and will dissolve in 72 hours, leaving harmless aluminum hydroxide. This is suitable for fumigation of the silo. Compounds of ethylene oxide and methyl bromide have also begun to be used recently.

Rodenticides and repellents are for rodent control. Slow-acting coumarine-based rodenticides and fast-acting monoflouoracetate rodenticides are popular. Coumarine-based rodenticides soluble in water are suitable for dry storehouses where rats tend to take water-soluble agents. Cycloheximide, an antibiotic produced from actimonyces, is known for its effectivenss as a rodent repellant. Its solution has an anti-rodent effect when applied to packing materials and the inside of storehouses. A summary of the main control chemicals now in use is given in Table 8-5.

Table 8-5. Main Control Chemicals in Japan.

Kind	Chemical	Application time	Dosage	Treatment
Grain protectants	PGP	Immediately after carry in warehouse	15 g/3.3 m²	2~3 times in a year
	DDVP fumigant	〃	one plate/100m³	
	DDVP smoke generator	〃	DDVP 25 g/100m³	
Fumigants	Methyl bromide	Early summer ~mid summer	10.5 g/1 m³	48 hours
	phospine	〃	0.5 tablet/1 m³	72 hours
Rodenticides	Coumarine-based rodenticides	Required		
	Sodium monofluoroacetate	Great damaged		
Rat repellent	Cycloheximide		0.2% water solution	