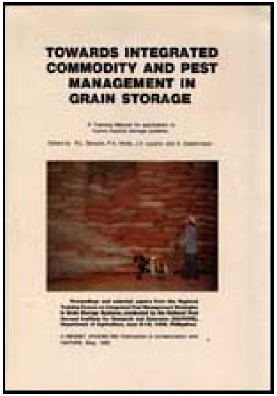

Towards integrated commodity and pest management in grain storage

Table of contents (526 p.)

A Training Manual for application in humid tropical storage systems.

Edited by R.L. Semple, P.A. Hicks, J.V. Lozare, and A. Castermans

Proceedings and selected papers from the Regional Training Course on Integrated Pest Management Strategies in Grain Storage Systems, conducted by the National Post Harvest Institute for Research and Extension (NAPHIRE), Department of Agriculture, June 6-18, 1988, Philippines.

A REGNET (RAS/86/189) Publication in Collaboration with NAPHIRE, May, 1992.

Contents (526 p.)

Annex: The role of naphire in coordinating national post harvest research extension and training in the Philippines

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Foreword

Contents - Next

This publication is the Report of the Proceedings of the Regional Training of Trainers Course conducted by the Regional Network for Inter-Country Cooperation on Post Harvest Technology and Quality Control of Foodgrains (REGNET) with the support of UNDP/FAO Project RAS/86/189 and the joint collaboration of the National food Authority (NFA) and the National Post Harvest Institute on Research and Extension (NAPHIRE) of the Republic of the Philippines.

This Training Course was conducted on June 6-18, 1988 at the NAPHIRE facilities, located at the Central Luzon University Campus in Munoz, Nueva Ecija, Philippines. The main objectives of the training were to strengthen the training capabilities of participating Network member countries and to enhance the transfer of existing technologies in Integrated Pest Management among institutions and national agencies in the Region.

Selected post harvest technology specialists in the Region, including the active participation of the private sector, provided the technical expertise on the various subjects covered. This training is the first of REGNET's two initiatives on Integrated Pest Management in food grains, with the second being held in Pakistan in April, 1989.

This publication covers the five working modules of Integrated Pest Management used in this course-the current state-of-the-art Asian grain post harvest industry, grain properties, pest infestation during storage, storage methods and systems, and training and extension methods. These components have been integrated in several training methodologies which included lectures, open forums, hands-on laboratory work, field simulation exercises and Country reports, both in big and small working groups for maximum learning.

This serves, therefore, as a technical reference manual for Post Harvest Technology institutes wishing to plan or conduct similar training courses at the national level, research and development specialists, post harvest technologists, rural extensionists, or even policy makers who may use the contained information to formulate new research, development, extension, or policy-generating activities, and for agricultural engineering, food science and technology students who may use this book as a text reference.

R.L Semple, P.A. Hicks, J.V. Lozare, and A. Castermans

Contents - Next

Section 1 - Physical grain characteristics of paddy/milled rice and its grades and standards

The anatomy and physical properties of the rice grain

by B. Belsnio

I. INTRODUCTION

A combined knowledge of the physical properties and anatomical composition of the rice grain is a prerequisite in gaining a closer understanding of what happens to the grain in the different postharvest operations. The understanding of the anatomy of the rice grain will clarify the reasons why rice kernels break so easily on mechanical impact during the physical operations of threshing and milling, and under thermal stress during drying. methods on the surface tissue of the grain kernel and the kernel itself, will indicate the importance of the correct adjustment of hulling machines in order to prevent breakage, and ensure higher milling recovery.

II. ANATOMY OF THE PADDY GRAIN

The anatomy of the rice grain consists of a brown rice kernel enclosed by the husk. The brown rice grain consists or a bran layer, a germ and the starchy center of the grain.

THE HULL

The most visible part or a rough rice grain is the husk. This is also known as the hull (figure 1). This is formed from the two leaves of the spikelet namely the palea covering the ventral part of the seed and the lemma covering the dorsal portion. Both parts are longitudinally joined together by an interlocking fold. This fold is a weak point in the hull and easily breaks up when a twisting force is applied to the grain. The upper end of the two hull sections transfer into the apiculus sections and finally ends in the pointed awn.

At the lower part, where the grain is fixed on the panicle is a tiny leaf-shaped part called the sterile lemma and then the rachilla. Normally the panicle breaks off during threshing, however a small part of the pedicel frequently remains attached to the grain. The husk is formed mostly of cellulosic and fubrous tissue and is covered with very hard glass-like spines or trichomes. The present of this make the husk abrasive and very hard thus, they give the grain a good protection against insects, microrganism, moisture and gases

The caloric value to the hulls is rather high and ranges from 3000 to 3500 kcal/kg making hulls an important source of energy in agriculture.

However, the most disturbing presence in rice hull is high proportion of silica which causes considerable damage to processing equipment through excessive wear of machine parts and interconnecting transfer facilities.

THE PERICARP

When the hull is removed, a thin fibrous laver can be seen (Figure 2). This is called the pericarp, frequently known as the "silverskin". The layer is usually translucent or greyish in color. When the pericarp is not translucent, but reddish in color the gain is referred to as red rice. It is considered as an integral part of the brown rice kernel (caryopsis) but is easily removed in the or whitening process. The main function of this layer is to serve as an additional protective layer against molds and quality deterioration through oxidation and enzymes due to the movements of oxygen, carbon dioxide and water vapor.

The pericarp actually consists or 3 layers namely epicarp, mesocarp & cross layer. Immediately under the pericarp layer is the testa or sometimes called tegmen layer which is only a few cells in thickness but with less fibrous than the pericrap layer. This layer is rich in oil and protein but its starch content is very low.

Sometimes this layer is considered as part of the seed coat but because of its oil content, it is normally considered as the outermost layer of the bran.

THE BRAN

Immediately under the testa or tegmen layer is the bran layer or aleurone layer (Figure 2). This part is the main constiturent removed in the whitening stage during milling. It has a very low starch content but has a high percentage of oil, protein, vitamins and minerals. Because of its high oil, content, the bran is easily affected by oxidation when the oxygen in the air comes in contact with oil.

In the milling process, the higher milling degree indicates a greater percentage of bran removed. Table 1 shows the degree of milling as determined by the quantity of the outer layer removed from the brown rice kernels. When rice is fully milled the vitamins (a complex), protein, mineral, and oil contents are lessened. This explains why persons with beri-beri (Vitamin A deficiency) are advised to eat brown rice. This also probably explains why persons who eat well milled rice are prone to be protein difficient or even malnourished. Thus, it is not surprising that some dieticians recommend the eating of regularly milled or even undermilled rice.

In the processing Industry, the vitamins in the grain can be retained by parboiling before milling. This allows the movement of nutrients from the bran layer to the inner part of the grain thus, making the vitamins available in the milled rice.

THE EMBRYO

The embryo is located at central bottom portion of the grain, where the grain has been attached to the panicle of the rice plant (Figure 2). This is the living organism in the grain which develops into a new plant. The embryo respires by taking in oxygen in the air, consumes food which comes from the starch in the grain itself while simultaneously releasing moisture and heat. This explains why grains during storage have the tendency to decrease in weight as a result of the loss in moisture and dry matter content in the endosperm. During milling, the embryo is removed resulting in an indented shape at one end of the milled rice grain.

THE ENDOSPERM

When the husk, the pericarp, the bran and the embryo are removed, what remains is the endosperm. It mainly consists of starch with only a small concentration of protein and hardly any minerals, vitamins or oil. Because of its high percentage of carbohydrates, its energy value is high. In the central core of the grain the starchy cells are somewhat hexagonal in shape, but between the centre and outside they are elongated with the long walls radiating outwards from the centre (Figure 2)

III. PHYSICAL PROPERTIES/ CHARACTERISTICS

1. Length

The length of the paddy grain is variable, even within a variety, because of variation in the length of the awn and the pedicel. It is for this reason that the type of paddy is not determined by the length of the paddy grain but by the length of the brown rice kernel. In threshing, it is important to watch at what point the paddy grain will break off its panicle, because the pedicel should not be a part of the grain, of else it will have a reduced milled rice recovery through the increase of "husk" production.

2. Husk-surface

The husk surface is rather rough and abrasive through its high silica content. It is for this reason that rubber-rolls of the hullers wear so fast, that precleaning machines have many parts which ferquently need to be replaced, augers used for paddy transport become very sharp, elevator discharge spouts, especially bends in spouts and elevator cups wear so quickly, and that parts of the husk aspirators in direct contact with the husk have to be repaired or replaced very often.

In rice mill equipment, the rough surface of the paddy grain compared with the smooth surface of the brown rice, plays an important role in the determination of specific design criteria.

3. Free space between the Husk and the brown Rice kernel.

When the grain is dried, there is a distinct space between the rice hull and the kernel inside. With the weak point in the interlocking fold and the space between the rice hull and grain kernel, a rubber roll huller or any dehulling machine can dehul the grain with minimum (or even without) abrasion to the pericarp and other internal parts of the grain. This enables the dehulling to be done with minimal pressure against the grain, thus minimizing breakage and losses.

4. Tight Interlocking fold of the husk

The husk sections consising of the lemma and the palea, are tightly seamed together through a double fold. This requires a level of force to open these folds in the process of dehusking which made the design of hullers rather difficult in order to avoid unnecesary breakage of the grain.

It is only when the rice is parboiled that dehusking will practically cause no problems because as a result of the hot water soaking and steaming process, the two husk sections open without releasing the brown rice kernel.

5. The Awn

The awn sometimes is very long on certain varieties, so that special machine is required in order to break off and remove the awns prior to the dehusking of the paddy. However, awners are expensive, energy consuming, slightly increase the amount of breakage and ultimately result in a less profitable, less efficient conversion of paddy into milled rice.

6. The Pericarp

When damaged, it allows oxygen to penetrate into the bran layer which leads to an increase of the free fatty acid (FFA) content of the oil in the bran. The oxidation process makes the bran rancid and will ultimately result in serious quality deterioration of the brown rice kennel. Its mainly the abrasive disc huller which damages the pericarp. But, this is no disadvantage if it is immediately converted into milled rice. However if brown rice is produced for storage (as in Japan) or for shipment as cargo rice to riceimporting countries or to central whitening plants, the use of rubber roll hullers is a must in order to avoid or at least reduce oxidative and enzymatic deterioration of the bran tissues.

7. The Longitudinal Starchy Cells

It is unfortunate that the outermost starch cells of the endosperm are elongated in shape, and from the processing point of view it is even more unfortunate that these long cells are positioned with the long side directed towards the center of the grain. This give the grain the potential to react to thermal stresses resulting in fissures and ultimately in cracks throughout the grain. It can easily break under the impact of force either when it is threshed, conveyed, cleaned or dehusked. And lastly, this characteristic gives the grain the potential to break when incorrect drying procedures are followed. This aspect has made it extremely difficult to design drying systems that would enhance an optimum milled rice recovery through minimum breakage.

Other physical properties that are related to the physical composition of the grain are:

8. Angle of Repose

Paddy forms a complete cone when it is vertically unloaded on a flat surface. The angle of the side of this cone-shaped mass of grain, measured after the flow of grain has completely stopped, is the angle of repose. This angle defers from each type of grain and depends much on the smoothness of the surface of the grain.

The angle of repose is also directly dependent on the moisture content of the grain. At a moisture content level of 20%, the angle of repose for paddy will be greater than for dry paddy at 14% MC.

This properties is important in the construction of bulk storage facilities and the calculation of the dimensions of intermediate holding bins of a given capacity.

9. Angle of Friction

The angle of friction refers to the angle measure from the horizontal at which paddy grain will start moving downwards over a smooth wooden surface with gravity discharging the paddy grain. This differs for each type of grain and characteristic of the surface, since it depends much on the smoothness. Also, the moisture content of grain has an impact on the angle of friction the angle for wet grain is greater compared to dry grain.

This angle of friction is important in the construction of self-unloading holding bins and bulk storage facilities. It also plays a role in the construction of grain discharge spouts.

10. Bulk Density

The bulk density refers to the ratio between weight and volume of grains. It is normally expressed in kg per HL, lbs per cuft or kg/cu m.

The density data are important in the calculation of the dimension of bulk storage facilities and intermediate holdings bins of given capacity. It also indicates the purity-degree of the grains since the presence of light foreign matter reduces the grain density.

11. Grain Dimensions

The dimension of the paddy grain and milled rice kernel play an important role in the determination of grain standards and throughout the processing cycle. This grain dimension is classified according or in relation to the following.

1. The type of paddy-classified according to the length of the whole brown rice grain.

   a. Extra long -paddy with 80% of the whole brown rice kernels having a length of 7.5 mm. or more.
   b. Long -paddy with 80% of whole brown rice kernels having a lenght of 6.5 mm. or more but shorter than 7.5 mm.
   c. Medium -paddy having 80% of the whole brown rice kernels with a length between 5.5 mm. to 6.5 mm.
   d. Short -paddy with 80 % of the whole brown rice kernels shorter than 5.5 mm.

2. The sub-type of paddy The sub-type of paddy grain refers to the ratio of length and width of the whole brown rice kernel

$$\text{RATIO} = \frac{\text{Length in mm.}}{\text{Width in mm.}}$$

   a. Slender-paddy of which the brown rice grain has a length/width ratio of 3.0 or more.
   b. Bold -paddy of which the brown rice grain has a length/width ratio of 2.0 or more but smaller than 3.0.
   c. Round -paddy of which the brown rice grain has a length/width ratio smaller than 2.00.

3. The type of Milled Rice-milled rice is classified according to the length of the whole grain.

a. Extra long - milld rice of which 80 % of the whole milled rice kernels have a length of 7.0 mm. or more.
b. Long -milled rice of which 80 % of the whole milled rice kernels have a length of 6.0 mm. or more but shorter than 7.0 mm.
c. Medium -milled rice of which 80% of the whole milled rice kernels have a length of 5.0 mm. or more but shorter than 6.0 mm.
d. Short -milled rice of which 80 % of the whole milled rice kernels are shorter than 5.0 mm.

4. The sub-type of milled rice -This refers to the length/width ratio of the whole milled rice grain. The 3 sub-types for milled rice is defined in the same manner as that for paddy as slender, bold and round.

5. Brokens in milled Rice -The definition of brokers is generally based on the length of the rice particle and is referred to in units 118th of the length of the whole unbroken milled rice grain. These are categorized as:

a. Head Rice -is a milled rice particle with a length of 618 or more of the length of the whole unbroken milled rice kernel.
b. Large Broken -is a milled rice particle with length of 618 or more of the length of the whole length of the whole unbroken milled rice kernel.

c. Small Broken -is a milled rice particle which will not pass through a perforated sieve with a round perforation of 1.4 mm. but the length of the grain is shorter than 3/8 of the whole unbroken mill rice kernel.
d. Brewer's Rice-is a milled rice particle which will pass through a sieve with a round perforation of 1.4 mm.

TABLE 1 Degree of milling based on the removed outer layer of the brown rice kernels

DEGREE	**PERCENT REMOVED FROM BROWN RICE KERNELS %**
Under milled	3 - 4
Medium milled	5 - 6
Fully milled	7 - 8
Over milled	8

References:

1. H. TH. Van Ruiten, Physical properties of paddy and milled rice. Grain post-harvest processing technology.

2. E.V. Aronilo, D.D. de Padua and Michael Grainham, Rice post harvest technology.

Paddy and milled rice grading

BY: REBECCA L. SAMPANG

INTRODUCTION

Rice is the staple food of the Philippines contributing 74% of total food consumption and per capita food consumption? More than 30% of all agricultural lands and more than 50% of the food cropland is devoted to rice. In 1986, the country produced 2.67 metric tons of paddy per hectare.

Under these accelerated production conditions, paddy and rice grading has become a major aspect in marketing both for local and international trade, quality assurance and in varietal

improvement programs since the 70s. The National Food Authority is the agency entrusted with grain market stabilization, market development and industry regulation.

IMPORTANCE OF GRAIN GRADING

Grain grading is a set of standard procedures and methods in quality determination which is essential in marketing, quality assurance operations and in the varietal improvement program of the country and other research projects involving paddy and milled rice.

GRADES AND MARKETING

Grading is necessary in the development of quality standards that define the relationship between grades and prices in the assessment of the value of grains. Official standards are important in the marketing process because they furnish the means of describing variations in quality and condition. They also provide a basis for merchandising contracts, for quoting prices, for loans on product in storage and for sorting and blending by producers to meet market requirements. Grading then provides for an orderly marketing and trading system.

When grades and prices are defined, the farmers become virtually interested in producing better crops because with grading they are assured that their return are based on the quality of their produce. This is supportive of the quality assurance program of the agency.

GRADES AND QUALITY ASSURANCE

With better crops procured, quality assurance in the other post-harvest operations becomes more manageable.

With grades and quality standards, quality evaluation or quality assessment operations aimed at preventing quality deterioration and reducing postharvest losses becomes more uniform.

Grading is conducted at regular intervals in the various stages of post-harvest operations as a means of quality monitoring. It becomes a basis for comparison between grain quality particularly of stocks before and after long storage, thus as basis for remedial measures to be undertaken.

Quality has become one of the dominant factors for consideration in the rice industry and the first step towards the achievement of quality rice is grading. Setting-up modern post-harvest facilities alone cannot solve the quality problem completely. Grading is particularly desirable prior to milling as it offers the following advantages: 1) immature grains are separated 2) more precise adjustment of the huller is possible, which minimizes breakages, and 3) independent milling of graded lots is possible.

GRADING AND IMPROVEMENT PROGRAMS

Since 1955, the country has developed a varietal improvement program through the Philippine Seed Board which has recommended a total of 96 high yielding varieties for

cultivation. It has been estimated that about 75% of the total riceland area are now planted to improved varieties.

Paddy and milled rice grading is a component of the varietal improvement program as different varieties have different intrinsic and acquired characteristics. This responsibility was entrusted to the National Food Authority since it joined the Board in 1979. Some quality standards set by NFA has since become the basis for comparison among varieties with respect to acquired characteristics such as headrice and brokers, chalky and immature kernels and brown rice and milling recovery. In the past 10 years, 26 lowland and 6 upland varieties were approved and are now widely cultivated.

PADDY AND MILLED RICE GRADING IN THE PHILIPPINES

Paddy and milled rice grading in the Philippines is patterned after the model rice grading system introduced by FAO through the Inter-Government Group on Rice. This grading system includes standard definition of terms.

PADDY GRADING

The present NFA grading system is of two types: Field grading during procurement and laboratory grading after procurement.

Field grading during procurement is a very important phase of the agency's post-production

operations. At this stage, all grains being procured from individual farmers, corporations or cooperatives are inspected and analyzed to establish the quality of the commodity. By doing so, the commercial value of the commodity is assessed as well as its fitness for processing, storage or distribution.

During procurement of paddy, moisture content and purity are quality factors which form part of the basis of payment and are therefore properly determined before the grain is procured.

At the buying stations, farmers' produce are sampled randomly by means of a grain probe and the gathered sample is then inspected. Purity, damaged and discolored kernels are determined by ocular inspection by quality assurance officers, while moisture content is determined by means of a calibrated moisture meter. The produce then is graded according to the following NFA buying specifications:

- **14% Moisture Content (MC)**
- **95% purity**
- **Not more than 7% damaged and yellow kernels**
- **Masagana and ordinary palay varieties**
- **Free from infestation**

Paddy with lower purity (below 95%) and/or high MC (adove 14%) may be accepted or bought at a reduced price subject to weight adjustments. using the Equivalent Net Weight

(ENW) (Table 2) for paddy, provided they do not exceed the lower limit set for purity (85%) and the upper limit set for moisture content (26%) and that they pass all other quality specifications. Paddy with MC above (26%) and that they pass all other quality specifications. Paddy with MC above 26% and purity below (85%) are not accepted

The laboratory grading based on the national standard considers the following factors for quality assessment:

1. Moisture Content

High moisture directly reduces the grade of rice; if the grain molds or spoils, the grade is lowered even more. This is a critical factor as it has a bearing on the keeping properties of grain during storage and also on the milling quality and yield. A tested and reliable moisture meter is used for moisture determination. For every region, only one brand of moisture meter is used to minimize variations of moisture reading.

2. Impurities and Foreign Matter

All materials other than paddy or rice kernels are called foreign matter or impurities. This includes soil, stones, weed seeds, fragments of rice stalk, dust, husk, and dead insects. The presence of impurities and foreign matter could result in grain deterioration in storage. It also affects the quality of milled rice and accelerates the wear and tear of the milling machine. Its presence likewise lowers the milling recovery of the grains.

3. Damaged and Yellow Kernels

Damaged kernels are defined as kernels and pieces of kernels of paddy/rice which are distinctly discolored or damaged by water, insects, heat or any other means. It is difficult to assess damaged and yellow kernels in paddy unless dehulling and whitening is done. The presence of these grains adversely affects the quality of milled products derived from such lots.

4. Immature and chalky Grains

Immature grains have a husk weight ranging from 30 to 40% of the grain weight. Hence, the presence of excessive amounts of immature grains in paddy lowers milling yield and increases the husk production. Furthermore, immature grains are predominantly chalky and brittle, breaking easily in the process of hulling and whitening, thus reducing both headrice and total milling yield.

5. Red Rice

Red rice is rice with discolored pericarp. The red seed coat (pericarp), usually in the form of a firmaly adhering bran, detrats from the appearance and market value of the commercial product. The bran of red rice adheres to the endosperm so firmly that it is difficult to remove in milling without causing excessive breakage of the gnain.

6. Classification of Grains (Varietal Purity)

The physical dimensions of the grains are important in many ways. Grouping of varieties are made on the basis of sizes: long, medium, and short and in the process, utmost care must be taken to see to it that they are of unifrom sizes. Admixture of different sizes adversely affects the milling quality and yield. Proper segregation of grain according to sizes is absolutely necessary. In some cases, rice is reprocessed several times to obtain the desired quality standards. Once the grains are mixed, it will be extremely expensive to improve the quality through milling.

For NFA Grade Specifications for Paddy, please refer to Table II Appendix B.

MILLED RICE GRADING

Grading of milled rice either for foreign or domestic consumption, is usually done after milling. Periodic inspection, however, is conducted during milling to check if the resulting product meets the required standard specifications. This makes possible the immediate restoration of a good process and prevent production of too many defective grain or rejects.

The quality parameters considered in milled rice grading are practically the same as in paddy grading with some additional parameters.

1. Head Rice Yield

When rough rice is milled, kernel breakages naturally occur resulting in different kernel lengths, hence, it is necessary to determine the variation. The length differences have been grouped into head rice, brokers and brewers with certain length limits.

Head Rice - a kernel or a piece of kernel with its length equal to or greater than 8/10 of the average length of the unbroken kernel.

2. Brokens

Brokens are still subdivided into the following types: Big Brokens, Medium Brokens, Small Brokens and Brewers.

Big Brokens - pieces of kernels smaller than 8/10 but not less than 5/10th of the average length of the unbroken kernel.

Medium Brokens-pieces of kernels smaller than 5110th but not less than 2/10th of the average length of the unbroken kernel.

Small Brokens - pieces of kernels smaller than 2/10th of the average length of the unbroken kernel.

3. Brewers

These are small pieces or particles of kernels that pass through a sieve having round perforations 1.4 mm in diameter. This is also known as "binlid" or "chips".

4. Paddy Kernels

Dehulling is not usually 100% efficient resulting in the presence of paddy kernels in the milled rice output.

Paddy - unhulled grain of Oryza saliva, which means grain with glumes enclosing the kernels. It is also known as "palay" of "rough rice" or "rice grain".

5. Red Streaked Kernels/Red Rice

As in red rice, these are kernels with discolored pericarp, whole or broken but having red streaks of the total length of which is one half or more of the length of the kernel as differentiated from red rice which have 25% of their surface red.

6. Milling Degree

Milling degree is determined by the degree of bran removal and are of the following types:

Undermilled - Rice grain from which the hull, a part of the germ and all or part of the outer bran layers but not the inner bran layers have been removed.

Regular Milled - Rice grain from which the hull, the germ, the outer bran layers and the greater part of the inner bran layers have been removed, but parts of the lengthwise streaks of the bran layers may still be present on more than 10% but not exceeding 30% of the kernels.

Well Milled - Rice grain from which the hull, the germ, the outer bran layers and the greater part of the inner bran layers have been removed, but parts of the lengthwise streaks of the bran layers may still be present on not more than 10% of the kernels.

7. Damaged and Yellow Kernels

8. Chalky and Immature Kernels

9. Foreign Matter

10. Contrasting Type (Varietal Purity)

11. Moisture Content

For NFA Grade Specifications for Milled Rice, please refer to Table 4.

TABLE 1: NFA VARIETY CODES

1.1 PALAY

For Procurement Purposes:

VARIETY (max. %)	MC	YELLOW AND DAMAGED (%)	CHALKY (Max %)	RED RICK (Max %)
XQP	14	0 - 3	10	1
PAO	14.1 - 26	0 - 3	10	1
PA7	14	3.1 - 7	25	5
PA9	14.1 - 26	3.1 - 7	25	5
SDP	14 - 26	6.1-55Y	-	-
		1.1 - 25D		

For Reclassification Purposes:

VARIETY (max. %)	MC	YELLOW AND DAMAGED	CHALKY (max %)	RED RICE (Max %)

		(%)		
PA1	14	7.1 - 15	25	5
PA2	14	25.1 - 30	25	5
PA3	14	30.1 - 50	25	5
PA4	14	Greater than 50	25	5

1.2 MILLED RICE

VARIETY (Max. %)	MC AND	YELLOW (Max %) DAMAGED (%)	CHALKY (Max %)	RED RICE
WM0/RM0	14	3	10	1
WM1/RM1	14	3.1 - 7	25	5
WM2/RM2	14	7.1 - 15	25	5
WM3/RM3	14	Greater than 15	25	5

TABLE 2 EQUIVALENT NET WET WEIGHT FACTOR FOR PALAY

%MC: 14%	: 14.1-:14.6-:15.1-:15.6-:16.1-:17.1-:
	18.1 -:19.1 -:20.1 -:21.1-:22.1 -:23.1 -:
	24.1 -:25.1 -:
Purity	14.5%:15%:15.5%:16%:17%
	: 18%: 19% :20% :21%: 22%
	: 23%: 24%: 25%: 26%:
95-100%	:1.00:0.98:0.97:0.96:0.95:0.93
	:0.92:0.90:0.88:0.87:0.85:0.84
	:0.82:0.81 :0.79:
90-94.9%	:0.97:0.95:0.94:0.93:0.92:0.91
	:0.89:0.87:0.86:0.84:0.83:0.81
	:0.80:0.79:0.77:
85-89.9%	:0.92:0.90:0.89:0.88:0.87:0.84
	:0.82:0.81 :0.79:0.73:0.77:0.75
	:0.74:0.73:

INSTRUCTIONS FOR THE USE OF THE TABLE 2:

1. **Determine the Gross Weight (GW) of the Palay**
2. **Determine the Wet Weight (NW) of the palay by subtracting the weight of container from the gross weight.**
3. **Determine the percent (5) Moisture Content and the percent purity of the palay**
4. **Based on the % moisture content and the % purity, determine the the Equivalent Net Weight Factor (ENWF).**
5. **Multiply the Net Weight to the Weight Factor to get the Equivalent Net Weight (ENW).**
6. **Peso Value-Equivalent Net Weight x Buying price:**

N.8 This table shall not used for liquidation or other puposes except for palay procurement only.

Quality Standards for palay: 14% and 95% purity

TABLE 3 GRADE REQUIREMENTS FOR PADDY

GRADING FACTORS	**GRADE PREMIUM :1:2:3**
Purity (Min%)	98.00: 95.00: 90.00: 85.00

Foreign Matter (Max %)	2.00: 5.00: 10.00: 15.00
a) Weed Seeds and other Crop seeds (Max %)	0.10: 0.10: 0.25: 0.50
b) Other Foreign Matters	1.90: 4.90: 9.75: 14.50
Defectives:	
Chalky & Immature Kernels (Max. %)	2.00: 5.00: 10.00: 15.00
Damaged Kernels (Max. %)	0.25: 1.00: 3.00: 5.00
Contrasting Types (Max %)	3.00: 6.00: 10.00: 18.00
Red Kernels (Max %)	1.00: 3.00: 5.00: 10.00
Discolored Kernels (Max %)	0.50: 2.00: 4.00: 8.00
Moisture Content (Max %)	14.00: 14.00: 14.00: 14.00

TABLE 4 GRADE REQUIREMENTS FOR MILLED RICE

GRADING FACTORS	**GRADE PREMIUM: 1: 2: 3**
Head Rice (Min %)	95.00:80.00:65.00:50.00
Big Brokens (Max %)	3.00: 10.00: 10.00:20.00
Broken Other than Big Brokens (Max %)	1.90: 9.75:24.00:29.00

Brewers (Max %)	0.10: 0.25: 0.50: 1.00
Defectives:	
Damaged Kernels (Max %)	- : 0.25:0.50: 2.00
Discolored Kernels (Max %)	0.50: 2.00: 4.00: 8.00
Chalky & Immature Kernels (Max %)	2.00: 5.00: 10.00: 15.00
Contrasting Types (Max %)	3.00: 6.00: 10.00: 18.00
Red Kernels (Max %)	- : 0.25: 0.50: 2.00
Red Streaked Kernels (Max %)	1.00: 3.00: 5.00: 10.00
Foreign Matter (Max%)	- : 0.10: 0.20: 0.50
Paddy (Max. no. per 1000 grams)	1 : 8 :10 :15
Moisture Content (Max %)	14.00: 14.00: 14.00: 14.00

Laboratory test methods for paddy and milled rice grading

BY Wenifreda C. Fajardo

INTRODUCTION

Laboratory tests and analyses used in grading paddy and milled rice are based on the physical characteristics of grains and involve ocular or visual inspection of the commodity at hand. The tests are carried out with the use of several laboratory equipment following the procedures for laboratory test methods for Paddy and Milled rice analysis.

The fallowing should be carried out in conducting these tests.

TEST METHODS

1. Preparation of working sample:

1.1 Pass the representative sample at least three times through a laboratory mixer or divider to ensure homogenous mixing.

1.2 Prepare the following working samples for three trials for each test.

1.2.1 For Paddy Grading

3 - 150 gms. - for moisture content determination
3 - 100 gms. - for purity determination
3 - 100 gms.-for immature, chalky, discolored, damaged and red kernels
3 - 250 gms.- for potential milling recovery

1.2.2 For Milled Rice Grading

3 -150 gms. - For moisture content determination
3 - 100 gms. - for headrice, brokers and brewers
3 - 100 gms. - for discolored, damaged, red, red streaked, chalky, immature and foreign matter

2. Moisture Content Determination:

2.1 Determine the moisture content from the 150 gram sample using a properly calibrated moisture tester appropriate for the grain being tested, or use standard air-oven method or any other method which gives equivalent results. (The weight of the working sample may vary depending upon the requirement of the moisture tester.)

PADDY GRADING

3. Purity Determination:

3.1. Using the 100-gram paddy working sample, separate the weed seeds using a sieve. pass the remaining paddy twice through a laboratory aspirator to separate other impurities such as chaffs, hulls, stones, stalks, weed seeds, etc. Gather and weigh all the impurities except the weed seeds. Sorting out of weed seeds and other impurities can also be carried out manually by handpicking.

3.2 Calculate the following percentage using the following formula:

$$\% \text{ Purity} = \frac{\text{weight of pure paddy}}{\text{wt. of working sample}} \times 100$$

$$\% \text{ Foreign Matter} = \frac{\text{wt. of foreign matter}}{\text{wt.of working sample}} \times 100$$

$$\% \text{ Weed Seeds and Other Crop Seeds} = \frac{\text{wt. of weed seeds and other crop seeds}}{\text{wt. or working sample}} \times 100$$

4. Determination of contrasting type and type classification

4.1 Contrasting type

4.1.1 Dehull the pure paddy sample obtained from the purity determination test by means of laboratory husker or laboratory huller.

4.1.2 Separate all whole brown rice kernels and weigh

4.1.3 Separate the kernels whose size and shape differ distinctly from the majority of the lot and weigh them

$$\% \text{ Contrasting type} = \frac{\text{wt. of contrasting kernels}}{\text{wt. of whole brown rice}} \times 100$$

4.2 type Classification:

4.2.1 Pick out 10 whole kernels at random form the dominant size in 4.1.3

4.2.2 Measure the individual length of the kernels and compute for average length.

4.2.3 Determine the type classification by referring to the standard specification of Rough Rice (Palay)

5. Determination of Defective Grains:

5.1 Dehull the second 100 gram paddy working sample and weigh the resulting brown rice

5.2 Segregate the following components on a sorting board

5.2.1 Immature kernels

5.2.2 Chalky kernels

5.2.3 Discolored kernels

5.2.4 Damaged kernels

5.2.5 Red kernels

5.3 Weigh each component and calculate the percentages using the following formula:

(Chalky and immature kernels are combined and treated as one component)

$$5.3.1\ \%\ \text{Chalky and Immature} = \frac{\text{wt. of chalky kernels and immature kernels}}{\text{wt. of working sample}} \times 100$$

$$5.3.2\ \%\ \text{Discolored kernels} = \frac{\text{wt. of discolored kernels}}{\text{wt. of working sample}} \times 100$$

$$5.3.3\ \%\ \text{Damaged kernels} = \frac{\text{wt. of damaged kernels}}{\text{wt. of working sample}} \times 100$$

$$5.3.4\ \%\ \text{Red kernels} = \frac{\text{wt. of red kernels}}{\text{wt. of working sample}} \times 100$$

6. Determination of Potential Milling Recovery:

6.1 Aspirate more than 250 gram working sample and weigh 250 grams (capacity of laboratory mill) of the pure paddy.

6.2 Dehull the pure paddy and mill the resulting brown rice to well milled rice using a laboratory testing mill

6.3 Weigh the resulting milled rice and calculate the percentage milling recovery

$$6.3.1\ \%\ \text{Potential Milling Recovery} = \frac{\text{wt. of milled rice}}{\text{wt. of pure paddy}} \times 100$$

MILLED RICE GRADING

7. Determination of headrice, big brokers, other brokers and brewers

7.1 Prepare the working sample for milled rice analysis following the procedures for the preparation of working sample in 1.

7.2 From the first 100 grams milled rice working sample, separate the brewers by using 1.4 mm sieve.

7.3 Separate the broken kernels by means of an indented plate, mechanical grader or by handpicking and weigh the remaining headrice.

7.4 From the separated broken kernels, segregate the big brokers.

7.5 Weigh each component and calculate the percentages using the following formula:

$$\% \text{ Brewers } \frac{\text{wt. of brewers}}{\text{wt. of the working sample}} \times 100$$

$$\% \text{ Big Brokens } = \frac{\text{wt. of big brokers}}{\text{wt. of the working sample}} \times 100$$

$$\% \text{ Other Brokens } = \frac{\text{wt. of other brokers}}{\text{wt. of working sample}} \times 100$$

$$\% \text{ Headrice } = \frac{\text{wt. of headrice}}{\text{wt. of working sample}} \times 100$$

8. Determination of Contrasting Type and Type Classification:

8.1 Contrasting Type:

8.1.1 Form the headrice obtained in # 7.2, separate the kernels whose size and shape differs distinctively form the majority of the lot

8.1.2 Weigh such kernels and calculate percent contrasting type using the formula:

$$\% \text{ contrasting Type } = \frac{\text{wt of contrasting type}}{\text{wt. of working sample}} \times 100$$

8.2 Type classification:

8.2.1 Pick 10 whole kernels at random from the dominant size in 8.1.1

8.2.2 Measure the individual length of the kernels and compute for the average length.

8.2.3 From the average length, determine the type classification by referring to standard specification for milled rice.

9. Determination of Foreign matter and Defective Milled Rice:

9.1 From the second 100 grams milled rice sample, count the number of paddy grains

9.2 From the remaining portion, segregate the following:

9.2.1 Discolored kernels

9.2.2 Damaged kernels

9.2.3 Red kernels

9.2.4 Red Streaked kernels

9.2.5 Chalky kernels

9.2.6 Immature kernels

9.2.7 Foreign matter

9.3 Weigh each component and calculate the percentage using the following formulas: (Chalky and immature kernels are combined and treated as one component)

9.3.1 $\% \text{ Discolored kernels} = \dfrac{\text{wt. of discolored kernels}}{\text{wt. of working sample}} \times 100$

9.3.2 $\% \text{ Damaged kernels} = \dfrac{\text{wt. of damaged kernels}}{\text{wt. of working sample}} \times 100$

9.3.3 $\% \text{ Red Kernels} = \dfrac{\text{wt. of red kernels}}{\text{wt. of working sample}} \times 100$

9.3.4 $\% \text{ Red Streaked kernels} = \dfrac{\text{wt. of red streaked kernels}}{\text{wt. of working sample}} \times 100$

9.3.5 $\% \text{ Chalky and Immature kernels} = \dfrac{\text{wt. of chalky \& immature}}{\text{wt. of working sample}} \times 100$

9.3.6 $\% \text{ Foreign Matter} = \dfrac{\text{wt. of foreign matter}}{\text{wt. of working sample}} \times 100$

10. Determination of Milling Degree:

10.1 Examine the bran layers or bran streaks from the head rice obtained by using a microscope or a magnifying glass.

1 0.2 Milling degree can be determined from the bran removal or by comparison with a standard sample. The classes of milled rice according to the degree of milling is as defined in the Standard Specification for milled rice.

11. Grading

Based on the result of analysis, the grade shall be evaluated against the Standard grade requirements. The grade designation is set according to the grade of the lowest quality characteristic.

GRADING OF PALAY AND MILLED RICE

EXAM PLES:

PALAY GRADING

To illustrate how the grade is determined, consider a sample of palay with the following characteristics:

Parameters	%	Grade

Purity	99.00	Meets premium
Foreign Matters	1.00	-do
a) Weed seeds and other crop seeds	0.09	-do
b) Other foreign matter	0.91	-do
Chalky and Immature kernels	6.50	Meets grade 2
Damaged Kernels	1.50	-do
contrasting types	3.50	Meets grade 1
Red kernels	0.20	Meets premium
Discolored kernels	2.50	Meets grade 2
Moisture Content	13.00	

Upon evaluation of each quality parameter (characteristics) the lowest grade obtained is chalky and immature kernels, therefore, the sample would be designated as Grade 2

MILLED RICE GRADING

To illustrate how the grade of milled rice is determined, consider a sample of milled rice

with the following characteristics:

Parameters	**%**	**Grade**
Headrice	70.00	Meets grade 2
Big brokers	8.00	Meets grade 2
Broken Other than Big Brokens	20.00	Meets grade 2
Brewers	0.20	Meets grade 1
Defectiveness:		
Damaged Kernels	0.30	Meets grade 2
Discolored kernels	2.50	Meets grade 2
Chalky and immature kernels	6.50	Meets grade 2
Contrasting type	5.00	Meets grade 1
Red kernels	0.25	-do-
Red Streaked kernels	4.50	Meets Grade 2
Foreign matter	0.15	Meets Grade 2
Moisture Content	14.00	

Since the lowest grade obtained is grade 2, the sample would be designated as Grade 2.

[Flow diagram]

[Flow diagram - continue]

[Figure 4. Interpretation of Brokens in Milled Rice]

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

NFA standard specification for milled rice (Second revision) TRED SQAD No. 2; 1980

Contents - Previous - Next

FOREWORD

This standard specification for milled rice is a revision of PTS 042:02: 1973 approved by the Bureau of Standards in 1973.

Adopting the basis principles, Provisions and terms of the "Recommended Model Grading System for Rice in International Trade" as approved by the FAO Inter-Governmental Group

on Rice, its revision was made in order to put the standard specification for milled rice in conformity with the revised standard specification for palay (paddy).

Any suggestions or comments regarding its revision should be addressed to the National Food Authority, 101 E. Rodriguez Sr. Avenue, Quezon City.

1. SCOPE

1.1 This standard specification covers the classification and grading requirements of milled and broken milled rice, except glutinous rice which are produced in the Philippines.

2. DEFINITION OF TERMS

2.1 For purposes of definition, the following terms shall apply:

2.1.1 Paddy. Unhulled grain of Oryza Sativa, which means, grain with the glumes enclosing the kernel. It is also known as "palay" or "rough rice" or "rice grain".

2.1.2 Milled Rice. Kernels obtained after removal of hull bran.

2.1.3 Sample. A samall quantity taken from various portions of the lot as representative of the whole lot.

2.1.4 Glutinous Rice. A special type of rice whose grains are white and opaque in appearance. It coagulates into a sticky mass cooked.

2.1.5 Broken Milled Rice. This contains a minimum of 75 percent broken kernels in the whole lot.

2.1.6 Size. Length category of at least 80 percent of whole milled kernels.

2.1.7 Degree of Milling. The extent in whicdh the bran layers and germ have been removed.

2.1.8 Enriched Rice. Milled rice which has been treated to enhance its nutritive value by adding vitamins and minerals.

2.1.9 Germ. Small white portion which lies on the ventral side of the rice kernel from where the seed germinates.

2.1.10 Brown Rice Rice grain from which only the hull has been removed. This is also known as "dehulled rice" "cargo rice" or "husked rice".

2.1.11 Hull. Outermost cover of paddy This is also known as husk.

2.1.12 Head Rice. A kernel or a piece of kernel with its length equal to or greater than 8/10th of the average length of the unbroken kernel.

2.1.13 Big Brokens. Pieces of kernels smaller than 8/10th but not less than 5/10th of the average length of the unbroken kernel.

2.1.14 Medium Brokens. Pieces of kernels smaller than 5/10th but not less than 2/10th of the average length of the unbroken kernel.

2.1.15 Small Brokens. Pieces of kernels smaller than 2/10th of the average length of the unbroken kernel.

2.1.16 Brewers. Small pieces of particles of kernels that pass through a sieve having round perforations 1.4 millimeters in diameter. This is also known as "binlid" or "chips".

2.1.17 Chalky Kernels. kernels, whole or borken one half or more of which is white like the color of a chalk and brittle.

2.1.18 Chemical Residue. Residue acquired by rice through the use of chemical as plant nutrients or as pesticides. The residue may also be acquired any stage of growing, harvesting, distribution marketing or processing, Residue of any approved chemical substances added to rice for human nutritional purposes are, however, excluded.

2.1.19 Contrasting Types. Kernels and pieces of kernels of varieties or types of rice other than the variety or type designated wherein size and shape of kernels differ distinctly from characteristics of kernels of the variety or type designated.

2.1.20 Objectionable Odors. Odors which are entirely foreign to rice.

2.1.21 Damaged Kernels which are distinctly damaged by insects, water, fungi, and/or any other means.

2.1.22 Discolored kernels. Kernels that have changed their original color as a result of heating and other means.

2.1.23 Foreign Matters. All matters other than rice kernel is rice polishings and paddy such as weed seeds and other crop seeds.

2.1.24 Grade. A designtion indicating the quality of rice determined with reference to its acquired charcteristics specified in Table I.

2.1.25 Immature Kernels. Kernels which are light green and chalky with soft texture.

2.1.26 Red Streaked Kernels. Kernels, whole of broken having red streaks the total lenght of which is one half of more of the length of the kernel.

2.1.27 Red Kernels. Kernels, whole or broken which have 25 percent or more of their surface red.

2.1.28 Moisture Content. The water content of the rice.

3. GENERAL REQUIREMENTS

3.1 The moisture content of milled rice shall not exceed 14 percent on "as received basis".

3.2 Milled rice shall be free from objectionable odor.

3.3 It shall be free from insect infestation.

3.4 It shall not contain chemical residues in excess of the maximum limits recommended by the joint FAD-WHO Codex Alimentarius Commission prescribed in Appendix A.

4. CLASSIFICATION AND GRADING

4.1 Milled rice shall be of the following types based on the size of the whole kernel.

4.1.1 Long. Rice with 80 percent or more of whole milled rice kernels having a lenght of 6.00 millimeters and above.

4.1.2 Medium. Rice with 80 percent or more of whole milled kernels having lenght of 5.00 to 5.99 millimeters.

4.1.3 Short. Rice with 80 perent or more of whole milled rice kernels having length of less than 5.00 millimeters.

4.2 The classes of milled rice according to the degree of milling shall be as follows:

4.2.1 Undermilled. Rice grain from which the hull, a part of the germ and all or part of the outer bran layers, but not the inner bran layers have been removed.

4.2.2 Regular Milled. Rice grain from which the hull, the germ, the outer bran layers and the greater part of the inner bran layers have been removed, but parts of the length wise streaks of the bran layers may still be present on more than 10 but not to percent exceed 30 percent of the kernels.

4.2.3 Well Milled. Rice grain from which the hull, the germ, the outer bran layers and the greater part of the inner bran layers have been removed but parts of the length wise streaks of the bran layers may still be present on not more than 10 percent of the kernels.

4.2.4 Overmilled. Rice grain from which the hull, the germ, and the bran layers have been completely removed.

4.3 Milled rice shall conform with the requirements specified in the following table:

4.3.1 Table 1 Grade Requirements for Milled Rice

Grading Factors	G r d e			
	Premium	1	2	3

Head Rice (min. %)	95.00	80.00	65.00	50.00
Big Brokens (max. %)	3.00	10.00	10.00	20.00
Brokens Other than				
Big Brokens (max. %)	1.90	9.75	24.00	29.00
Brewers (max. %)	0.10	0.25	0.50	1.00
Detectives				
Damaged Kernels (max. %)	0.25	0.50	2.00	
Discolored Kernels (max. %)	0.50	2.00	4.00	8.00
Chalky and Immature (max. %)	2.00	5.00	10.00	15.00
Contrasting types (max. %)	3.00	6.00	10.00	18.00
Red Kernels (max. %)	—	0.25	0.50	2.00
Red Streaked Kernels (max. %)	1.00	3.00	5.00	10.00
Foreign Matters (max. %)	—	0.10	0.20	0.50
Paddy (maximum				
number per 1,000 grains)	1.00	8	10	15
Moisture Content	14.00	14.00	14.00	14.00

4.3.2 The maximum percentage of the Big brokers and brokers other than big brokers may be exceeded provided that the maximum percentage of brewers is not exceeded.

4.4 Milled rice which does not meet the requirements for any of the grades in 4.3.1 shall be graded as "sub-standard grade".

4.5 Milled rice which contains 50 percent or more red kernels shall be graded according to the grade requirements in 4.3.1 and the word "red rice" shall be added as part of the grade designation.

4.6 Enriched rice shall be graded according to the grade requirements in 4.3.1 and the word "Enriched Rice" shall be added as part of the grade designation. A certificate attesting that said rice is enriched shall be secured from the Food and Drug Administration.

4.7 Brokens milled rice shall conform with the requirements specified in the following table.

4.7.1 Table 2 Grade Requirements for Broken Milled Rice

Grading Factors	**Grade**			
	Phil.	**Phil.**	**Greded**	**Graded**

	Broken1	Broken2	`Broken1	Broken2
Head rice (max. %)	5.1-25	5.1-25	0-5.0	0-5.0
Head rice & big broken				
(singly or combined, min. %)	20.00	-	-	-
Medium brokers (3% permissible)	0-80.0	0-100	-	-
Small brokers (max. %)	20.00	50.00	20.00	50.00

Grading Factors	Grade			
	Phil. Broken1	Phil. Broken2	Graded Broken1	Graded Broken2
Foreign matters max. %)	0.50	1.00	.50	1.00
Damaged kernels (max. %)	2.50	5.00	2.50	5.00
Moisture content (max. %)	14.00	14.00	14.00	14.00

4.7.2 The percentage of medium brokers shall be determined by subtracting from 100% the combined percentage of head rice, big brokers and small brokers.

Computations: % Medium brokers = 100% - (% Head rice + % Big brokers + % small brokers)

5. PACKING AND MARKING

5.1 Milled rice shall be packed in durable jute or plastic sacks without patches to give maximum protection from normal hazards of transportation and handling and shall weigh 50 kilograms net. Smaller packages may be allowed provided the net weight be one or two kilograms or multiple of five kilograms subject to buyer/seller agreement.

5.2 Each sack of milled rice shall be properly labelled with the following information.

5.2.1 Type, grade and milling degree

5.2.2 Date of milling

5.2.3 Name and address of miller

5.2.4 Net weight in kilogram

6. SAMPLING

6.1 Samples of milled rice shall be drawn in accordance with TRED-SQAD SM-1: 1975

Standard for grain Sampling

6.2 Projected shipments of milled rice for which request for inspection has been received shall be inspected sampled and classified and graded by quality control inspectors duly assigned by NFA.

6.3 Requests for inspections shall be made on forms provided by the NFA and it should be submitted to NFA at feat five days before shipment.

6.4 The required analysis to determine the quality of the commodity shall be done by persons duly assigned by the standards and Quality Assurance Division of NFA.

6.5 On conclusion of the grading, the sample shall be placed in a moisture proof container, sealed and labelled, so as to be readily identifiable and the sample shall be retained by the grader for at least one month. If necessary, the sample shall be stored in such a manner that there is no detorioration of the material.

6.6 Grading advices shall be sent to the seller not later than three working days after the milled rice has been graded. In case of a dispute, the seller shall lodge an objection to the

inspector within ten (10) working days for a second grading to be carried out by an independent inspector appointed by the Director of the Technical Research and Extension Directorate of the NFA whose grading shall be taken as final.

7. TEST METHOD

7.1 Moisture Content Determination. Moisture content shall be determined by using a properly calibrated moisture tester or by the standard air -oven method or any other method which gives equivalent results. Samples for moisture test must be placed in airtight of moisture proof container at the time of sampling.

7.2 Insect Infestation in Milled Rice. Insectinfested rice shall be graded and designated according to the grade requirements of this standard, but the word "Infested" shall be added as part of the grade designation. The rice is infested if any one or more of the following conditions are found from a portion of the sample weighing not less than 50 grams.

a. **Contains more than one weevil, or**
b. **Contains one weevil and any other live insects, or**
c. **Does not contain any weevil but does contain five or more other live insects.**

7.3 The determination of head rice, brokers and brewers shall be made on a working sample weighing 100 grams. All other determinations except that of paddy shall be made on a

duplicate working sample weighing 100 grams.

7.4 Contrasting Type and Type Classification, Using the head rice obtained from the head rice determination in 7.3, separate the kernels whose size and shape differ distinct!} from characteristics of kernels of variety and type under consideration. Weigh such kernels and express the weight as percent contrasting types. To determine the type to which the sample belongs, select 10 whole kernels at random from the remaining head rice. Measure the individual length of the kernels and compute the average length.

7.5 Milling Degree. The assessment of milling degree shall be guided by comparison with a standard sample.

7.6 All tests shall be conducted in duplicate.

8. EFFECTIVITY

This Standard Specification shall take effect upon its approval.

APPENDIX A - GUIDE TO MAXIMUM LIMITS FOR PESTICIDE RESIDUES RECOMMENDED BY THE JOINT FAO/ WHO CODEX ALIMENTARIUS COMMISSION AT THE 1976 MEETING

Chemical Compound	Maximum Limit (mg/kg) (ppm)

1. Chlordane	0.05
2. Chlorfenvinphos	0.05
3. Diazinon	0.10
4. Dichlorvos	0.50
5. Diquat (usually dibromide)	0.20
6. Endrin	0.02
7. Fenitrothion	1.00
8. Hydrogen Phosphide	0.01
9. Paraquat	0.50
10. Pirimiphos-Methyl	1.00

Limit at or about the limit of determination.

The limits are expressed in milligrams of the residue per kilogram of milled rice (mg/kg) also expressed a parts per million (ppm)

Contents - Previous - Next

Section 2 - Summary requirements for safe grain storage

Storage of cereal grains

by S.C. Andales

SIGNIFICANCE OF STORAGE

Storage of perishable products is a paradox. It is something that must be done and yet it is something that should be avoided as much as possible. It is a good thing to do because it will give one the assurance that something is in reserve to use or eat for tomorrow. Storage capability allows continuous supply of materials for processing or for distribution. On the other hand, it is undesirable because it means that huge capital investments in storage facilities will be required. Moreover on reception in storage, the product is subject to pest infestation and natural product deterioration.

Most agricultural commodities are produced seasonally. Their harvesting is normally done during a short period of two to three months while their consumption is constant throughout the year. For this reason, storage becomes necessary.

The primary aims of storing food commodities are normally as follows:

1. **To effect a uniform supply of food throughout the months of the year, either for domestic use or for export.**
2. **To provide a reserve for contingencies such as droughts, floods, and war.**
3. **To speculate on high prices either in domestic or in the export market.**

THE ROLE OF STORAGE IN THE RICE POST-HARVEST SYSTEM

Storage is a critical component of the rice postharvest system. In graphic form, the relationship of storage with other operations in the systems is as shown in Figure 1.

As shown in the diagram, there are two points at which the storage operation is taking place - after procurement (or drying) and just before distribution. Procurement is dictated by production in terms of timing quantity and quality. It is generally predictable and therefore the paddy storage operation can be programmed.

Local distribution is more or less fixed in terms of the constant rate of consumption. Export on the other hand is to some extent unpredictable. Delays in ship arrival and variation of

quality specification by buyers demand that allowance in milled rice storage capacity has to be provided.

Between the two storage operations is the milling operation. These three operations make a problematic trio to coordinate and control. Their functional relationship is illustrated in a model shown in Figure 2.

COMPONENTS OF THE GRAIN STORAGE SYSTEM

The primary concern in storage is the safety of the product. For perishable crops, the product quality and quantity have to be maintained or deterioration has to be minimized. To be able to achieve this purpose the five aspects of storage has to be considered, attended to and understood, namely:

1. **The stored product**
2. **The storage structure**
3. **The environmental factors**
4. **The storage pests**
5. **The personnel involved**

The interrelationship of these five components or factors may be shown graphically in Figure 3 or may well be stated as follows:

"The personnel involved in storage operation have the primary responsibility of keeping the stored product safe and secure inside the structure against storage pests and environmental factors.

FACTORS AFFECTING LOSSES IN STORAGE

A. Mechanical and Environmental

1. **Handling damage**
2. **Handling spillage**
3. **Moisture stresses and movements**

B. Infestation:

1. **Bacteria, molds, and fungi**
2. **Insects**
3. **Rodents**
4. **Birds**

C. Biochemical Processes

1. **Vitamin loss**
2. **Fat acidity**

3. **Natural respiration**

$C_6H_{12}O_6 + 6O_2$--$6CO_2 + 6H_2$ + 677 Kcal.

MEASURES FOR PREVENTING OR MINIMIZING LOSSES

Losses in storage can be minimized or prevented by adopting any or combination of the following:

A. Chemical Control

1. **Insect control**
2. **Mold, fungi and bacterial control**

B. Biological Control

1. **Predators and parasites**
2. **Entomogenous fungi**
3. **Entomopathogenic diseases**
4. **Varietal resistance**

C. Physical Control

1. **Air conditioning (temperature & R.H. control)**
2. **Drying (moisture control)**
3. **Controlled atmosphere (gas concentration control)**
4. **Aeration**
5. **Heat disinfestation**
6. **Irradiation**

D. Proper Design of Structure

1. **Weather tight**
2. **Rodent and bird proof**
3. **Gastight**

E. Sanitation

1. **Cleaning of storage facilities before and after storage**
2. **Regular inspection of storage condition.**

TYPES OF STORAGE

Storage systems maybe classified according to storage capacity, handling method or container structural materials.

A. Farm House Storage

1. **Sacks**
2. **Wooden boxes**
3. **Bamboo baskets**
4. **Cans**
5. **Drums**

B. Granary (Sack or bulk handling)

1. **Wooden**
2. **Bamboo**
3. **Sheet metal**
4. **Concrete**

C. Warehousing (Indoor)

1. **Sacks in piles**
2. **Uncovered bulk container**
3. **Flat store for bulk storage**

D. Silos (Outdoor)

1. **Metal sheet (flat structures, bulk handling)**
2. **Concrete (tall structures, bulk handling)**
3. **Clay-straw silos**

GENERAL RECOMMENDATIONS

A. Manufacture of storage facilities and structures should be done locally by domestic technology. This would result in saving of foreign exchange and reduction in cost.

B. Government subsidy should be provided to effect the adoption of locally developed technology by farmers and processors.

FIG. 1

Fig. 2 Model of Paddy and Rice Storage Capacity Needs with Different Potterns of Milling and Procurement

NOTES

The quantity of paddy to be stored at end of harvest season is a function of the rates of harvesting, milling and sales during a 4-month harvesting season.

Sales of milled rice at 1000 metric tons per month would require 12,000 tons of paddy (in

rice equivalent) to be procured by end of harvesting season.

$$S = \frac{\text{Paddy to be stored by end of harvest season}}{\text{Total Annual Production}}$$

= 0.60 for existing harvesting/milling pattern: line ac

= 0.48 for improved harvesting/milling pattern: line bed

= 0.64 for existing harvesting/improved milling pattern: line a-d

= 0.44 for improved harvesting/existing milling pattern: line b-c

Fig. 3 Components of the Grain Storage System.

Grain aeration

Ruben E. Manalabe

INTRODUCTION

The storage of foodgrains is normally done for extended periods in order to maintain a uniform supply of food for consumption, for the domestic and export market and to provide a buffer stock for contingencies such as drought floods and war. Millers, traders and other private entrepreneurs adopt it to speculate on good price.

Like any post production operation, losses in storage are considered significant. And these are attributed mainly to spillage, attacks by insects, mites, rodents, moulds and dry matter loss due to respiration. In Southeast Asia, for instance, it is reported that grain losses in storage ranges from 5% to 15% (Champ and Highly, 1981). Insect infestation accounts for the single largest component of these losses.

The storability of grains is affected by their temperature and moisture content. Either or both factors must be reduced to ensure a conducive environment for storage. This could be done through aeration. Aeration involves moving a relatively low volume of air through the grain bulk to control grain temperature. The process was found to reduce the risk of damage or spoilage of grains.

Aeration is normally done using ambient air. The cooling process is termed ad ambient air aeration or natural aeration. Otherwise, dehumidified air is used as in other countries where the ambient air may have too high a heat content or enthalpy to effect sufficient cooling.

PURPOSES AND BENEFITS OF AERATION

A. Temperature Control

There are two general objectives of aeration. These are: a) to maintain a uniform temperature in the grain bulk; and b) to keep that temperature to a low level as practical.

Like most stored products, grain is a poor conductor of heat. As such, heat does not dissipate or escape easily or quickly in some portions of the bulk. Non-uniformity of temperature keeps warm spots to remain warm and if high temperature differences exist in the bin as induced by solar radiation, air convection currents are generated causing moisture migration. In this phenomenon, the convected air picks up moisture from warmer grain and transfers this moisture to the cooler grain where condensation of moisture would likely take place. This results in grain damage which is attributed to moulding, caking, rotting, and sprouting. This is considered critical in areas where large seasonal changes in temperature exist. The respiration of insects, moulds and the grain itself also creates localized heating in the grain bulk which could also raise the temperature of the region they occupied. This center of insect activity is known as the "hot spot". The hotspot expands in size because insects migrate because of its high temperature and create identical conditions along side through further respiration. The water produced by respiration tends to rise in the warm air of the hot spot and condenses in the cold grain. Both phenomena can cause damage and loss due to mould infestation.

Maintaining a low temperature in the grain bulk can deter the development and growth of

fungi and could also inhibit insect infestation. Generally, at low temperature, the rate of multiplication of insects is very low. For instance, the saw-toothed grain beetle will not breed if the temperature is below 18C. The grain weevil, on the other hand, can breed at temperatures as low as 13C. Other studies have shown that cooling the grain to 63 F (17C) or below prevents granivorous insects from completing their life cycle quickly enough to cause significant build up and damage to grain (Burges and Burrel 1964). Furthermore problems on insects are limited to temperatures in the approximate range of 15-40C. In tropical climates, however, storage temperatures are normally in the range of 2030C. Hence, cooling or heating the commodity to temperatures near or beyond the limiting temperatures gives a measure of control over insect development.

Low temperature in the grain bulk can significantly reduce the amount of pesticide required to give longterm protection from insects. Also, the rate of decay of pesticides is independent of the initial condition of grain. This means that the final concentration of pesticides on aerated grain after a given storage period is about the same, whether the grain be initially warm and wet or cool and dry. (Thorpe 1985).

Microbial growth is enhanced with increase in temperature. Reports have shown that an increase in growth of about 2.5-4.5 fold can be expected with 10C increase in temperature if the temperature does not exceed the optimum for fungi. The optimum range for a variety of storage fungi is about 23 to 40C. Other storage microorganisms have high optima and if the grain moisture is high, they can grow at temperatures of 65 to 75C. Aeration with sufficiently

low ambient temperatures could pervert this cyclic effect.

B. Other uses of Aeration

1. **Removing odors from grain - unnecessary odors such as those associated with the use of chemical preservatives, mouldy or sour odors, etc. can be removed or reduced in intensity by aeration.**
2. **Equalizing grain moisture - in bulk storage, there is greater chance of storing lots of batches of grain with varying moisture contents. This moisture variation can be equalized through aeration.**
3. **Fumigant application - grains in deep bins and silos can be effectively applied with fumigant through the aeration system.**
4. **Holding moist grain - newly harvested grain can be stored in receiving bins in short periods without appreciable damage using aeration to provide cooling and dessipating heat caused by respiration. This method of holding wet grain is important to ease out the varitation of grain received during peak harvest. Studies have shown that corn can be kept at moisture ranging from 24% to 26% if it is cooled quickly to below 50F.**
5. **Removing dryer heat - sometimes called dryeration or bin cooling. Aeration is applied in tempering bins after every pass in continuous flow multistage drying.**

COMPONENTS OF AN AERATION SYSTEM

The components of aeration system basically consist of the following:

1. **Fan - of sufficient capacity to supply the airflow requirement.**
2. **Supply-duct - conveyance for the aeration air leading from the fan to a perforated duct placed in the store or plenum beneath the bin.**
3. **Provision for airflow - into or out of the air space over the grain surface.**

If recirculatory fumigation is to be carried out, a return duct is also included. Except for this return duct, the above basic components are found for both the bulk and bagged grain aeration systems. Fig. 3 and Fig. 4 show the typical bulk storage and bagged grain storage system, respectively, with the principal components of an aeration system.

AERATION PRINCIPLE AND SYSTEMS DESIGN

The temperature of the grain stored in bulk is reduced by allowing cool air to flow through the warm grain mass. The grain is cooled by displacing the warm air and by contact cooling. Ideally, the moisture content does not significantly change as the relative humidity of the aeration air is in equilibrium with the moisture content of the grain. When the cooling air has a low relative humidity, however, drying may take place. If this condition persists, then the grain may be cooled to below the incoming air temperature due to the evaporation from the surface of the grains. Conversely, the delivery of air above the equilibrium relative humidity of the grain at a given moisture content will result in rewetting the grain. Furthermore, climate and moisture content determine the requirement for aeration (Teter, 1981).

There are three principal considerations in the design of aeration systems. These are 1) airflow rate, 2) fan selection and 3) air distribution. Automatic controls which are now widely used mayle part of the system.

Airflow rate - This is the volume of air desired to maintain uniform conditions in the stored bulk and to remove the generated heat and water. The recommended rate depends on the purpose of aeration, the type of grain being aerated, the size and type of storage structure, and climatic conditions. In the United States, an airflow rate of 2 liters per second per ton is widely used for shelled corn and soybean stored in farm bins and in flat types of storage. For wheat and other smaller seed grain, one (1) liter per second per ton is more common. A range of 1 to 0.5 liters per second per ton is widely used especially when cost limitations for fan power is considered.

Fan selection - The selection of fan is normally based on the airflow rate used for a particular grain, the kind of grain handled and the grain depth. These factors determines the resistance of grain to airflow and the static pressures against which the fan must deliver the required airflow.

Two types of fan are used for aeration. These are the centrifugal and the axial flow fan. generally, the axial flow fan will deliver more air than centrifugal fans at a static pressures up to about 4 inches of water (1,000 Pa). For higher static pressures, the centrifugal fans are recommended.

Air distribution - This includes the ductings, false floors, etc. which are used to move the air to the desired points. The proper sizing of the ducts, the sizing and spacing of the openings in the ducts to let the air move between the duct and aerated grain, the layout of the duct system are important to maintain the entering (or exiting) air at an acceptable velocity and provide uniform airflow through the grain. Teter (1981) has outlined a detailed procedure in the design of aeration in bulk storage. Part of this procedure is shown in Annex A.

AERATION SYSTEM OPERATION

In controlling temperature, continuous ventillation is necessary during the early stages unless air temperatures are excessive. But for economic considerations, fan operation is selected only at a particular time of the day when the ambient relative humidity is lower or equal to the equilibrium moisture content of the grain. The use of humidity controllers which is interlocked with the fan controls provide convenience in the operation of the fan.

Generally, the grain temperature is reduced to below 15C as soon as possible. Once the desired temperature is reached, only minimal ventillation is required. In this aspect, temperature sensors are likewise convenient to monitor and check the temperature in the bulk.

REFERENCES

1) FOSTER, G.H. and TUITE, J. F. Aeration and Stored Grain Management. Storage of Cereal

Grains and Their Products. pp. 117 -142.

2) TETER, N. C., 1981. Grain Storage. southeast Asia Cooperative Post-Harvest Research and Development Programme. SEARCA, College Laguna, Philippines.

3) Preserving Grain Quality by Aeration and In-Store Drying. ACIAR Proceeding No. 15 of an International Seminar held in Kuala Lumpur, Malaysia. 9-11 October 1985.

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Section 3 - Storage losses and their estimation

Contents - Previous - Next

TYPES OF STORAGE LOSS

Storage is but one part of the post-harvest system through which food material passes on its way from field to consumer. Losses occurring in this postharvest system, are finite and unlike growing crop losses they cannot be made up by further plant growth.

Losses occuring during storage are affected by conditions prevailing in the pre-storage stages (harvesting, threshing and drying). Similarly, poststorage losses may be affected by conditions during storage.

There have been many attempts to define the term "loss" and much confusion has arisen since "loss" has frequently been used synonymously with "damage". Loss is a measurable decrease of the foodstuff which may be quantitative or qualitative. It should not be confused with damage which generally refers to the superficial evidence of deterioration, e.g. broken grains (which may later result in loss). Loss precludes utilisation, damage inhibits utilisation.

TYPES OF LOSS

Loss may be considered in terms of either quantity or quality.

Quantitative loss is a physical loss of substance as shown by a reduction in weight or volume. It is the form of loss that can most readily be measured and valued.

Qualitative loss is more difficult to assess and is perhaps best identified through comparison

with well defined standards. Nutritional loss and loss of seed are both aspects of quality losses.

1. Weight loss

Reduction in weight is obvious but it does not necessarily indicate loss. It may be due to reduced moisture content and this is recognised by a shrinkage factor. Weight loss results from the feeding of insects, rodents and birds or from spillage, due to improper handling or by the activities of pests.

Moisture changes may lead to an increase in weight and in some cases production of water by and insect infestation may partly offset the weight loss. In many instances weight loss may go undetected as the trader sells by volume. In commercial storage weight is the important factor sometimes leading to malpractices such as adulteration with water, stones, and earth to make up the deficiency. Usually some allowance is made for slight changes in moisture and also standard weight packages may be used.

2. Loss in quality

Generally quality is assessed and products graded on the basis of appearance, shape, size, etc., but smell and flavour are sometimes included. Foreign matter content and contaminants are factors in loss of quality. Foreign matter may be in the form of insect fragments, grass, rodent hairs and excrete; weed seeds, parts of plants, earth, stones, glass,

etc. Contaminants that cannot be readily removed, include soluble excretions of pests, oils, pesticides, pathogenic organisms spread by rodents, and toxins arising from fungal infections.

Chemical changes may also be important, e.g. in oilseeds. Infestation in groundnuts may cause an increase in the free fatty acid level leading to rancidity in the oil, similarly in maize meal.

3. Nutritional loss

This, is the product of both the quantitative and qualitative losses. Weight loss during storage (not due to a loss of moisture) is a measure of food loss but the latter may be proportionately larger owing to selective feeding by the pests. Rodents and moth larvae may preferentially attack the germ of the grain thus removing a large percentage of the protein and vitamin content, whereas weevils feeding mainly on the endosperm will reduce the carbohydrate content. Many pests may eat the bran of cereals reducing vitamins such as thiamin. Other storage factors such as moisture and fungal infection also lead to changes in vitamin content. In beans in particular, loss of protein is very important where there is infestation, as up to 25% of the dry matter may be crude protein.

4. Loss of seed viability

This relates to loss in seed germination. Seed grain is usually more carefully stored owing to

its greater potential value. Loss may be caused by changes of light, temperature, moisture, excessive respiration, infestation and, in some cases, the methods used to control infestation. Insects that selectively attack the germ will cause a greater loss in germination than others.

5. Commercial losses

Commercial losses may be a consequence of any of the foregoing factors or be the preventive or remedial actions required, as well as equipment costs. These losses are generally incurred through a lack of knowledge, experience or managerial ability.

a) Monetary loss

Weight loss is an economic loss as is any downgrading of produce due to poor quality. Any control measure that has to be employed to render or keep the commodity saleable can be counted as an economic loss and is perhaps the most easily accountable loss.

Losses in packaging and the costs of repacking due to rodent and handling damage, repairs and stoppages in machinery, damage to the fabric of the store are all economic losses that can be the result of infestation.

b) Loss of goodwill

This is not directly accountable but nonetheless it is very important, especially with regard to rising quality standards. A control measure that may seem uneconomic at first but leads to better custom or at least retains custom, is better than no control that leads to losing custom. This is particularly so in exports where a reputation for high quality produce is valuable to a country's economy.

c) Loss due to legal action

This may include damages awarded due to impairment of health of humans and animals, expenses incurred by third persons due to infestation traceable to a particular shipment, and various actions due to contamination.

ASSESSMENT OF STORAGE LOSSES

The extent of losses occurring after harvest and particularly during storage has been the subject of considerable speculation because of the difficulties of reaching accurate assessments of the amount being lost. It is generally accepted that assessment of storage loss is difficult, particularly in relation to the rural situation in developing countries and there is a need for assessing storage losses.

The extent of loss is important but not allimportant; other factors, economic, sociological or political, need to be considered in deciding on the methods of reducing loss. Measurement of storage loss then calls for an integrated multidisciplinary approach. Any project estimating

losses should include the following essentials:

1) Clearly defined objectives

Loss measurements must be undertaken with a positive aim in view - that of loss reduction. When remedial measures have been introduced subsequent measures of loss using the same technique will enable the effectiveness of the remedial measures to be determined.

2) Reproducible methods

Methods used should be adequately recorded so that they may be used by future workers for similar types of estimation. Obvious sources of error should be noted as they occur. Techniques used should be simple and only require relatively simple and robust apparatus if this has to be used under field conditions with unskilled personnel.

3) Representativeness

This includes the choice of the area to be investigated, choice of stores within the area and the sampling of these stores. Many factors may influence the 'typical' nature of the area so there has to be a balance between the ideal and practical approach. Factors that influence storage losses inculude climate, tradition, and extension influence. For a full statistical survey of losses at the farm level, farmers should be placed in categories that influence their storage, e.g. subsistence or commercial growers, and selection of stores made randomly

within these various categories. This is known as statified random sampling but there are other methods which may be of use for various situations and can be found in textbooks on sampling of populations. The danger lies in extrapolating the data recorded and using it wrongly to sometimes support preconceived ideas; so one must be aware of the inherent limitations in such data.

4) Basic framework

All loss estimations should be built up from a survey, a sampling method and the analysis of the sample to determine the loss.

4.1 Survey:

This enables one to examine the area under investigation and define any factors influencing storage so that the selection of stores accounts for these differences. Field testing of any questionnaires or sampling techniques should be done during the initial survey to remove any practical difficulties. During this stage the criteria of loss should be decided upon and once the stores have been chosen any back-ground data needed for the assessment of their losses obtained.

4.2 Sampling:

This refers to removal of grain samples from the stores. If the store is to be visited regularly,

then a large sample should be taken when the grain is placed in store to provide basline data with which subsequent samples will be compared. Sampling once a month until the store is empty, coupled with records of grain consumption and disposal will enable an accurate estimate of the losses over the season to be obtained.

When such an intense sampling system cannot be undertaken, at least three samples need to be taken: 1) at the time of storage; 2) approximately halfway through; and 3) about a month before the store is emptied. These samples should be taken from the whole store to determine the pattern of infestation. Note should be made of the way in which grain is removed and of the pattern of consumption.

Sampling throughout the store causes grain to move and changes the pattern of infestation within the store so should not be used if a monthly sampling routine is operated. It is however necessary if samples are to be taken on very few occasions.

4.3 Analysis of the sample:

Testing seed grain for loss normally involves only a simple germination test using a set of sub-samples.

Analysis for quality loss is best carried out using a local grading system so that valuation of quality deterioration may be made. This will involve such points as defective and damaged grain, extraneous material, etc.

Nutritional losses need specific analysis for the particular substance one is interested in and comparison with its concentration at storage. It is important to remember that a weight to weight comparison will give misleading results as the insect damaged grain would originally have weighed more. A volume to volume comparison will be better or a comparison of a fixed number of grains taken at random. Measurement of protein using nitrogen determination will be prone to error as insects contain and produce a considerable amount of non-protein nitrogen. It is also possible that when grains are cooked whole, more nutrients may be lost from insect damaged grain than from intact grain.

Weight losses in samples removed for analysis may be estimated in several ways but prior to these it is usual to sieve off the dust and insects. These would normally be removed under field conditions prior to consumption. The proportion of these sievings can be used as a component of weight loss and for quality loss. Identification of the insects present will help the choice of possible control measures and show the relative importance of the various species.

There are three main methods of measuring weight losses caused by insects:

a) Volumetric

These may also be referred to as bushel weight or bulk density methods. They are based on obtaining an accurate standard volume of grain using simple apparatus using fixed drop heights into a standardised volume measure.

b) Gravimetric

This method only involves weighing and counting. It needs smaller samples than volumetric techniques with a maximum of about 1,000 grains and is a useful, quick, field method.

c) Indirect

These methods use some factor related to weight loss which can easily be measured and then transformed into an estimate of loss using a graph or formula. A laboratory experiment is usually done first, to determine the relationship. The results are then applied to the field samples of the same variety infested by the same pest. The most commonly used factor is percentage damaged grain as it is easily measured. Unfortunately this is complicated in the larger grain by multiple infestation leading to several emergence holes per grain and variation in the weight loss per grain. This could be avoided by using number of emergence holes per 100 grains instead of percentage damaged grain.

Losses caused by fungi

A considerable proportion of the grain rejected by the farmer is often discarded because of mould and the presence of infected grain causes a drop in quality grading. Therefore the impact of fungal infection on loss can be estimated by including the separation of mould damage from other types of damage during the analysis.

Losses caused by vertebrate pests

Vertebrates such as rodents and birds frequently remove whole grains from store so losses caused by them are often obtained by difference. Losses remaining unaccounted for are attributed to them. Some attempts to estimate losses have been made using population census and feeding trials. Both pests utilise stored food as part of their diet only so feeding trials may overestimate the consumption of stored food.

Dry matter loss

Nicasio M. Quindoza

I. INTRODUCTION

The quantity of the grain from the time of harvest until it reaches the ultimate consumers (man or domestic animals) decreases due to natural causes that can be difficult to prevent. In the warehouse, the quality and quantity of the grains received may not always be the same as that issued after several days or months of storage. Physical loss of grain in storage is the result of pest infestation (Insects, birds and rodents), microbial infection, change in moisture content, poor handling and grain respiration and microorganic/microbial consumption.

A recognition and understanding of the factors that contributes to dry matter or quantitative loss may be helpful In formulating possible preventive measures against grain losses particularly in storage.

II A. Respiration of grain and microorganisms.

Quality of the grain is usually associated with the dry matter or quantitative loss that occurs because of respiration (Teter, 1981). Teter further noted that the actual respiration or breathing of grain itself is small. However, various organisms that live on grain are always present and respond in reasonably predictable ways to the ambient environment that consists of: 1) humidity or grain moisture, 2) temperature, 3) presence of toxins such as acids, 4) presence of microorganisms that cause deterioration such as bacteria, yeasts, and molds, and 5) physical stresses such as processing blows, heat stress, moisture stress and physical losses that reduce the quantity of materials. Moreover, the percentage of losses due to bacteria and fungi is connected to a considerable number of factors such as species of microorganisms, moisture content, temperature, aeration conditions, sanitation, degree of infestation, and duration of storage (Caliboso, 1982).

The concept of loss due to respiration has not been readily accepted in the assessment of losses in storage due to difficulty in quantification. Recently, Teter (1981) suggested that the percent dry matter can be calculated using the equation:

% DML/day = $(CO_2)\ 10^{-3}\ (0.682)$

Carbon dioxide generation can be related to dry matter loss where, for each gram of CO2 given off, 0.682 gram of dry matter is lost.

For rough rice, equations developed from the laboratory and field are:

$\log (CO_2) = 0.44\ Mw - 6.08$ For Mw (13.3 to 15.6%)
$\log (CO_2) = 0.21\ Mw - 3.04$ For Mw (10.0 to 13.2%)
$\log (CO_2) = 2.39 \sin 7\ 5\ (Mw - B)$ For Mw (15.7 to 28%)

where:

CO_2 = mg CO_2 per 100 g dry matter per day
Mw = % moisture, wet basis

The general equation for rough rice for the range 10 to 17% is:

$\log (CO_2) = AMw - B$

Where A and B are constants as shown in Table 1.

Seib, et al (1980) formulated the equation for dry matter loss using grain moisture content, grain temperature and relative humidity, and length of storage. The equation which is rather empirical is as follows:

DML = 1-Exp - (At) Exp D(T - 60) Exp E(W-0.14)

where:

DML = decimal value of dry matter loss
ACDE = constants
t = time elapsed, hours/1000
T = temperature, F
W = moisture content, wet basis, decimal from The constants are:

Palay	**A**	**C**	**D**	**E**
Long grain	0.001889	0.7101	0.02740	31.63
Medium grain	0.000914	0.6540	0.03756	33.61

In the study on Warehouse Inventory (Philippines) conducted by NAPHIRE, the estimated loss due to respiration of rough rice and microorganisms was calculated using the formula:

LR = I ave. wt. of DM stored I I (0.68) (| 0 44 | | Mw - 11 08 |) x I storage period I

where:

DM = dry matter
Mw = average moisture content of the grain stored, wet basis

Teter (1982) summarizes the following principles that should always be considered in the estimation of dry matter loss:

1. **Deteriorating grain generates 10.9 times the heat required to evaporate the water generated.**
2. **Badly deteriorated grain has a higher percentage of protein than the same grain in a sound condition.**
3. **Water generated by grain deterioration must be removed.**
4. **Deterioration continues as a summation of all spoilages encountered in the history of the grain.**
5. **When grain begins to heat, move it.**
6. **Unsuitable climatic air with deterioration index of over 3.0 to 5.0 should not be used.**
7. **The deterioration at the end of the storage time should not exceed 0.8% dry matter loss.**

B. Loss caused by insects.

Based on the capacity to infest sound kernels, insects are classified as either primary or secondary. Primary insects are those that make initial attack on fresh grain while the latter are those that feed on grain after it has been initially bored. Damage done by these insects consists of contamination and direct grain loss. Caliboso (1982) stated that a rice weevil can eat 14 milligrams during its developmental period from egg to adult.

A researcher from Tropical Products Institute recommends a "weight per unit volume method of estimating weight loss of insect infested grain."

On the other hand, researchers from CRIA Grain Processing Research Center, monitored loss and insect damage for shelled corn in four (4) different containers and formulated the equation based on the relationship between loss and insect damage.

% dry master = $1 + x^{(0,0085x+0.15)}$

Where x is % of insect damaged kernels.

In storage loss assessment, Quitco and Quindoza (1986) used the converted percentage damage method to obtain a rough indication of loss caused by insects.

L1 = I 0.5 I x I % damage x dry wt. I

where:

$$\% \text{ insect damage grain} = \frac{\text{No. of insect damaged grain}}{1{,}000 \text{ grains}} \times 100$$

Example:

In a particular warehouse, 3 batches of rough rice were stored. Infestation was measured at 12% for 1st batch weighing 2,000 kg. at 14% M.C., 15% for the 2nd batch at 1,000 kg. (13.8% M.C.), and 20% for the 3rd batch weighing 2,000 kg. at 14.5% M.C., the weight loss is:

L1 = | 0.51 | x | 0.12(1,720 kg.) + 0.15(862 kg.) + 0.2(1,710 kg.)| = 677.7 kg,

C. Loss due to rodents

In Philippine storage, rodents are considered a serious pest that causes considerable amount of loss. According to Rubio (1971), the annual rodent damage was estimated at 0.8 to 4.12 cavans per ricemillwarehouse in Laguna (Philippines). In Nueva Ecija (Central Luzon), Aganon reported that the annual grain loss per warehouse due to rodent contamination and spillage was estimated at 1.92 to 2.93 cavans. Based on previous researches, the major species affecting food in Philippine storage are the Norway rat, rattus norvegicus, the common ricefield rat, Rattus rattus mindanensis, and the house mouse, Mus musculus. Benigno (1982) found that rodents weighing more than 50 grams consume 15%. Sayaboc, et al (1984) revealed that rodents have preference for whole kernels, and that rough rice

constitute 95% of their diet. Considerably more grains are lost through spillage and contamination.

Caliboso and Teter (1983) suggested that to assess losses due to rodent, a constant estimate of the population density is needed. This can be obtained through trapping or by rougher methods such as counting of trails. The Zippin's (1958) method was found useful in estimating population density in the warehouse.

Based on the average body weight of Mus spe. (161 kg.), Rattus mindanensis (160 kg.), and Rattus norvegicus (330 g.), the daily intake of food constitutes 95% of the total diet. Thus, the daily loss can be computed by the formula:

$$L_R = (Pd_1 \times di_1) + (Pd_2 \times Di_2) + (Pd_3 \times Di_3)$$

where:

Pd_1 = Population density of specie 1 (n)

Di_1 = Daily intake of species (g)

For example, in a particular warehouse, there are 10 Norway rats, 3 Philippine rice-field rats, and 2 mice, the loss can be calculated as:

L_R = (10 0.0314)+(3 0.0152)+(2 0.0025) = 0.3646 kg./day

Rodent infestations may be controlled by three general methods: biological, physical and chemical. The use of these methods (individual or combination) depends upon the prevailing storage or warehouse conditions. However, in most of the National Food Authority (NFA) warehouses, rats were controlled through good structural design of storage facilities. Warehouse floors were elevated, and windows or airvents are screened to serve as physical barriers to exclude rodents. If properly maintained, these warehouses could remain rat-proofed for many years.

D. Loss due to birds

In the Philippines, the species of bird pests which feed on crops such as rice and sorghum are known locally as "maya" or Philippine weavers. Losses caused by these birds in stored products and often observed but seldom quantified. Grain on floor due to careless handling attracts birds and regular spillage may lead to establishment of a resident population.

Initial results of NAPHIRE study indicate that stored grain weight losses attributed to birds may be calculated in the same way for rodents. A population estimate may be based on visual counts or trappings.

The mean body weight of Passer montanus, a bird species that is predominant in Philippine grain stores, is approximately 20 9. The daily intake was estimated at 30% of the mean body

weight. Paddy constitutes 91 % of the total daily consumption. Thus, a single bird may consume 0.0055 kg. per day.

If estimated bird population is 150, loss is determined by:

L_B = (Population Density) (Daily intake, kg.) = (150) (0.0055) = 0.825 kg./day

Several methods of controlling bird infestations in grain stores were suggested such as chemical means (poison baiting), biological methods, and physical methods. Caliboso (1982) recommends that the probable best method of bird control is to keep them off from the warehouse by bird proofing with nets or screen wire on all possible entrances like air vents and windows. Utmost care should be taken to keep the store and surrounding area clear of spillage and attractive food debris.

III. SUMMARY

The factors that contribute to dry matter loss are the respiration of the grain and microorganisms, activity of insects, and vertebrate pests such as birds and rodents.

In loss assessment, a practical and easy sampling technique in determining population density of pests is necessary in order to arrive at reasonable estimate of losses. Some of the formula that are presented can be useful tools in stock accounting and inventory control.

A warehouse with excellent sanitation should have minimal loss of dry matter. Screening to exclude vertebrate pests, integrated insect control, and microclimate control to maintain dry uniform warehouse conditions should minimize storage losses. Usually, it is only a matter of discouraging pest habitation to significantly reduce losses in warehouse.

REFERENCES

AGANON, T.M. 1981. Survey of Rat Damage in Nueva Ecija Ricemill-Warehouse. Unpublished M.S. Thesis, UP at Los Banos, 40 p.

BENIGNO, E.A.1982. Rodent Pest Control in Storage. In Grain Quality Deterioration and Losses and Grain Stock Inventory. Seminar on Efficient Grain Handling for NFA Supervisory and Executive Personnel. p. 128-153.

CALIBOSO, F.M. 1982. Birds and Pest of Grain Storage. In Grain Quality Deterioration and Losses and Grain Stock Inventory. Seminar on Efficient Grain Handling for NFA Supervisory and Executive Personnel. p. 105-127.

CALIBOSO, F.M. 1982. Insect Pest Infestation in Storage. In Grain Quality Deterioration and Losses and Grain Stock Inventory. Seminar on Efficient Grain Handling for NFA Supervisory and Executive Personnel. p. 154-192.

CALIBOSO, F.M. and N.C. TETER. 1983. Warehouse Stock Inventory and Loss Assessment.

Maintaining Good Grain Quality. Proc. of the 6th Annual Workshop on Grain Post-Harvest Technology. Puncak Pass, Bogor, Indonesia. May 3-6, 1983.

QUITCO, R.T. and N.M. Quindoza. 1986. Assessment of Paddy Loss in Storage. Unpublished Terminal Report. NAPHIRE. 46 p.

RUBIO, R.R.1971. Survey of Rat Damage in Laguna Rice Mill-Warehouses. Unpublished Undergraduate Thesis. UP at Los Banos.

SEIB, P.A., PFOST, A SUKABDI, V.G. RAO and R. BURROUGHS. 1980. Spoilage of Rough Rice Measured by Evolution of Carbon Dioxide. Proceedings of Grain Post-Harvest Workshop. Kuala Lumpur, Malaysia. p. 75-94.

TETER, N.C.1981. Grain Storage. SEARCA College, Laguna, Philippines. 86 p.

TETER, N.C.1982. Dry Matter Loss. In Grain Quyality Deterioration and Losses and Grain Stock Inventory. Seminar on Efficient Grain Handiing for NFA Supervisory and Executive Personnel. p. 60-89.

ZIPPIN, C.1958. The Removal of Population Estimation. J. Wild. Man 22 (1): 82-90

Table Rate of deterioration constants for some cereal grains (To compute CO_2 generation).

GRAIN	MOISTURE RANGE, Mw	CONSTANT A	CONSTANT B
Corn,yellow dent	10.0-13.2%	0.17	2.00
	13.3-17.0%	0.27	3.33
Sorghum	10.0-13.2%	0.125	1.65
	13.3-17.0%	0.32	4.19
Rough rice	10.0-13.2%	0.21	3.04
	14.2-17.0%	0.44	6.08
Polished rice	10-14.1%	0.16	2.83
	14.2-17.0%	0.49	7.48
Brown rice	10.0-13.7%	0.17	2.67
	13.8-17.0 %	0.44	6.41
Wheat, soft	14.1-17.0%	0.36	5.15

APPENDIX I. DETERMINATION OF PERCENTAGE INSECT DAMAGE GRAIN.

Procedures

A random sample of 100-1000 grains is taken and the number of bored grains is counted. This should be done immediately or within a few days after sampling.

The percentage of damaged grains is calculated with the following formula.

$$\frac{\text{Number of bored grains}}{\text{Total no. of grains counted}} \times 100 = \text{\% bored grains in sample}$$

This percentage is converted into a percent weight loss by dividing it by the conversion factor or multiplying it by 1/c.

The following conversion factors have been established in practice where the larvae stages develop within the grain, e.g. Sitophilus spp., Sitotroga carealella:

Corn (stored as shelled corn or as ears without husks)	**% bored grains x 1/8 or 1/3**
Corn (stored as ears with husks)	% bored grains x 2/9
Sorghum	% bored grains x 1/4

Paddy	% bored grains x 1/2
Rice	% bored grains x 1/2

APPENDIX II. POPULATION ESTIMATION FROM REMOVAL DATA CALCULATION BY MULTINOMINAL METHOD SUMMARIZED FROM ZIPPIN, 1985

1. Calculate total catch:

$$T = \sum_{i=1}^{k} Y_i = Y_1 + Y_2 ... Y_K$$

2. Calculate:

$$\sum_{i=1}^{k} (1-1) Y_i = Y_2 + 2Y_3 + ... (K - L)\ Y_K$$

3. Determine the ratio:

$$R = \frac{{}_{i=1}(i-1)Y_1}{T}$$

4. Determine (1 + qk) from the graphs:

5. Determine N. the estimated population:

$$N = \frac{T}{(1-qk)}$$

Figure Graphs for estimation of (1 - qkX from the ratio R. (Zippin, 1958).

Source: Biotrop Special Publication No. 12, 1980

Standardized methods for the assessment of losses due to insect pests in storage

Contents - Previous - Next

by ROLANDO L. TIONGSON

1. INTRODUCTION

Of the agricultural commodities consumed as food, cereals contribute to the bulk of the world's calories and protein. Unfortunately, a considerable quantity of the world total cereal production is lost after harvest. While losses of lesser magnitude can be expected in developed countries, post harvest losses of grains are frequently high in developing countries where the grain is usually inadequate and the need for conservation is urgent.

Losses of stored grains as high as 30% weight loss and an average of 8.7% during 3 to 6 months storage period has been reported in Tanzania due to the outbreak of Prostephanus/truncatus (Horn) (Golop and Hodges, 1982). Whether the potential for postharvest losses from one country to another is alarming or negligible, a means to come up with a reliable loss estimate is necessary. Although methodology for assessing post harvest grain losses will not in itself reduce losses, sound assesement procedures are essential to post harvest operational programs so that priorities for loss reduction can be determined.

This paper compiles available methodologies that can be applicable in the assessment of losses caused by insects.

Methods for determination of losses due to insects are of four types:

1. **Determination of the weight of a measured volume of grain. In this case the loss in weight in samples taken over a known time period will be the reflection of losses.**
2. **Separation of damaged and sound kernels and determination of their comparative weights calculated in terms of the whole sample.**
3. **Determination of the percentage insectdamaged grain and is conversion to weight loss using a conversion factor.**
4. **Comparison of the Thousand Grain Mass (TOM) between sampling occasions.**

II. METHODOLOGY

A. Sieving

For all methods, it is necessary that the grain sample be sieved to remove dust, insects and other foreign materials that may be associated with the grain. An appropriate size of sieve should be used.

B. Determination of the Original Condition of the Grain

Since the weight to volume method is based on differing weights for different levels of loss, it is necessary to obtain a baseline point. This will be the reference sample, from which it is possible to compare all future measurements. This baseline needs to be in the form of curve

covering all of the grain/moisture conditions to be found in the particular grain situation because some grain volumes change significantly and most often, regularly at varying moisture contents.

The curve is obtained from analysis and calculation of a baseline sample. In case it is not possible to obtain this sample until after storage or the process under study has already begun, a visibly undamaged sample should be taken and analyzed as early as possible. This should be split into three replicate subsarnples and the measurement required by the appropriate methods applied to each subsamble. Each subsample should then be placed in a jar covered with cheesecloth to prevent the insects entering of leaving and kept for four weeks. After four weeks, the grains must be examined for insects and damage. If there is no damage in any jar, then all three replicates can be used to calculate a value. If there is damage in one, this must be discarded; if two have damage, both are discarded and if there is damage in all three, then sample(5) with 5% or less damaged kernels should be taken. If the damage is above 5%, assistance from an expert in determining the appropriate correction factor will be needed.

C. Method for Baseline Determination

A sample of approximately 5 kg is either taken from every farmer's store if they are being treated as individual case studies or if there are distinct grain varieties under study, a representative sample of at least 5 kg is taken for each variety, assuming that they are fairly

homogeneous. If any of the varieties is not uniform (does not have a standard weight-to-volume variation with changes in moistrue due to intravarietal variations of the local grain(s) then either each lot of stored grain must be treated individually.

This large sample is sieved in the laboratory. The bulk sample is subdivided into five replicate subsamples. The moisture content of a representative subsample is measured. The range of moisture content which might be expected in the field over the storage season is determined either from locally available data or by approximation (a normal range that fulfills most purposes is 8-18%, depending on climatic conditions). The weight/volume relationship is taken over the range as follows: the range is broken down into five equal steps, e.g., if it is 10-18%, this will be 10,12,14,16,18. If it is small, perhaps 1% steps such as from 8-12%, this will be 8, 9, 10, 11, 12%. One subsample will have a moisture content near to one of these figures and the moisture contents of the other subsamples will have to be changed either by drying or wetting to cover the range.

Drying down to a moisture content. This should be done with the grain in a shallow layer either in a warm, dry place withe a current of air passing over it but protected from insect attack or, preferably, in ventilated oven in shallow trays at a temperature not execeeding 35C. Its moisture content should be checked at regular intervals by allowing a sample to cool and measuring its approximate water content. When it has reached the required moisture content, it should be placed in a sealed container to cool and the moisture content should be measured accurately. As a rough guide, a sample of known weight can be placed on a

dish in the oven and its loss in weight checked.

Wetting up to a Moisture Content. This requires addition of a calculated weight of water to the grain to bring it up to a required moisture content. The weight of water required is given by the formula.

Weight of water to be added (g) = weight of grain

$$\frac{x_1(ug / l) \times V_1(l)}{1.195(ug / ul)} = d_1(ul)$$

For example, if we have a subsample of 1000 9 of grain at 12% moisture content and require it to be at 16% moisture content the calculation is:

Weight of water

= 1000 (16 - 12) / (100 - 16) = 1000 4 / 84 = 47.6 g

This can be weighed out or since 1 g.of water occupies in ml, it can be measued out as a volume. Water is added to the grain with sufficient headspace for thorough mixing. It is left

for two weeks to condition, but vigorously shaken daily. For moisture content over 16%, the container should be kept at 5-10 C in a refrigerator to discourage mold growth. At the end of the conditioning period, an accurate moisture content is determined for each subsample. For each subsample, the weight that occupies the volume measure should be determined by filling a test weight container (weight/liter tester or a chrondrometer). The grain should be weighed to the nearest 0.1 9. This should be done three times for each subsample to obtain a mean result.

There will now be five mean weights for each variety at five accurately measured moisture contents. Each of these weight should then be converted to dry weight as follows:

$$\text{Dry weight} = \text{weight of grain} \times \frac{100 - \%\ \text{moisture content}}{100}$$

For example, if the volume of grain in the test weight container weighed 800 9 and had a moisture content of 15% then its dry weight is:

Dry weight = 800 x (100 - 15) / 100 = 800 x 85/100 = 680 g

This is done for all subsamples so as to obtain a set of dry weight for each moisture content. A graph is now drawn of the dry weight against the moisture content for example:

% MC	10	12.0	14.1	16	17.9

Dry Weight	700	670	650	620	600

From this, a reference line can be plotted of dry weights as determined by measuring the actual moisture content and test weight at the time a test is made. This graph can be used throughout the rest of the sampling period to represent the dry weight of sample at any moisture content as if it had not been damaged in store.

III. LOSS ASSESSMENT TECHNIQUE

A. The Standard Volume/Weight Method

This can be carried out after the preliminary laboratory work for the baseline figures is completed.

Equipment

1. **Test Weight apparatus**
2. **Balance such as a triple beam balance capable of measuring 1.0-1.5 kg accurately to 0.1 9**
3. **Moisture meter, calibrated for the type of grain being tested.**
4. **A suitable size grain sieve to remove dust and other impurities.**

5. Plastic bags

Procedure

A well mixed sample, taken from the store is first sieved by locally appropriate methods and the weight of sievings are counted as a loss if they are not used locally or calculated back to the weight/volume if they are used. Then the moisture content of samples are measured.

The weight occupying the volume of a standard container is measured in three replicates and a mean taken. This weight is converted to dry weight using the moisture content and the formula for dry weight.

The graph is used to find the dry weight of the sample at the same moisture content at the time of storage. For example, if the moisture content of the farmer's sample was 12.0% then referring to the example (appendix 1) the dry weight would be 670 g.

The weight loss in the farmer's sample is then calculated as follows:

$$\%\ \text{weight loss} = \frac{\text{dry wt. from graph} - \text{dry wt. in sample}}{\text{dry wt. from graph}} \times 100$$

For example, if our farmer's sample at a moisture content of 12.0% had a dry weight of 600 9 then as the dry weight on the graph for 12.0 moisture is 670 9 the loss would be:

% dry weight loss = [670 - 600] / 670 x 100 = 10.44%

This is the dry weight loss, which by definition excludes moisture content changes.

Sources of Error

1. **Inaccuracies may result from grain samples containing very high levels of damage, where some of the grains may be crusted.**
2. **Admixture of an insecticidal dust to shelled grain increases friction between grains and will reduce packing and hence, the weight per unit volume will be less.**
3. **For rough rice, the effect of moisture content on the dry weight occupying a given volume is negligible. Within the range of 5% moisture, there is no requirement for a predictive graph.**

B. Modified Standard Volume/Weight Method When a Baseline Cannot be Determined

There are some situations where the Standard Volume/Weight Method cannot be used without modification. It may also be difficult to obtain reliable moisture content determination in some cases.

It is often necessary to make loss estimates in the middle of the storage period when no baseline has been previously determined. It also frequently occurs that in rural areas, different varieties of grain are grown under different conditions. This may affect the size of

grains and consequently the volume/weight ratio.

Application of insecticide dusts may also affect the settling of the grains in the standard volume and increase the volume occupied by the grain.

Because of these various conditions, a separate baseline may have to be determined for each individual farm or storage situation. This is often impossible to achieve between harvest and storage.

Procedure

The standard volume/weight method should be used but an artificial baseline should be prepared by selecting undamaged samples from the grain present in the store at the time of loss determination. The loss is the difference the undamaged and the a percentage) between the undamaged and the damaged sample. Conversion for moisture need not be used this in case since the moisture content will be approximately the same.

Sources of Error

1. Unreliable results may be produced if during selection there is hidden internal infestation, preferential feeding and egg deposition by insects in grains of different sizes, and a difference in moisture content.

2. To overcome the problem caused by hidden infestation the same procedure for obtaining an undamaged sample as indicated for the normal standard volume/weight method can be followed.

3. Another way to reduce this error is to take the undamaged sample at random as much as possible. In addition, a sample must be taken which is larger than necessary and after good mixing, only a part of the sample should be used for baseline determination.

C. The Count and Weigh Method

There are many situations in which a loss estimate is required but where there is only minimal equipment available, the baseline could not be determined before the storage period. In addition, it is sometimes imossible to determine a baseline for the standard volume/weight method because too many grains have been damaged.

This is essentially a method that takes a sample, separates it into undamaged and damaged portions, counts and weighs each and calculates the percentage weight loss. It assumes that the undamaged portion is totally undamaged.

Equipment

1. **Balance with a range of 0.5 g to 1.5 kg accurate to 0.1 g**
2. **Tallycounter**

3. Plastic bags

Procedure

The grains are separated into undamaged and damaged categories, the latter being separated according to cause. Grains in each category are counted and weighed. The resultant data may be substituted in the formula below:

$$\%\ \text{weight loss} = \frac{(UNd) - (DNu)}{U(Nd + Nu)} \times 100$$

where:

U = weight of undamaged grains
Nu = number of undamaged grains
D = weight of damaged grains
Nd = number of damaged grains

Sample Size

A sample size of 100-1000 grains is recommended. Besides its simplicity, the method has the advantage that damage by different species of insects, such as Sitophilus, Sitotroga, Ephestia spp., and Rhizopertha can be measured.

Sources of Error

1. **Hidden infestation results in an underestimation of loss because grains that have lost weight are included in the undamaged portion. When the grain is heavily damaged, it may become so broken as to lead to counting errors.**
2. **Since insects will sometimes select and infest larger kernels, any procedure that compares the individual weight of kernels may result in a negative weight loss finding. The selection of internally infested kernels and their inclusion and weighing as undamaged can also result in negative loss findings unless care is taken to recognize and account for these samples.**

D. The Converted Percentage Damage Method

This method provides a useful estimate for quick appraisal of losses without needing equipment.

When grains are heavily infested, feeding by secondary pests and multiple infestation may disturb the relations and so lead to an underestimation of losses.

Although the converted percentage damaged method is liable to the same sources of error as modified standard volume/weight method and the count and weight method it has given very good results in practice.

When earlier mentioned methods cannot be used, it is recommended to use the converted percentage damage method rather than guessing.

Materials

1. **Tally counter**
2. **Plastic bags**

Procedure

One thousand grains are counted at random from the working sample. Then the damaged grain(s) are separated from the sound grains and expressed in percentage using the formula:

$$\frac{\text{Number of bored grains}}{\text{Total number of grains counted}} \times 100 = \text{\% bored grain in sample}$$

This percentage is converted into percent weight loss by dividing it by the conversion factor (c) or multiplying it by 1/c.

The following conversion factors have been estalished in practice where the earlier larval stages develop within the grain eg. Sitophilus species, sitotroga cerealella.

Maize (stored as shelled maize or as ears without	

husk)	**% bored grains x 1/8**
Maize (stored as ears with husk)	% bored grains x 2/9
Wheat	% bored grains x 1/2
Sorghum	% bored grains x 1/4
Paddy	% bored grains x 1/2
Rice	% bored grains x 1/2

D. The Thousand Grain Mass (TOM)

Basic Principles

When an entire lot of grain is weighed before and after being attacked by insect pests, microorganisms or some other causing agent, the percentage loss of mass is easily calculated by using the formula:

$$\frac{m1 - mx}{m1} \times 100 = \% \text{ weight loss}$$

where:

m1 = grain mass before attack
mx = grains mass after attack

"mass" in this context refers to the dry matter weight

A sample taken from the lot in strict accordance with representative sampling principles should possess all the characteristics of the grain in proportion to their ccurrence in the lot at the time of sampling. Therefore, if the lot consists of 40% large grains, 50% medium size grains and 20% small grains, these proportions should be found in representative samples. Likewise if 7% of the grains in the lot are damaged, this percentage of damaged grains should also be found in the representative sample.

It is important that the mass per standard unit of a representative sample should be the same as the mass per standard unit of the entire lot of grain at the time of sampling. A reduction in the value of this unit between two sampling occasins should be proportional to a dry weight loss in the grain lot and should therefore provide a means of estimating the loss.

Mass per standard unit is defined as the dry weight (mass) of 1000 grains calculated from the wet weight and number of grains in a representative working sample by the formula:

$$\frac{10m\ (100\ -\ H)}{N} = M$$

where:

m = is the wet weight of the working sample
H = is the percentage moisture content (WB)
N = is the number of grains in the working sample
M = is the Thousand Grain Mass

The formula is obtained by multiplying [m x 1000] / 100 which gives the Thousand Grain Mass on a wet basis, and by [100 - H] / 100 to convert the TGM to the dry basis.

D.1 The Simple TGM Method

When samples for analysis are obtained in a truly repersentative manner both before and after the grain lot has been attacked by loss-causing agents, the loss can be estimated with reasonable accuracy by the simple TGM method.

Procedure

On each occasion the submitted sample is first weighed and then screened to remove as much foreign matter as possible. Large pieces of foreign matter may: be removed by hand.

The partially cleaned sample is then reweighed if data on grain purity is required. Then it is reduced to a working sample of a desired size.

Next, the percentage moisture content of the grain is determined, preferably using a calibrated moisture tester. The working sample is thoroughly cleaned of all foreign matter and weighed with a balance having an accuracy of at least 0.1 gm.

If the submitted sample was obtained some weeks or months after the beginning of the study, the weight loss occuring in that occasion can be calculated by using the formula:

$$\frac{M1 - Mx}{N1} \times 100 = \%\ \text{weight loss}$$

where:

M1 = TGM of the grain at the begining of the study
Mx = TGM of the grain on occasion "x"
N 1 = Number of grains in the working sample

D.2 The Multiple TGM

There are instances in some loss assessment studies that the collection of the majority of samples does not fulfill all the requirements of representative sampling. Thus, while it may

be possible to obtain a good representative sample as a grain store is filled, subsequent samples usually have to be drawn while the bulk of grains remains in store.

Even the initial sample may have to be drawn after the store has been filled. Such samples, however carefully taken, cannot be considered to represent the entire contents of the store and cannot, therefore, be used for estimating weight losses relating to all grain by store. This problem can be overcome substantially by multiple TGM analysis.

This method should be used when the grain under study is variable in size and it is known that one or more of the samples cannot be fully representative of the whole contents of the store.

Procedure

After weighing, the submitted sample is screened to remove as much foreign matter as possible. The partially cleaned sample is then passed through a series of sieves with different aperture widths to divide it into two or more portions according to grain size. (At the beginning of the study a comprehensive set of sieves which will divide the sample into portion of sufficient quantity for TGM determination are selected for subsequent use).

Each portion is weighed and then divided into two working samples: (1) for moisture content determination and (2) for TGM determination. The working samples for moisture content determination are combined for this purpose. The TGM working samples are

analyzed separately.

When all analyses are completed the "potential weight" of the grain in each portion of the submitted sample is calculated using the formula:

$$\frac{M1}{Mx} \times Wx = Wp$$

Where:

M1 = is the TGM of the corresponding grain portion at the beginning of the study
Mx = is the TGM of the portion on occasion "x"
Wx = is the actual wet weight of the portion on occasion "x"
Wp = is the "potential weight" of the portion on occasion "x"

The percentage weight loss of the grain in the submitted sample obtained in occasion "x" can be calculated by using the formula:

$$\frac{(WP1 + Wp2 + \ldots) - (Wx1 + Wx2 + \ldots) \times 100}{(Wp1 + Wp2 \ldots)} = \%\ \text{weight loss}$$

where:

P1, P2… and x1, x2…represent the various portion of samples

Sources of Error

The naturally occuring variability in grain weights and the variations in the representative nature of samples are the two main factors that may affect the reliability of the TGM method.

REFERENCES

Adams, J.M. and G.G.M. Schulten, 1978. Losses caused by insects mites and microorganisms. Paper 83-89 in Post Harvest grain Loss Assessment Methods. K.L. Harris and C.J. Lindblid, eds. Am. Assoc. Cereal Chem: St. Paul MN

Golob, P and R. Hedges, 1982. Study of an outbreak of Prostephanus truncates (Horn) in Tanzania. Tropical Product Institute, London, England 16) 23 pp.

Proctor, D.L. and J.Q. Rowley 1983. The Thousand Grain Mass (TGM): a basis for better assessment of weight losses in stored grain. Page 19-23 in Tropical Stored Products Information. J.A. Mc Earlane ed. Storage Department of the Tropical Development and Research Institute Slough, Berks, England.

ACKNOWLEDGEMENT

Much of the information included here are extracted from the "Post Harvest Grain Loss Assessment Methods" developed and compelled by Kenton L. Harris and Carl J. Lindblad. This manual was published by the American Association of Cereal Chemists in cooperation with The League for International Food Education, The Tropical Product Intitute (England) Food and Agriculture Organization of the United Nations and The Group for Assistance on Systems Relating to Grain After. Harvest.

APPENDIX 1 - MOISTURE CONTENT (%), wb

Fig. 1 dry Weight of grain in test weight containing at different moisture content.

Table of conversion factors to obtain grain weights at 14% moisture content

Practical loss assessment method for storage losses

The FAO Prevention of food Losses (PFL) Project in Bangladesh, funded by the Netherlands (GCPP/ BGD/017/NET)

For each selected storage the following information was collected:

a. **Details of the storage structure, construction, maintenance, etc.**
b. **Baseline information about the commodity at the time of storage.**
c. **Records of the quantity of grain stored, quantities removed and grain use.**
d. **Estimation of quantitative and qualitative loss by analysis of samples.**

A series of forms will be used to facilitate collection of these data.

SAMPLE COLLECTION

1. At the first visit to a store:

(i) Record a full description of the selected store using Form Sl - DESCRIPTION OF STORAGE STRUCTURE. Complete each section of the form as fully as possible and make a simple sketch of the store, giving dimensions, on the back of the form.

(ii) Weigh the grain into store, or if this is not possible estimate the quantity stored. Enter full details concerning the condition of the grain at storage on Form Sll, the INITIAL SAMPLE RECORD.

(iii) As the grain is loaded into the store collect a sample to provide the necessary baseline information. The sample may be collected in one of the following ways:

a. **By withdrawing small samples from each lot of grain as it is placed in store. The samples are bulked, mixed and divided by coning and quartering to produce a sample for analysis of about 1 - 1.5 kg.**
b. **By collecting a 1 -1.5 kg sample from grain already in store, using a grain probe.**
c. **By emptying the store, and refilling drawing samples as in (a). This method may be appropriate when a relatively small quantity of grain is stored and when the store is visited for the first time within a few days of filling.**

Record the moisture content of the sample (three determinations).

Enter details concerning the initial sample on Form SIT-INITIAL SAMPLE RECORD.

(iv) Pack the sample in a sample bag; enclose a sample label with the sample and secure a second label to the outside of the bag.

(v) Send the grain sample together with the Forms Sl and Sll to the laboratory for analysis.

2. At Subsequent Visits

(i) Each store will be visited at approximately monthly intervals.

(ii) During the visit complete a SAMPLE RECORD FORM (Form SIII).

(iii) Collect a sample of grain of approrimately 1 1.5 kg.

(iv) Record the quantity of grain removed since the previous visit.

(v) Place the sample of grain in a sample bag, complete two sample labels and enclose one in the bag and secure a second to the outside of the bag. Return sample and record form to the laboratory for analysis.

(vi) As the storage season progresses insect infestation may become serious. When insect infestation is detested, all samples should be fumigated (using Phostoxin in a sealed container) before being dispatched to the laboratory.

ANALYSIS

1. Procedure for all samples

(i) Register all samples received at the laboratory in the laboratory log book and give each sample a serial number.

(ii) Record the results of the analysis on Form SIV - STORAGE LOSS, LABORATORY ANALYSIS.

(iii) Weigh the sample, clean it by sieving and hand picking. Record the weights of sample and foreign matter.

(iv) Identify and record insects present in the sample. Those insects which cannot immediately be identified should be placed in a suitable container, labelled and sent to the entomologist for identification.

(v) Divide the sample to provide the following subsamples as necessary:

a. **Thousand grain mass**
b. **Weight loss from single sample**
c. **Quality analysis**
d. **Milling yield**
e. **Mycotoxin analysis/Microflora analysis**

2. Details of specific analyses

(a) Thousand gram mass

(i) Reduce sample to obtain at least three replicates of approximately 50 g.

(ii) Using remainder of sample determine moisture content.

(iii) Weigh each subsample of approximately 50 g. accurately.

(iv) Count the number of grains in each subsample. Record total.

(v) Calculate the thousand grain mass (TGM) as follows:

$$TGM = \frac{\text{Wt grain}}{\text{No of grains}} \times 1000$$

(vi) Correct for moisture content to 14% as follows:

$$\frac{TGM \times (100 - M.C.)}{86}$$

(vii) Calculate mean TGM

(viii) Determine % weight loss as follows:

$$\frac{\text{Baseline TGM (from initial sample)} - \text{Sample TGM}}{\text{Baseline TGM}} \times 100$$

(b) Weight loss from a single sample

Under certain circumstances it may not be possible to obtain a baseline sample and so the following method may be used to determine a weight loss. The method may be used as a

cross check on the thousand grain mass method of calculating % weight loss.

(i) Reduce the sample to obtain three replicates of 25 - 50 g.

(ii) Determine moisture content of the sample.

(iii) Separate grains into large and small categories using a suitable sieve for the separation. (N.B. If necessary further categories of grain size may be used).

(iv) For each size category of grains, separate into undamaged and damaged fractions.

(v) Count and weigh the number of grains in each fraction.

(vi) Calculate the weight loss by comparing the weight of the sample with the predicted weight of the same sample in the absence of damage:

$$\text{Weight of "Undamaged Sample" (WtUN)} = \frac{\text{Wt. Undamaged large grains}}{\text{No. Undamaged large grains}} \times \text{Total large grains} + \frac{\text{Wt. Undamaged small grains}}{\text{No. Undamaged Small Grains}} \times \text{Total Small Grain}$$

$$\% \text{ Wt Loss of sample} = \frac{\text{Wt Un} - \text{Wt of sample}}{\text{Wt Un}} \times 100$$

SUMMARISING DATA AND CALCULATION OF LOSS

(i) A SUMMARY SHEET (Form SV) will be used to assemble all relevant data for the calculation of total weight loss. This summary sheet can be completed as and when the data are available. All weights will be expressed on a 14% moisture content basis.

(ii) The total accounted loss will be obtained from the difference between the quantity stored and the total quantity of grain removed (i.e. the final entry in the balance column).

(iii) The weight loss due to insects in any one month calculated from the "loss in sample" result and the quantity (adjusted to 14% M.C.) of grain removed on or about the same day.

Example:

QUANTITY OF GRAIN ORIGINALLY STORED = 270 kg (at 14%)

QUANTlTY REMOVED IN MONTH = 50 kg (at 14%)

LOSS IN SAMPLE BY TGM or COUNT AND WEIGH = 5%

Weight Loss:

$$= \frac{\text{Quantity removed}}{(100\ -\ \%\ \text{loss in sample})} \times 100\ -\ \text{Quantity Removed}$$

= 50 / 95 x 100 - 50

= 52.63 - 50

= 2.63 kg.

Weight loss as % Quantity Stored:

= 2.63 / 270 100

= 0.97 %

The 'monthly' loss figures are summed to obtain the cumulative weight loss due to insects.

(iv) By subtracting the cumulative total loss due to insects from the total recorded loss (i.e. the difference of quantity stored/quantity removed)

the loss due to other causes can be obtained. By reference to field observations this "other" loss may be attributed to rodents, birds, etc.

(v) The quantity of grain discarded as unfit for consumption represents a loss of food and must be expressed as a percentage of the quantity of grain stored. It should be remembered that this discarded grain may also have been subjected to a weight loss (due to insects) at least equal to the loss recorded in the quantity of grain removed for consumption.

(vi) The total loss therefore consists of:

Loss due to insects + Loss due to other causes + Loss of discarded grain (+ some additional weight loss in discarded grain.) = Unaccounted Balance at end of Season

FORM S I

FORM S II

FORM S III

FORM S IV

WEIGHT LOSS FROM SINGLE SAMPLE

Form SV

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Section 4 - Principles and theory of integrated pest management

Contents - Previous - Next

The concept and components of integrated pest management

Belen Morallo-Rejesus

Professor and Chairman, Department of Entomology
College of Agriculture, University
of the Philippines at Los Banos

and

Romeo S. Rejesus
Consultant, Postharvest Reserarch
and Training Center, Dept. of Horticulture
Visiting Professor, Dept. of Entomology, University of the Philippines at Los Banos

INTRODUCTION

The goal of development is to maximize the use of energy, natural resources, capital and scientific information for the welfare of mankind. However, the process of developing agricultural production, water resource management, improvement of health and other activities of mankind, create an environment favorable to the development of organisms competing with man. This organism is designated as a pest but such a designation is not static, since a pest may be damaging and edible at the same time. For example, crickets and grasshoppers are acceptable as food by some people, but can be a curse to rice farmers.

A pest problem exists when an organism interferes with human activities or desire, or otherwise competes with man. To rationally minimize or control pest depredations, an holistic approach to suppression is emphasized. The control strategy that has subsequently evolved is called Integrated Pest Management (IPM).

PHILOSOPHY OF INTEGRATED PEST MANAGEMENT

IPM brings together into a workable combination the best strategies of all control methods that apply to a given problem created by the activities of pests. IPM has been defined in various ways but a more scientific definition describes it as, "the practical manipulation of pest populations using sound ecological principles to keep pest populations below a level causing economic injury". The emphasis here is "practical" and "ecological". There are many ways of controlling insect pests but only a few are practical, and fewer are ecologically sound, such that an undesirable citation is created.

Another term we frequently encounter is "intergrated pest control". It is offer used interchangeably with IPM, though in the strictest sense these terms are not identical. Originally, integrated control simply meant modifying chemical control in such a way as to protect the beneficial insects and mites, or integrating chemical and biological control methods. Subsequently the concept was broadened to include all suitable methods that could be used in complementary ways to reduce pest populations and keep them at levels which did not cause economic damage. This essentially is IPM It includes a variety of

options, any one of which may not significantly reduce the Pest population, but the sum total of which will give adequate reduction to prevent economic losses. A modern definition of IPM may be-the use of all available tactics in the design of a program to manage, but not eradicate pest population so that economic damage and harmful environmental side effects are minimized.

IPM is not a static, unyielding system. It is dynamic, ever-changing, as we develop a better understanding of all factors that affect the system. These factors include climate, alternate host plants, beneficial insects and man's activities. In a narrow sense, IPM means the management of the few important pests generally found on our crops, but consciously or not it must include all insect pests, not only the "key" ones but also the secondary pests, which seldom do any harm. If this were not so, we might suddenly find some of these minor insect pests or even non-pests elevated to the status of serious insect pests because of our failure to consider them in the total scheme.

IPM as a concept is not new, but one that is receiving new emphasis as man looks for better methods to grow and store food for an expanding population, and at the same time preserve his environment. The rationale for using IPM is threefold. First, it can cut production costs mainly by reducing energy inputs. Secondly, IPM can reduce environmental contamination through the judicious use or reduced use of pesticides. And finally, an IPM program allows for maximum utilization of cultural practices and natural enemies (for plant pests) and physical methods (for storage pests). IPM can be designed to take advantage of

the ecological principles governing pest population abundance. This requires a thorough understanding of the role of all the factors responsible for a pest population reaching certain levels at a particular time of the year, or duration of storage.

ELEMENTS OF IPM

There are four basic elements of IPM: natural control, sampling economic levels, and insect biology and ecology.

The first element of IPM relates to the fullest utilization of naturally occurring suppressive factors, including any practice by man which will make the total ecosystem less favourable for growth of the insect pest population. Obviously, this requires a thorough understanding of the ecosystem.

The naturally occurring suppressive factors may act directly or indirectly on pest populations. Indirectly, the ecosystem may be managed or altered in such ways as to make the environment more harmful to the pest and thus limit population growth. More directly, protection and the use of beneficial insects may help keep potentially damaging insect pest populations at subeconomic levels In storage, parameters that can be manipulated to control the buildup of a pest population are temperature, relative humidity, moisture content and composition of gases within the storage atmosphere.

The second element is that of using sound economic threshold (ETL) levels as the basis for

applying control measures, especially chemical measures. Establishing and using dynamic ETL's provide a basis for delaying the use of insecticides. This permits the maximum utilization of other control methods, such as the use of beneficial insects.

The use of economic threshold levels implies adequate sampling of all harmful and beneficial insects in the agroecosystem and particularly in any one crop at a given time. The levels found through sampling must then be measured against the economic level established for the crop, the beneficial insects, and the probable population trend of the pest species. The sampler thus becomes a key person in an IPM system.

The fourth element, insect biology and ecology, is essential to the fullest utilization of the other three elements. Little concerning natural control can be understood without detailed knowledge of the biology and ecology of all the species present. This knowledge is also essential in establishing the role of each species in the system and in deermining the amount of damage inflicted by each pest species. Adequate sampling is directly dependent a thorough familiarity of the species involved.

Knowledge of the biology of a certain problem pest will serve as a basis for planning the control strategies and provide operational guidelines for these strategies. In this context, it is important to know the relationship between the pest and the crop (crop life tables) and the mortality factors (pest life tables), both biotic and abiotic (parasites, predators, temperature, relative humidity) which play a major role in the determination of pest

population dynamics.

An understanding of the sequential dominance of pests in relation to growth stages could provide the immediate impetus for developing a simple integrated control program based on minimum pesticide application (Rejesus, 1976). By delineating the succession of major pests at different stages of plant growth (or storage time for stored products), the frequency, timing and dosage of insecticide application could be synchronized, hence avoiding pesticide use on a time-wise basis, or the "calender" method. The control program could then be based on expected pest population at any given growth stage of storage duration.

ECONOMIC INJURY LEVELS AN D ECONOMIC THRESHOLD

There is a wide variation in the degree to which pests may be tolerated even for the same species in different areas, in different times of the year on different host plants, and in different stages of crop development. Thus, determination of the Economic Injury Level is critical in defining the ultimate aim of any pest management program, and in delineating the pest population level below which damage is tolerable and above which specific intervention is needed to prevent a pest explosion and to avert significant damage (Fig. 1). Stern et al. (1959) defined Economic Injury Level as "the lowest pest population that will cause economic damage" while economic threshold level (ETL) of more accurately Control Action Threshlod (CAT) as "the density at which control measures should be applied to prevent an increasing pest population level from reaching the economic injury level".

Although the damage or losses at the economic threshold can be tolerated of neglected, it is at this level that every effort should be made to reduce the pest population by various methods (i.e. chemical, physical, biological, etc.).

Determining the Economic Injury Level and Control Action Threshold is generally a complex matter based on detailed operations of pest ecology as it relates to bioclimatology, predation diseases, the effect of host plant resistance and the environmental consequences of applied control interventions (Luckman and Metcalf, 1975). Rabb (1972) has suggested the following factors as essential for the determination of the Economic injury Level:

1. **Amount of physical damage related to various pest densities.**
2. **Monetary value and production costs of the crop at various levels of physical damage.**
3. **Monetary loss associated with various levels of physical damage.**
4. **Amount of physical damage that can be prevented by the control measure.**
5. **Monetary value of the portion of the crop that can be saved by the control measure.**

From this information, it is possible to determine the level of pest density at which control measures can be applied to save crop equal to, or exceeding the cost of control.

The rise and fall of the Control Action Threshold is determined by the importance of the ecosystem, value of the crop, the pest status, and consumer standards. For example, Heliothis zea feeding on cotton boll, has an economic threshold of four larvae per plant (Stern, 1965) and generally requires insecticidal treatment several times yearly. H. zea

feeding on sweet corn, has an economic threshold approaching zero population in the United State since the consumer will reject sweet corn with any damage or one larva on it.

In special cases, where pests serve as vectors of plant, animal and human diseases, the economic threshold is zero. A single pest attack may cause the death of a valuable tree, a domestic animal or human. A good example is Aedes aegypti which transmits yellow fever.

In grain storage, ETL is influenced by consumer attitudes, Export regulations often specify nil-tolerance of any live insects, be it injurious or benefucial.

COMPONENTS OF IPM

Five general types of single component control methods may be used in IPM programs in stored ecosystems. These are: chemical control, physical and mechanical methods, biological control, host plant resistance and regulatory control.

Chemical Control:

A variety of insecticides and acaricides have been and are continuously being developed for control of insect pests. However, these chemicals are but one tool and should be used in combination with other tactics in an IPM program. The total reliance on chemicals has led to a crisis situation (including pest resurgence, insect resistance, secondary pest outbreaks, environmental contamination, and hazards to human health). However, IPM does not

advocate the complete withdrawal of pesticides. That would be impractical. IPM simply demands use of pesticide only when necessary and at rates compatible with other strategies.

Physical and Mechanical Methods:

Physical and mechanical methods are direct or indirect (non-chemical) measures that completely eliminate pests, or make the environment unsuitable for their entry, dispersal, survival and reproduction. Physical-mechanical control measures may include environmental manipulation (temperature, relative humidity, control atmosphere), mechanical barriers, light taps, irradiation, thermal disinfestation, sanitation, etc. Many times, mechanical and physical methods require considerable extra equipment, materials and labor, hence, they may only be economical in certain situations. For field pests, these methods are rather inefficient but in a storage ecosystem, many of the physical techniques are effective and have great potential for use in an IPM system.

Biological Control:

Biological control may be defined in a narrow sense as "the manipulation of predators or patho. yens to manage the density of an insect population". This definition does not include the naturally occurring control agents, but only parasitoids, predators and pathogens that are purposely manipulated by man. In a broader sense, it includes "the manipulation of other biological facets of the pest life system, such as its reproductive processes (i.e. sterile

male technique), its behavior (pheromanes), the quality of its food and so forth."

There are some constraints to the potential use and success of natural enemies. Predators, parasites and pathogens found amongst the grain will be regarded as contaminants by consumers and grain exporters. Thus, it makes it very difficult to maintain a pest population level that will enable the biological control agents to establish themselves. The use of pheromones is one of the potentially useful biological agents that could be utilized in IPM for monitoring and partially suppressing pest population not only in agricultural fields but in storage ecosystems.

Host-Plant Resistance:

The manipulation of the genetic make up of the host so that it is resistant to pest attack is called host plant resistance. Over the years there have been numerous successes in breeding for resistance to a variety of pests and currently many crops are being selected for this purpose.

This approach has not been attempted to any great extent in stored products protection systems Investigations in this field have been few. However, research (mainly of rice, maize, wheat) has provided evidence of the utility of varietal resistance in grain storage. Unless research on varietal resistance to storage pests is integrated with breeding of plants that are resistant to field insect pests and deceases the potential of this tactic in storage IPM is limited.

Regulatory Control:

Fundamental regulatory control principles involve preventing the entry and establishment of foreign plants and animal pests in a country or-area, and eradicating, containing or suppressing pests already established in limited areas. Under the auspices of various quarantine acts, numerous control measures are implemented in an attempt to exclude potential pests, to prevent spread and to supplement eradication programs. Ports of entry are the first line of defense against the introduction of new pests. Pests which break through the port of entry are eradicated or contained within limited areas. Quarantine action is used only against insects of economic importance, although it is sometimes necessary to contain insects which are of no economic importance in another country until their behavior in a new environment can be studied

Trogoderma granarium is a most serious pest of stored commodities and every effort is extended to prevent its spread in international trade. In many countries, imported consignments found to contain J. granarium are segregated and immediately fumigated with methyl bromide (at a dosage of 80 9/cu m for 48 hours). Lately, Prostephanus truncates originating from Central America has become a pest of international quarantine importance.

Component Integration:

Each of the many methods in insect control has its place in IPM. There are many situations where two or more can be used in an integrated program. Not all methods, however, are

suitable for use in every situation.

In a storage ecosystem, hygiene and good warehouse management are essential. It provides the framework for other supplementary infestation control methods. An IPM system would therefore supplement sanitation and good warehouse keeping with one or more combination of the following practices:

1. **improved harvesting and threshing techniques**
2. **judicious use of residual insecticides**
3. **use of fumigants (MeBr; PH3)**
4. **use of ambient aeration, and refrigerated aeration**
5. **atmospheric gas modification (hermetic; CO2; N2)**
6. **thermal disinfestation**
7. **irradiation techniques**
8. **insect resistant packaging**
9. **insect growth regulators: (IGRs: methoprene, hydroprene)**
10. **biological control (parasites, predators and entomopathogens, pheromones)**
11. **Use of resistant varieties if possible**
12. **Storage management (FIFO)**
13. **Adequate grain cleaning prior to storage storage.**
14. **Storage design (for pest exclusion, principally for rodont and bird pests)**
15. **Adequate grain cleaning prior to storoge**

16. **Monitoring, evaluation and inspection of stored commodities, storage structures and their immediate surroundings.**

Summary chart insect pest management (After Osmun, 1985)

Insect Pest Management for Stored-Products

There is a number of differences for IPM for stored-products compared to field agriculture. There is far greater variety of tactics that could be employed for storage pest management. In both situations, a systems approach is usd in order to facilitate monitoring and implementation.

Comparison of IPM Between Field Agriculture and Stored-Product Pests

Field Production

1. **Ecological condition - more complex and dynamic.**
2. **Sanitation process - difficult to implement.**
3. **Economic threshold - appropriately applicable.**
4. **Physical control - often impractical and expensive.**
5. **Mechanical control - often impractical and expensive.**
6. **Regulatory control - more complex and require intensive logistical support.**
7. **Chemical control - considerable impact on the ecosystem.**

8. **Biological control - field**
9. **Host - plant resistance - whole plant modification relatively easier.**

Stored Product Setting

1. **Relatively simple and manageable.**
2. **Easier and alone could provide complete control.**
3. **Not generally applicable, food industry often require zero infestation.**
4. **Most physical factors could be manipulated under storage condition.**
5. **More feasible by as built - in feature of storage.**
6. **Detection and implementation generally selfcontained.**
7. **More contained and limited in spatial proliferation.**
8. **Problem of contamination.**
9. **Genetic manipulation to render resistance to seed only more complicated.**

In both situations three additional elements must be incorporated to the development of IPM: 1) appropriate people, 2) a systems approach, and 3) adequate evaluation. Aside from the individual expertise of the team members it is important that the people involved must develop a good personal and working relationship in the pursuance of the common objectives.

REFERENCES

FLINT, M.L. and VAN DEN BOSCH R. 1981. Introduction to Integrated Pest Management. Plenum Press, N.Y. and London. 240 pp.

GLASS, E.H. (ed.) 1975. Integrated Pest Management, Rationale, Potential Needs and Implementation. Entom. Soc. Amer. Spec. Publ. 75-12,141 pp.

METCALF, R.L. and W. LUCHKMAN (eds.). 1975. Introduction to Insect Pest Management. John Wiley & Sons, N.Y. 587 pp.

STERN, V. 1973. Economic Threstholds. Annul Rev. Entomol. 18: 259-280.

WATSON, T.P., L MOORE, G.W. WARE. 1975. Practical Insect Pest Management. W.H. Freeman & Co. San Francisco. 196 pp.

OSMUN, J.V. 1985. Insect Pest Management and Control. In Bauer, F.J. ed. Insect Management for Food Storage and Processing. American Association of Cereal Chemists, St. Paul, Minnesota. pp. 15-24.

Some basic economic principles in pest management

Belen Morallo-Rejesus
and
Romeo S. Rejesus

INTRODUCTION

Entomologists and biologists defing pests as those organisms reaching a certain biomass or population level enough to cause physiological damage to crop and eventually impair either the quantity and quality of the produce. The concern used to be concentrated solely on devising control strategies with the aim of increasing the pest-kill efficiency and/or minimizing the control's unwanted side effects on the environment. In doing so ,a damage function (one that relates yield loss or crop damage to pest density levels) and a kill-function (one that measures the efficiency of a particular control strategy in terms of percent pest killed) are determined simultaneously. Perhaps, the ultimate goal of these efforts is to realize the yield potential of crops by eliminating pest hazards which is possible only where there is maximum protection. In years past, maximum protection was closely associated with prophylactic dosages of pesticides.

Economists view pest problems and solutions quite differently. For one, pests are those organisms that destroy what man has produced, compete for resources needed by man in the production of food and fiber, or contaminate the environment in such a way that man finds it unhealthy or unattractive (Headley and Lewis, 1967). An economist would not be

very particular about the exact levels of pests, damages, and mortalities; but would pay more attention to the value of pest damage and the costs of alternative control strategies with or without special consideration to time. Usually, he would not desire for the yield potential of crops because he knows that it does not always pay to spend for maximum protection. In fact, the urge to control pests does occur to him until he finds that the cost of doing so is more than offset by the benefits. Biologists, to a great extent, do not worry about costs in as much as they find delight in quantifying apparent yield increases due to control action.

Almost for two decades now, attempts have been made to reconcile the disciplinary concerns of both the natural and social scientists to benefit the farmers and the public at large. To put their interests together, the US National Academy of Sciences (1969) states that: entomologists develop and perfect various methods of insect control and determine their physiological impacts on crops; economists depend on entomologists for information regarding various inputs combined to produce a particular outcome. To some extent, pest management was conceived to pool together the concerns of people coming from various fields in a most coordinated fashion. Pest management is defined as an ever-changing process of attacking pest problems by applying (in the field of storage) whatever economically feasible control of combination of controls that produces the best combination of immediate and long-term results in terms of both reduced pest damage and the absenec of unwanted side effects (Beirme, 1967). This implies that pest management may utilize a single-component-tactic or it may be accomplished through a complicated integrated pest

management system as discussed earlier. Some Terms and Assumptions in Economic Analysis:

We start by making an assumption about the behavior of individuals: a rational farmer would maximize profit or minimize costs and would seek more than increase in yield or decrease in the use of input in his production decisions. He is knowledgeable about the exact outcome of the decisions and the prevailing prices in the market.

In the analysis of crop protection, it is necessary to define what are we putting in and what are we getting from this activity in order to evaluate if such is really worth it.

Input/Cost. The factors of production such as buildings, machines, materials, labor and management skills are called inputs and if valued at their respective prices are called farm costs or expenses. Let x = quantity of input and Px = Price of input. Then Cost = (Px)(X)

Output/Beturn. Through some physical or biological processes, the above inputs are transformed into usable products or output. Similarly, it can be valued by its price to get the return, revenue or benefit. The benefits from pest control is indicated by the increase in yield or added returns.

Let X = yield (increase) and Py = price of corp. Then Return or Revenue = (Py)(Y)

Pest management. Pest management is becoming more essential in our modernizing

agriculture as problems about pests and damages increase with time. As an input it has 5 components: pest control materials, labor and management or knowledge about pests, expected damage, and alternative control methods.

Pesticides. Pesticides used to be the single most important protectors of crops from insects, weeds and pathogens but because of the ever-increasing price and unwanted side effects, nonchemical methods are being tapped. Nevertheless, continued dependence on pesticides in the near future is a reality that pest managers have to reconcile with. Generally, pesticides form a regular feature of the farm cash expenses.

Non-chemical control. This method is likewise called labor control because it relies heavily on a farmer's manual efforts. Non-chemical methods do not necessarily mean that the materials needed for its utilization are cost-free.

Efficiency. We define the most efficient pest control strategy as one that requires the least combination of labor cash input for a given level of yield increase, their factors held constant. The definition combines the "efficiency" and effectiveness concepts presented by Semple (1985). According to him the efficiency of an insecticide is the minimum dosage required to reduce the population of target pests by a fixed proportion (80%) regardless of pest pressure. Effectiveness, on the other hand, is indicated by the number of surviving insects of the extent of yield damage after the treatment. It is determined not by the "efficiency" of insecticides but by the strength of pest perssure as insecticides by the over-all

farm operations. One needs to know the compatibility of his control measure to his pest problems and an effective manager does.

Optimum thresholds. At least, there are two sets of pest population thresholds found in pest management literature, one being a shadow of the other. Studies regarding plant physiology in relation to phytophagous organisms that reveal there is a tolerable level of plant destruction due to pests wherein the crop is still able to recover and remain vigorous. Apparently, economic injury level (EIL), sometimes termed as the biological threshold level (BTL) is the critical pest density level going beyond what is tolerable to crops. With the EIL, biologists justify control actions. For the economists, such could never be unless the cost of control is zero. Economic threshold level (ETL) is the level of pest density at which suppression action is initiated, the control cost at least equals the value of expected damage. Some IPM specialists prefer to use the term control action threshold (CAT) for EIL since it connotes immediately that it is that level control action is necessary. The mathematical expression for ETL below tells the basic relationship between the critical pest density level and economic variables. If we assume d and K as pre-determined (constant) variables then only the cost and crop prices affect the ETL. Note the prohibitive character of cost control action. If prices of pesticides would be very, very high, ETL would also be and control action may not be economically warranted. However, if the crop is of high value or if the market requires high quality products, ETL will be small and the propensity for control action will be high.

ETL = c/pdk

Where
c = cost of control action
r = price of crop
d = damage coefficient
k = kill efficiency

Partial Budgets: A Guide to Pest control Decision

A private farmer, faced with a limited cash budget and credit would think twice before he puts in money into an otherwise biologically attractive innovation. He might not be doing detailed accounting of the proposed change but deep in his mind, he calculates and balances the relative benefits and costs of every new undertaking. If the perceived economic net gain is positive and acceptable, then he evaluates the resource requirements and explores ways finance it.

Partial budgetting is perhaps the most popular decision tool employed in the conduct of applied research by the entomologists in an attempt to add economic substance to experimental results. Partial budgets are designed to show, net profit or loss for the farm as a whole (this is called costs and returns analysis), but the net increase (decrease) in farm

income resulting from a (proposed) minor change in the on-going operations. It contains 4 major items bearing exact information about the changes in monetary terms, namely: added returns, reduced costs, added costs, and reduced returns.

Added returns is the value of the increase in yield and/or the value of quality improvements.

Reduced costs is the value of inputs no longer used under the proposed change. If previously the farm is using 6 man-days of labor but the new technology requies only 4 man-days, then the wage that should have been paid to 2 man-days represent a reduction in cost.

Added costs is the value of additional inputs as a result of the proposed change. This is the exact opposite of reduced costs. The classical example is the cost of additional fertilization, labor and machine service associated with modern farming.

Reduced returns is the value of forgone output. It the proposed change diminishes yield, then it reduces returns. In some instances, the increase in production is shared with the landlord and harvester/thresher so that the value of harvest that went to them is accounted as reduced returns.

The procedure for partial budgetting is straightforward. Analysts have just to be keen the details in the change of process. Given data on market prices, he can put values to each change item and determine if such diminishes or adds to returns or costs. After which, he can compute for the net change in income by subtraction the sum of Added costs and

Reduced returns from the sum of added returns and reduced costs:

Net gain/loss in income = (Added returns + Reduced Costs) - (Added costs + Reduced returns)

Biological studies on pest control strongly assume that farmers do not control pests; this is the implication of comparing- treated as against the untreated plots. Such standard experimental procedures directly ease out computations involved in the economic analysis but, at the expense of intuitive value of practical content. It does not provide the analyst a grasp of the general and actual problem situation because at this time very few farmers are indifferent to pests. Pesticide consumption growths observed for rice, vegetables and bananas indicate that pest control is very active in our agricultural/farming system. Quite recently, field studies on the control of rice pests use farmers' practice as a separate benchmark for comparison.

It is quite necessary that analysts look for flexibilities in the data set and mold the framework according to the dictates of the local problem situation. In that case, he could come up with a matrix of problem situations and alternatives. For each situation, the dominant alternative may be decided based on at least 2 criteria: (1) magnitude of net change in income (2) resource requirements and accessibility.

Other Decision-Making Models

In reality, farms are multi-enterprise in nature. There is also substantial interdependency in decision across crops and over time. Uncertainties or lack of information about pests, damage, controls and prices also exist. In other words, the type of control a farmer applies to his main crop influences his control decision for the second crop. Similarly, his control practices in the previous season greatly affect his decision in both present and future cropping. Imperfect knowledge and limited skills concerning pest control decisions and the presence of natural disturbances may render actual decisions "inferior" to that predicted by the partial budget model. And as one tries to develop realistic models, the analytical tools tend to be conceptually complicated and computationally irksome. This leads us to a brief discussion of the various models developed recently.

Whole farm budgets. This is merely an extension of the partial budgets. It recognizes interdependent decisions which means that an adoption of technology in one enterprise affects the rest. Thus, the entire farming system is changed. Oftentimes, it will be hard to distinguish the cause from the effect. Taking the entire system as the unit for analysis makes it simpler.

Production Function Analysis. It is basically statistics in form and is widely used in production economic research. A production function tells the average relationship between the farm product and its factors of production. It bears powerful estimates of the precise contribution of each input to the total product. Headley (1968) formalized the economic study of pest control and applied this framework in the analysis of pesticide expenditure in

US agriculture. He concluded that pesticides are indeed productive inputs placing a $4 contribution to the value of agricultural production per dollar spent on it. He thus predicted an expanding market for agricultural pesticides in the 70's and challenged the technical faculty to develop a less hazardous but comparatively productive substitute.

Reichelderfer (1980) criticized the common practice of using pesticides as a proxy for pest levels to explain variability in production. Note that it is the pest and not the control action that directly affects yield. She pointed out that production functions for pest control are unrealistic if they do not express yield as a funtion of pest levels. Since this practice is necessitated by lack of (pest infestation) data, economists are reminded to be careful in the interpretation of results. For one thing, the so-called productivity of pesticides is dependent completely on pest pressure. It is important, therefore, that the economists understand the biological system with which they are working

Benefit-cost analysis. BCA is probably the most comprehensive analytical tool unfortunately, it requires voluminous data and it is usually not workable. BCA treats pest control as an investment or a folw of costs and returns. Though time is the core of B-C analysis wherein discounting methdods are used to calibrate the flow of money in order to come up with timeless measures of efficiency the internal rate return (IRR) and the benefit-cost ratio (BCR). The ideal situation is for the IRR to be greater than the market interest rate and for the BCR to be greater than 1. BCA's can be done both at the farm and the community levels. For the latter, we call it extended BCA. This is of great use in analyzing pollution problems related to

pest control which is quite beyond the concern of farmers and yet it bears tremendous impact to the is shown below (Table 1,)

Space fumigation using PhostoxinR for a warehouse of approximately 980,000 cubic feet volume (or 27,750 m). The quantity of corn stored was 147,000 sacks x 75 kilograms or approximately 11,000 tonnes. The total value of corn at current prices of P2.40 per kilo is P26,460,000.00. The reported loss due to Sitophilus granarius (L.) infestation over a period of three (3) to four (4) months was 10% to 15% of the total weight. In real terms, this is equivalent to 1,102,500 kilograms or P2,646,000.00. The cost of fumigation at the current prices of P150.00 per 1,000 cubic feet, is P148,200.00. Equating this figure to the possible loss if no fumigation is done, there is a saving of P2,497,000.00.

Risk analysis. Finally, the latest add-on to our list views the resurgence of pests as an involuntary risk (unlike gambling which is voluntary) taken by farmers, pest control actions as means to minimize the risks or variability of yields and profits, and control costs as the premium farmers pay to avoid it. This analysis exerts less pressure on biological data requirements, specifically, pest infestation levels. This type of analysis has the potential of influencing pest control policies particularly crop insurance and pest information services.

We conclude this paper by saying that the economic research on pest control is catching up with our needs. In the same way that economists try to understand the biological system, the biological science community must likewise understand the economic system.

Table 1. Costs of fumigation with methylbromide (MBr) and phosphine generating forumulations (PH3 tablets) for various applications.

	FUMIGANT	
SITUATION	**MBr**	**PH3**
Space fumigation	P200 per 1000 ft or	P150 per 1000 ft or
P7.06 per m or USD	P5.30 per m or	USD 0.38 Per m
	0.50 per m	
Block fumigation	P25 per 1000 ft or	P220 per 1000 ft or
	P8.82 per m or	P7.77 per m or
	0.63 USD per m	0.55 USD per m
Container fumigation	P250 per 20-footor or	P200 per 20-footer or
	17.86 USD	14.29 USD
	P400 per 40-footer or	P18 per 40-footer or
	28.57 USD	27.14 USD

where 1 ft - 28.3168 liters or 1000 ft 28,3168 m
P14 = 1 USD

The prices quoted include labor, contractors tax, and all other expenses incidental to the fumigation. Applicable only to Metro Manila Area, cost of transportation, board and lodging for at least three (3) personnel must be added.

Source: Fumigation Specialists Inc., Aurora Blvd., Q.C.

REFERENCES

Beirme, B.P. 1967. Pest Management. London: Leonard Hill Publ.

Headley, J.C. 1968. Estimating the productivity of agricultural pesticides. Amer. Jour. Agric. Econ. 50: 13-23.

Headley, J.C. and J.N. Lewis. 1967. The pesticide problem: an economic approach to public policy. The John Hopkins Press. 141 pp.

National Academy of Sciences. 1969. Economic principles of pest management. In "Principles of Plant and Animal Pest Control." NAS, Washington, D.C.

Reichelderfer, K.H.1980. Economics of integrated pest management: Discussion: AJAE 62: 1012-13.

Ruisink, W.G.1980. Economics of Integrated Pest Management - An Entomologist's View of

IPM Research Needs. Amer. J. Agric. Econ.162(5): 1014-1015

Semple, R.L. 1986. Entonomics: economics of integrated pest management. In "Insect Pests of Stored Grains and Their Control". Vol. 9. IPM Part I.

Contents - Previous - Next

Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Socio-economic and technical dimensions of integrated pest management

Contents - Previous - Next

Zenaida F. Toquero

Pest control has gone through an evolution from the sixties where emphasis was on the use of chemicals as the best technical option against pests, to the eighties where the thrust is on judicious, needbased use of pesticides (rather than the commonly adopted practice of calendar-based prophylactic spraying) that integrates biological, cultural, and chemical control methods. (Panganiban and Sumangil, 1983, Martin, 1988). This new pest control concept, referred to as Integrated Pest Management or IPM has been stimulated by the

intensification and increasing complexity of crop protection problems, coupled with the associated environmental, financial, and health hazards of heavy chemical use.

Kenmore (1987), defined the meaning of integrated pest management as follows:

....."It's INTEGRATED because it tries to reassemble into one unit the best mix of pest controls for a particular field in a particular season or time. The glue that holds these controls together in an integrated system is the natural population control ecology of the community of species that live in the field. Natural forces which include biochemical immunity (coconut diseases never attack rice) habitat invulnerability (more than 99% of the world's weeds can never live in flooded conditions along with rice) and carnivory (more than 99% of plantfeeding insects found in rice fields are killed by predators, parasitoids, or pathogens before they grow up) keep more than 99% of pests under control 100% of the time......

.....PESTS means any species that eats the crops and prevents farmers from reaching their goals for a particular crop. Pest may include weeds, rodents, insects, fungi, bacteria, viruses, nematodes, birds and mycoplasms. A species becomes a pest only if it eats too much of that crop or commodity which reduces yield from its agronomic potential......

.....MANAGEMENT means the set of skills ... to be learned and practiced.

.....INTEGRATED PEST MANAGEMENT, therefore, is a set of skills that enable farmers, users,

of practitioners to recognize which of the few populations out of the many in their fields or warehouses are likely to become pests. IPM then gives these users a large selection of control tactics from which they can choose the best mix of pest controls without necessarily involving use of more pesticides "

In the context of the associated environment and the population dynamics of the pest species, IPM utilizes all suitable techniques and methods in as compatible a manner as possible to maintain the pest population at levels below those causing economic injury (FAO, 1967). This means the rational use of all techniques in suppressing pest population through such measures as biological control, genetic techniques, host plant resistance, and cultural, mechanical and chemical controls. It is an effort to bring together multidisciplinary methodologies in developing agroceosystem management strategies and decision-making tools that are workable and economically feasible, ecologically sound, and socially acceptable (Kenmore, 1983; Litsinger, 1984; Adalla, 1988).

Technical Dimensions of IPM

Pesticides are scarce commodities whose life spans must be maximized to ensure that they are available for continued use, if so desired, within the integrated pest management programmes. Insecticide residues decay over a wide range of temperature and grain moisture contents, thus the need to determine these (data to allow for; (a) accurate prediction of the amount of pesticide needed for a specific crop or commodity; (b) avoidance

of under- or over-dosing; and (c) possible definition of residue tolerances.

Insect/Pest Biology

A major problem in insect/pest control is the lack of knowledge of pest biology and the factors causing physical loss and quality deterioration of grains in storage. Correct identification/ recognition, of the various pests, their life cycle and behavior patterns have a considerable bearing on the inspection methods and timing of control application for more effective results. For instance, some egg-laying species like the grain weevils, lesser grain borers and the grain moths, initiate their infestation and damage to the grain by leaving their eggs on the unharvested grain in the field. These eggs then mature and become adults when these infested grains are already in storage causing the most damage.

It is, therefore important to have a knowledge of pest biology because different species require different strategies of control at the various stages of their life cycle. Some storage pests are much less dangerous than others and may not necessarily require immediate pest control. Conversely, others are highly destructive, thus the need for immediate control measures becomes imperative.

Biological control

Another major issue about chemical pest control is the propensity of some pests to develop resistance to pesticides through time. The problem is further aggravated by the limited

number of chemical classes of pesticides/insecticide available, and its continuing soaring prices. One possible solution to these problems is the use of biological control measures such as parasites and predators (see Appendix Table 1) and disease organisms or pathogens such as various subtypes of the bacterium, Bacillus thuringiensis amoebae and sporozoans such as Triboliocystis garnbami, Mattesia trogoderma and other species, Nosema spp., Halics spp., which are most frequently encountered in dense populations of insects and can cause high mortality (Semple, 1985). None of these are known to infect man and therefore offer considerable potential for use in biological control.

The use of various botanical insecticides is another cheap pest control method in paddy storage. One good example is the neem plant (Azadirachata indica A. Juss, Meliaceae) which was found to inhibit insect population buildup, primarily Sitophilus oryzee and Rhizopertha dominica after three months of storage (Muda, 1984). The repellant effect of the volatile, biologically active ingredient in neem, such as azadirachtin and melianatrol has been evaluated, the former of which possesses known antifeedant properties against R. dominica (Malik and Muttaba, 1984). Neem leaves or seed in powder form had been previously studied to show long persistency with proven effectiveness against S. oryzee, R. dominica, and Trogoderma granarium in wheat for nine to twelve months of storage (Jilani, 1984). Neem can therefore be a cheap alternative to synthetic insecticides, with potential adaptation for large scale use. Extracts from black pepper have bee evaluated in the Philippines (Morallo-Rejesus, 1983) and other vegetable oils such as palm oil, bran oil, peanut of,, and corn oil at 5-15 ml/kg have provided insect control for four months on

legume seed without affecting seed viability (Suprakarn and Tauthong, 1981).

Several studies have likewise looked into the issue of varietal resistance as a possible pest control measure. One of these is the study done by Rejesus and Dimaano (1984) on the resistance of 20 varieties of milled rice to corn weevil (S. zeamais) and red flour beetle (T. castaneum). The study showed that IR36 and IR32 are highly resistant to corn weevil and red flour beetle respectively. Varieties such as IR29, IR38, IR42, IR43, IR46 and IR5853 were highly susceptible to T. castaneum. These results indicate that insects preferred some varieties for feeding because in some cases, these varieties are suitable for the insects' survival and development. The varieties' chemical composition (such as percent amylose content which was positively correlated to index of susceptibility) may likewise explain degree of proference.

Effective Loss Assessment

According to Hodges, et.al. (1984), there had been virtually no scientific evaluation of the methods used in the detection of insect infestation or the interpretation of results that are obtained therefrom. From what is currently known about distribution and behavior of insect pests in grain stores, it seems that the levels of infestation are very likely to be inaccurately reported. As a result, expensive control procedures such as insecticide spraying and fumigation may often be applied either too early or too late so that the maximum benefits are not realized.

Farmers usually spray insecticides during crop production when they perceive the need for it even when in most cases, the pest level is below the economic threshold level (ETL), And to think that total area coverage rather, than spot application, is often practiced one can imagine the waste of the whole exercise. Furthermore, this socalled economic threshold does not consider the population of beneficial organisms.

It is therefore very important that prior to any rational campaign againsts insects and pests in stored products there is an updated knowledge on the pest complex occuring in the warehouse, the relative importance of each species, products attacked and nature of damage, and the presence and abundance of the natural enemies of the identified pests. Such information will give an indication on changes in pest situation such as pest resurgence, shifts in pest dominance, and the causes of such altered conditions (Sabio, et. al., 1984). It is equally important to obtain reliable and fairly accurate estimates of grain losses caused by insects from which the ETL at which control measures (particularly fumigation) should be applied can be established. This information will aid in developing possible improvements in pest control strategies currently being utilized by applying them at a time that will economically justify their use.

Economic Dimensions of IPM

According to Norgaard (1976), there are three interrelated ways by which economics may enter into the design of IPM strategies: (a) the farmer's pest management goals are largely

economic; (b) economics being a science of resource allocation can aid in selecting optimal quantities and combinations of pest management inputs; and (c) the adoption of new management practices can be speeded up through an economist's understanding of the incentives underlying farmer's behavior and the effect of alternative social institutions on these incentives.

Physical and Economic Environment of Affected Sectors

The ultimate pest management goal of a rational farmer, trader and/or miller/processor is to maximize profit (if he is market oriented) or to produce enough for his needs (if he is a subsistence farmer). This is done through selective reduction or increase of chemical use, selective use of pesticide with a more narrow action spectrum, and use of new biological and other control methods. This is where the importance of studying the socio-economic component of IPM technology is highlighted wherein farmers, traders and/or millers practice pest management strategies according to their resource capacity, their objectives, and their perception of pest attacks (Role and Ocampo, 1986). Their acceptance or rejection of the IPM technology will be partly conditioned by the physical and economic environment within which they operate and this includes the size or scale of their operation, access to capital, infrastructural support and services, etc.

The size or scale of a business operation (whether it be at the farm, traders or processor's level) largely determines the willingness (or the lack of it) of a potential adoptor or user to

accept or use a give postproduction technology. In the case of rice producers, small-sized farms are generally on subsistence level that receptivity to new and/or improved technology such as IPM will be nil or totally lacking. As the size of his operation gets bigger and more of his produce is market-directed, his financial resources improves and he becomes more quantityand quality-conscious in order to avail of any price premium for such products. Thus, he may become more receptive to IPM. The same condition can be said of the traders and processors. As their volume of business expands, the more they tend to improve their facilities and management operation. They begin to be more conscious of the quantity and quality of product they procure and distribute to have a greater share of the rice market.

Risk and Uncertainty

Farmers living near subistence levels are commonly reported adverse to risk because a reduction in income, even for a relatively short period of time, could seriously affect the wellbeing of the farm family. When analyzing why potential adoptors and/or users do not adopt new techniques, the new technique must be measured against their needs as well as their capabilities. Surely these targeted beneficiaries have a right to be skeptical when proposed changes involved some financial outlay as compared to the total income that they might have, for something which is new or different from their regular practice or way of life. Moreover, those "improvements" might be too technical or too cumbersome or complicated for these potential users to fully comprehend and use. Thus, an understanding of the decision-making processes of farmers can help facilitate the adoption of certain pest

management techniques. An understanding of this process and how farmers are influenced by their resource endowments, management skills and knowledge of marker factors can help explain potential constraints in the adoption of technology. Unless these constraints are identified and considered during technology development, the present generation of agricultural research scientists may again fail where their predecessors did; the technology they developed was so efficient and perfect, but it hardly conformed to basic realities and farmers' needs (Role and Ocampo, 1986).

Loss Assessment

In order to effectively estimate/verify the financial benefits of IPM, there is a need to accurately estimate as much as posible the postproduction losses (quantitative and qualitative) incurred due to pest infestation, the costs incurred due to this loss and the consequent costs of pesticides used under pure chemical control. This information is very important before any appropriate intervention procedure can be undertaken to elucidate where the major losses are being incurred within the system, the magnitude of such loss and the kind of strategy that is best suited for alleviating or improving the situation, both in terms of weight loss reduction and maintenance of quality. The importance of this exercise may not be as great at the farm level - where volume of grain stored is just sufficient for home consumption - as it is at the commercial and/or government level where big volumes of grains are being stored and handled for market.

Social Dimensions of IPM

Traditional Value System

According to Castillo (1965), the farmers are claimed to resist technological innovations because of their adherence to deeply rooted traditional patterns. But whether farmers are really to blame for the nonadoption is debatable. Decisions of farmers and/or potential adoptors-users are influenced not only by identifiable techno-economic factors but also sociocultural factors. Central to this problem is the value system. According to Rola and Ocampo (1986), traditional families are characterized by the stability of their value system. The essential feature of such is the complex web of agreed norms of behavior, a kind of cumulative common wisdom unconsciously accepted by everyone without need of visible proof. This complex web is often developed over hundreds of years and for this reason the society gives value to particular practices.

Decision-Making Process

Integrated pest management is a new concept of a people-oriented technology and its success or failure will depend on how the clientele group will perceive its benefits vis-a-vis their traditional farming practices on the one hand and possibly how change agents or technocrats relate the technology to its end users on the other hand (Adalla, 1988). IPM

involves a lot of management decision-making which calls for serious efforts on the part of the extension agent in his tasks to equip and train the targeted clientele with the necessary technical expertise on which to base his decision. Because of the developed bias of farmers/users as regards pesticides as an important input in their production, farmers may initially look at IPM as a risk and will therefore hesitate to readily adopt it. Their hesitancy is further compounded by the new activities they have to undertake (which are necessary so that every IPM decision can be based on objective reality) which may be quite "foreign" and tedious to them. This includes: (a) regular visit/monitoring of pest population; (b) learning about "friendly" pests vs. real ones; (c) deciding whether or not immediate action is needed based on infestation levels they themselves have to determine; and (d) facing the consequence that pesticide application is not a sure guarantee of eliminating pest damage.

IPM offers changes in farming methods, hence, changes also in the farmer's way of life. Its introduction demands that farmers be provided not only with the material farm inputs, but also sets of decision-making tools; what resistant variety to use, when to use pesticides, what pesticides to use, etc. The IPM approach requires regular field monitoring, and farmers are encouraged to define what is the economic threshold level, without which judicious and economical use of pesticides will never be realized... The introduction of IPM, therefore, requires the adaptability of the approach not only to the natural environment and economic conditions but perhaps more importantly, to the attitudes, values, and perception of the small farmer.

Effective Extension and Delivery System

The mere existence of IPM technology is not enough. The introduction of IPM would be meaningless if it will not be transformed and repackaged to suit the farmer's needs. What is therefore needed is an effective extension mechanism, appropriate diffusion approaches and other information support services on crop protection to make the technology usable by the targeted clientele. These IPM approaches must be developed and modified and made compatible to the social system of small farmers. According to Stuart (1988), the verification of location specificity of IPM technology should be done with the active and wholehearted participation of farmer cooperators as "research partners." It should seek to enable the targeted users or practitioners to experience the research process by comparing the agronomic and economic performance of locally adapted IPM with the user's practices in paired-parcel trials within his own facilities. Because of the complexity of IPM, not only the farmer or potential adoptor should be involved in the training/extension process but the potential role of non-traditional IPM audiences such as women, children, and other members of the household or community should also be considered. Studies have shown that women generally take over the responsibility of on-farm storage so there's probably a need to redirect to these non-traditional sectors future training and extension programs. Moreover, since women can easily/conveniently relate to women extension workers better than the male, upgrading of these female extension agent's skills in this area need to be looked into. Based on IRRI records of IPM training program, out of the 171 Asian traineesas of 1987, only 17 were women. Whether or not there is a deliberate attempt to discriminate

against women extension agents, the end result seems to indicate that the core of women extension agents has not been given equal chances as their male counteraprts, yet the expectations from them are the same.....

Ecological impact

According to Rola (1986), total reliance on chemical control in the past has proven to be a disastrous solution to the long-term problems of insect and other pests. Experiences from many parts of the world show that too much pesticide misuse and overuse create a host of other problems like insecticide resistance, pest resurgence, outbreaks of secondary pests, environmental contamination and increasing food residue levels (Table 1). These latter two problems affect the general population, not just the direct users but the indirect users as well. This is reflected in the available statistics on pesticide poisoning cases shown in Table 2. The table reflects the data gathered from government hospitals in 48 provinces for 1980-83 showing 659 total cases of acute pesticide poisoning in 1980, 633 in 1981, 238 in 1982 and 824 in 1983. There are no available statistics from rural doctors who routinely treat patients for occupation "sickness" during and after the main spraying season, so the above figuress are likely underestimated. About 60-71% of the cases were suicidal or non-agricultural related since most of these hospitals are located in the urban areas.

A recent study by Loevinsohn (1987) has indicated that in the major rice growing areas of the Philippines, widespread adoption of insecticides by small holder farmers appear to have

resulted in an increase in mortality of 27 percent among economically active users as a result of pesticide misuse. This would imply an annual mortality of many tens of thousands in the rice growing areas across Asia whose farmers adopt similar practices. It also indicates that the commonly adopted figure of 10,000 deaths worldwide from accidental and occupational poisoning is understated. That the impact is among economically active men implies that the social or economic impact is greater than the undifferentiated number of deaths would suggest.

In terms of pesticide residue analysis, the accepted practice have always been to analyze the residues of harvested/milled crop at the market. The local marketing, however, does not allow for the disposal/rejection of produce due to high residue levels. Thus, even if residues found in food exceed the maximum residue limit set by FAO or even our own FPA guidelines, nothing is being done. With regard to our export grain, if they do not pass the quality control of the importing country, then the produce is dumped in our local market. For safety/health reasons, it is important that residue analyses be done at the farm level where, given a certain amount of pesticide being used, one could determine the corresponding residue based on a transformation function. There's likewise a research need that will relate toxicity levels and residue levels.

Table 1. Some possible side-effects of the production and use of pesticides.

1. **Entrance and persistence of pesticides into different compartments of the environment,**

including the food chain.

2. **Occupational hazards associated with chemicals with high biological activity.**
3. **Unintentional exposure of people as a result of careless spraying operations.**
4. **Careless transportation, storage, and destruction of pesticides and pesticide containers.**
5. **Mismanagement of dangerous wastes at the production plants.**
6. **Ecological effects, including development of resistance in disease vectors.**

Source: Environmental Pollution Control in Relation to Development Report of a WHO Exper Committee, Technical Report Series 718, Geneva, 1985, p. 21.

Taken from Rola, A.C. 1986. Policy Recommendations for Pesticides. Center for Policy and Development Studies. Working Paper No. 86.03.

Table 2. Pesticide poisoning cases admitted to government hospitals according to chemical grouping, Philippines, 1980-1983.

Chemical Grouping	**1980**	**1981**	**1982**	**1983**	**Total**	**%**
Organosphate	229	246	90	346	911	38.8
Organochlorines	116	114	61	154	445	18.9
Carbamates	82	52	35	129	298	12.7
Pyrethroids	5	5	5	5	20	0.8

Chlorophenoxy compounds	11	70	4	8	93	3.9
Dipyridyle	—	1	—	—	1	—
Rodenticides	19	7	2	11	39	1.6
Fungicides	—	1	—	1	2	—
Herbicides	7	3	6	12	28	1.2
Not Specified	148	114	33	126	421	17.9
Mixtures	32	14	3	26	75	3.1
Other Ag. Chemicals	1	3	2	6	12	0.5
TOTAL	650	633	238	824	2345	100.00

Source of data: UP-PGH. Taken from Rola, A. C. 1986, Policy Recommendations for pesticides. Center for Policy and Development Studies. Working Paper No. 86.03.

There is also an urgent need to develop protective covering for farmers/users during pesticide application. Although pesticide companies have already developed protective clothing, they may find difficulty in selling them because of the psychological effects on the farmers/suers (i.e. it warns users that they're dealing with a hazardous substance). This may further discourage users from using that particular pesticide. Proper and strong extension

programs should be undertaken to make possible farmers education and understanding of the proper use and handling of pesticides. Barangay nutritionists and health workers as well as village elders and other respected people in the community can be effective contact points for this extension/training programs.

BIBLIOGRAPHY

HAINES, C. P.1981. Paddy loss to insects. In GTZ Paddy deterioration in the humid tropics, a GASGA Seminar, 11-18 October, Bagulo, Philippines. pp. 67-76.

JILANI, G. 1984. Use of botanical materials for protection of stored foodgrains against insect pesta review. Presented at Research Planning Workshop on Botanical Pest Control Project, IRRI. Los Banos, Laguna, Philippines, 6-10 August 1984. 18 p.

KENMORE, P. E. 1987. IPM means the best mix. Rice IPM Newstetter. Vol.1, No. 1, July 1987. International Rice Research Institute.

MALIK, M. M. and S. H. Mujtaba, 1984. Screening for some indigenous plants as repellents or antifeedants or stored grain insercts. J. Stored Production Research. Vol. 20(1): 41-44.

MUDA, Rahim A.1984. Utilization of neem as a pest control agent for stored paddy. In

Semple, R.L. and A. S. Frio, eds. Health and Ecology in Grain Postharvest Technology: Proceedings of the 7th ASEAN Technical Seminar, 21-24 August 1984, Kuala Lumpur, Malaysia. pp. 117-128.

REJESUS, B. M. and D. Dimaano. 1984. Some factors responsible for the varietal resistance of milled rice to Sitophilus Zeamais (Motsch) and Tribolium castaneum (Herbs"). In Semple, R.L. and A. A. Frio, eds. Health and Ecology in Grain Postharvest Technology: Proceedings of the 7th ASEAN technical Seminar, 21-24 August 1984, Kuala Lumpur, Malaysia, pp. 129-142.

SABIO, G. C. et al.1984. Establishment of economic threshhold level in stored grains and preliminary trial on methacrifos as stack spray. In Semple. R. L. and A. S. Frio, eds. Health and Ecology in Grain Postharvest Technology: Proceedings of the 7th ASEAN Technical Seminar, 21-24 August 1984, Kuala Lumput, Malaysia, pp. 65-93.

SAYABOC, P. D. et al. 1984. Rodent losses in commercial grain storage. In Semple, R.L. and A. S. Frio, eds. Health and Ecology in Grain Postharvest Technology: Proceedings of the 7th ASEAN Technical Seminar, 21-24 August 1984, Kuala Lumpur, Malaysia. pp. 101-115.

LITERATURE REVIEW

ADALLA, C. B. Women in Rice IPM: The Calamba experience. Paper presented at the Women

in Rice Farming Systems Workshop held at IRRI, 211 May, 1988. 13 p.

BATTAD, F. 1972. Factors associated with the adoption of rice technology in Cotabato, Ph. D. dissertation, UP at Los Banos, Philippines.

CASTILLO, G. T. 1965. Towards understanding the Filipino farmers. Presented at a seminar, IRRI, Los Banos, Laguna.

GOODELL, G. 1983. Improving administrator's feedback from the local level. Agricultural Administration. 13: 29-55.

GOODELL, G. 1984. Challenges to international pest management research and extension in the Third World: do we really want IPM to work? Bulletin of the Entomological Society of America 30(3), Fall 1984.

HODGES, R. J. et al. 1984. The assessment of methods of inspection for insects in bagged rice. In Semple, R. L. and A. S. Frio, eds., Health and Ecology in Grain Postharvest Technology: Proceedings of the 7th ASEAN Technical Seminar, 21-24 August 1984, Kuala Lumpur, Malaysia.

KENMORE, P. E., Eeong, K. L. and C. A. Putter. 1984. Political, social and perceptual aspects of integrated pest management programmes in Lee, B. S., Loke, W. H. and K. L. Heong. eds. Integrated Pest Management in Malaysia. Malaysian Plant Protection Society (MAPPS), Kuala

Lumpur, Malaysia, pp. 47-66.

KENMORE, Peter E. Crop loss assessment in a practical integrated pest control programme for tropical Asian rice (no date). Mimeograph.

LOEVINSOHN, M. E.1987. Insecticide use and the increased mortality in rural Central Luzon, Philippines. The Lancet, June 13.

MARTIN, John.1988. Integrated pest management in rice: integrating economies, extension and policy. Australian International Development Assistance Bureau Development Papers No. 7. AIDAB.

NORGAARD, R. B. 1976. Integrated economics and pest management in J. Apple and R. Smith, eds. Integrated Pest Management, Plenum Press. New York.

OCAMPO. P. P. 1980. Adoption of recommended crop protection technology among rice farmers in Bulacan, Philippines. Unpublished M. S. Thesis, University of the Philippines at Los Banos.

PANGANIBAN, D. and J. P. Sumangil. 1985. Integrated pest control for Philipping rice farmers. Paper presented to the International Rice Commission 16th Session, IRRI, Los Banos, Laguna, Philippines.

ROLA, A. C. and P. P. Ocampo. The socioeconomic component of integrated pest management in FAO Proceedings of regional consultative workshop on integrated pest management, 17-21 June 1986, SEARCA, Los Banos, Laguna, Philippines. pp. 121-130.

DEMPLE, R. L. 1985. Pest control in grain storage systems in the ASEAN region. ASEAN Crops Postharvest Programme Technical Paper Series No. 1, Philippines. 77 p.

STUART, Teresa H. 1988. Operationalizing participatory development communication in an action research project on integrated pest management extension and women. Presented at the Women in Rice Farming Systems Training and Planning Workshop, IRRI, Los Banos, Laguna, Philippines, May 2,1988,17 p.

SUMANGIL, J. P.1984. The integrated pest control component of cost reducing technology for Masagana 99 in the Philippines. Paper presented at the Agritech 84 Conference, 9 September 1984. Manila, Philippines.

SUPRAKARN, C. and Tauthong. 1981. Stored products insect research in Thailand. In BIOTROP Special Bull. No. 9, "Pests of Stored Products", published by BIOTROP, Bogor, Indonesia: 77-86.

Appendix 1. List of parasites and predators positively identified in surveys conducted in

ASEAN.

Order, Common Name and Scientific Name	Country	References
ARACHNIDA		
ACARINA: (Acari-mites)		
PROSTIGMATA: (Acariformes)		
Suborder ACTINEDIDA:		
Pyemotidae:		
Pyemotes sp. (indet)	Indonesia	Haines and Pranata (1982)
Acaropsis sp.	Philippines	Sabio, et. al., (1984)
Cheyletidae:		
Cheyletus malaccensis (Oudemans)	Indonesia	Haines and Pranata (1982)
		Sabio, et. al., (1984)
Tarsonemidae		
		Sabio et.al., (1984)
Tydeidae:		
Tydeus sp.	Philippines	Sabio et.al., (1984)

MESOSTIGMATA (Parasitiformes):		
PARASITOIDEA (Gamasina):		
Ascidae:		
Blattisociuss dentriticus		
(Berlese)	Indonesia	Haines and Pranata (1982)
Blattisocius keegani Fox	Indonesia	Haines and Pranata (1982)
Blattisocius tarsalis (Ber lese)	Indonesia	Haines and Pranata (1982)
	Philippines	Haines (1981)
	Singapore	Haines (1981)
Blattisocius sp. (indet)	Philippines	Sabio, et.al., (1984)
Agistemus sp. (indet)	Philippines	Sabio, et.al., (1984)
Lasioseius sp.	Philippines	Sabio, et.al., (1984)
Subclass: PSEUDOSCORPIONES		
Cheliferidae:		
9. and sp. indet	Indonesia	Haines and Pranata (1982)
Withius subruber (Simon)	Indonesia	Haines (1981)
Subclass ARANEA (Araneae)		

fem. indet.	Indonesia	Haines and Pranata (1982)
Subclass OPILIONES: (= Phalangida)		
fem. indet.	Indonesia	Haines and Pranata (1982)
Class INSECTA:		
Order HEMIPTERA-HETEROPTERA		
Reduviidae:		
9. and sp. indet	Philippines	Sabio, et.al., (1984)
Peregeinator biannulipes		
(Montrouzier)	Indonesia	Haines and Pranata (1982)
? Vesbius sp. (indet)	Indonesia	Haines and Pranata (1982)
Lyctocoridae:		
Xylocorus? flavipes (Recter)	Indonesia	Haines and Pranata (1982)
	Philippines	Haines (1981)
HYMENOPTERA		
Braconidae:		
Bracon hebator Say	Indonesia	Haines and Pranata (1982)
	Philippines	Haines (1981)

Chalcididae:		
Euchalcidia sp. (indet)	Indonesia	Haines and Pranata (1982)
Pteromalidae:		
Anisopteromalus calandrae		
(Howard)	Indonesia	Haines and Pranata (1982)
Chaetospila elegans Westwood	Indonesia	Haines and Pranata (1982)
Dinarmus laticeps (Ashmead)	Indonesia	Haines and Pranata (1982)
BETHYLIDAE:		
Cephalonomia tarsalis (Ashmead)	Indonesia	Haines and Pranata (1982)
Cephalonomia waterstoni Gahan	Indonesia	Haines and Pranata (1982)
Holepyris hawaiiensis (Ashmead)	Indonesia	Haines and Pranata (1982)
Plastanoxus? munroi Richards	Indonesia	Haines and Pranata (1982)
Phabdepyris seae Turner &		
Waterston	Indonesia	Haines and Pranata (1982)
COLEOPTERA		
Carabidae::		

9. and sp. indet	Indonesia	Haines and Pranata (1982)
Dioryche sp.	Thailand	Suprakarn and Tauthong (1981)
Dioryche indochinensis Bates	Thailand	Suprakarn and Tauthong (1981)
Cleridae:		
Thanoclerus buqueti (Lefevre)	Indonesia	Haines and Pranata (1982)
	Thailand	Suprakarn and Tauthong (1981)
Histeridae:		
Carcinops troglodytes (Paykull)	Indonesia	Haines and Pranata (1982)

Taken from Semple, R.L.1985. Pest control in grain storage systems in the ASEAN region. ASEAN Crops Postharvest Programme Technical Paper Series No. 1, Philippines. 77 p.

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Section 5 - Introduction to general taxonomy and biology/ ecology of stored products insect pests

The classification of storase insects

INTRODUCTION

Insects would have to be considered the most successful group of animals in the world if the basis for this statement was on the immense number of species already described (1 million ea) and the population densities that can be and so often are attained. Approximately 85% of all known animal species presently existing on earth are insects and it is generally assumed that only one fifth of all insects have been classified and named, meaning overall numbers of species would be approaching 4 million!

Because insects have existed on earth ever since the Palaeozoic era (230-570 million years ago) and those resembling existing present day forms have been found in the rocks of the Permian period (230-280 million years ago), it is little wonder that due to their potential adaptation, diversification and immense numbers of different species, some have found an

ecological niche in stored grain!

The advantages of small size and short generation intervals are important in their survival, when you consider that small animals need less food and oxygen to maintain them; small animals can find more room in a given area than larger ones and can find shelter where larger animals can find none.

If we exclude casual visitors to stores and warehouses (i.e. crickets, grasshoppers and other field related pests), we find that stored products range in size from approximately 1 mm-12 mm, while the majority do not exceed 5 mm. Therefore a gap in floorboards, or any cracks on crevices in which floor sweepings become lodged, may support an insect population sufficient to give rise to serious infestation of grain stocks being received into the warehouse.

Insects are members of the superclass Hexapoda, class Insecta of the Phylum Arthropoda (Latin meaning "jointed legs") which also contains the arachnids, crustaceans, myriapods, pycnogonids merostomes, symphylans and trilobites (extinct). Insects have the following morphological characteristics as being representative of the class;

(i) invertebrate animals that have a cuticle hardened to from an external skeleton
(ii) body divided into obvious segments
(iii) three pairs of jointed segmented legs
(iv) most insects have bodies clearly divided into

- **the head, which carries the mouthparts, the eyes, and a pair of antennae**
- **the thorax, which carries the 3 pairs of legs and 2 pairs of membranous wings (in most adults), and**
- **the abdomen, which contains the digestive and reproductive organs.**

Like all animals, insects are classified into various groupings or taxa, the basic unit being the species defined as, "a group of inter breeding organisms which is reproductively isolated from other related groups." Systematic taxonomy attempts to classify animals according to either their evolutionary relationships (phylogen) or by morphological divergence (phenetic affinity). A simplified representation of the class Insecta is given in Appendix I.

The following insect orders are most commonly encountered in stored products.

a)COLEOPTERA:	Beetles-most of these are either primary or secondary pests, some are associated pests such as scavengers, fungus-feeders, structural pests or predators.
b)LEPIDOPTERA:	Moths-either primary or secondary pests, the larval stage inflicting losses.
c)HYMENOPTERA:	(i) wasps-beneficial parasites or parasitoids on beetles and moths.

	(ii) ants-usually scavengers, but occasionally pests.
d) PSOCOPTERA:	Dustlice-scavengers and pests, particularly in Southeast Asia where they sometimes occur in prolific numbers.
e) HEMIPTERA:	Bugs-some incidental pests but mostly beneficial predators on beetles and moths.
f) DIPTERA:	True flies-some invaders or incidental intruders, some are scavengers and a few are predators.
g) DERMAPTERA:	Earwigs-incidental intruders and scavengers.
h) ISOPTERA:	Termites-structural pests in warehouses of wooden construction.
i) THYSANURA:	Cockroaches-scavengers which may occasionally approach pest status.
k) ORTHOPTERA:	Grasshoppers, crickets and locusts-most are incidental field pests, but the "house cricket", Acheta domesticus Linnaeus, occasionally becomes a nuisance indoors, eating almost any kind of food or refuse.
l) SIPHONAPTERA:	Fleas-bloodsucking ectoparasites of mammals and birds. Wingless, with complete metamorphosis. 1900 species of which Pulex irritans Linnaeus and Xenopsylla cheopis Rothschild are sometimes found in granaries and warehouses.

Nearly one thousand species of insects have been associated with stored products throughout the world, of which the majority belong to the Coleoptera (60%) and Lepidoptera (8-9%).

Beetles and moths are advanced, holometabolous types of insects which have a life-cycle we describe as COMPLETE METAMORPHOSIS. This life-cycle has two very important features:

(i) Because an insect has an external skeleton that cannot grow or stretch, a growing insect has to shed its skin (external skeleton) so that it can expand its size while the new skin is still soft. The development of an insect happens in several stages, and at the end of each stage the old skin is shed (the discarded old skins are called "exuvia").

(ii) The immature insects (larvae) that develop from the eggs have evolved as rather simple stages designed for feeding and growing. They are completely different in appearance from the mature adults. Therefore at the end of the period of larval growth, the larva becomes a pupa. This pupa does not feed or move, but inside its skin the body becomes completely changed into the form of the adult. At the end of the pupal stage, the mature adult emerges from the pupal skin. The four basic stages-egg, larva (consisting of several growth stages, known as "instars"), pupa and adult are completely different in appearance.

The life-cycle of beetles and moths is summarized in the following diagram. The larvae of all beetle and moth storage pests feed on the stored food. The adults lay eggs in large numbers during their lifetime. The adults of many important beetle pests also feed on the stored

food, but the adults of some beetle pests and all moth pests are shortlived (laying many eggs very quickly) and do not feed.

Figure

Importance of the major pests in world cereal production:

Stored grain insects can be grouped according to their relative importance on a particular commodity in a particular geographic region. Species can be classified according to frequency and abundance on particular commodities, such that "major insect pests" are found frequently due to their almost cosmopolitan distribution and in large numbers. Examples are Sitophilus oryzae Linnaeus and Tribolium castaneum Herbst. "Minor insect pests" would then simply mean those species that are encountered infrequently and at relatively low population densities.

A more frequent and misunderstood classification is based on the insects capacity or ability to infest sound, undamaged kernels. On whole cereal grains, pulses and oilseeds we often distinguish between primary and secondary pests, which have the following distinguishing characteristies; primary pests are:

i. **capable of successfully attacking, feeding and multiplying on previously undamaged grains;**
ii. **are adapted to feed on a narrow range of commodities;**

iii. **usually cause very distinctive damage;**
iv. **usuall develop within the grains, and often complete their entire development within a single grain;**
v. **are selective in their egg-laying behaviour;**
vi. **often infest the ripening crop before harvest; and**
vii. **usually cannot develop on the same food if the grains are ground (milled).**

secondary pests are

i. **not capable of attacking previously undamaged grains, but can only attack and breed in grains that have been damaged by primary pests, physical damage by bad handling, threshing, drying or intentional processing that removes or damages the seedcoat.**
ii. **usually attack a very wide range of commodities;**
iii. **usually cause non-distinctive damage;**
iv. **sometimes develop within grains, but never complete their development within a single grain;**
v. **do not usually have selective egg-laying behaviour;**
vi. **are very rarely found on the crop at harvest; and**
vii. **are usually capable of developing on the same food after it is ground.**

It must be emphasized that primary pests does not necessarily mean more important, but simply the dynamic processes involved whereby secondary pests can cohabitate or follow

primary pests and inflict serious and economic losses, especially under longterm storage. Controlling primary pests can reduce the potential damage caused by secondary pests. Some pests do not fall into either specific category, whereby some secondary pests can attack whole grain if the moisture content is high, some preferentially feed on the germ while others can breed on whole grains, but do so much more rapidly on damaged grains. A more convenient and meaningful classification of the relative importance of insect pests, can be best described in relation to both losses incurred on different commodities and the absolute need to implement control strategies to prevent economic loss.

Pests of Major Importance -	Those that regularly cause significant losses of commodity or require applied control measures to prevent such losses;
Pests of Moderate Importance -	those that occasionally cause significant losses or need control measures;
Pests of Minor Importance -	those that rarely cause loss or need control but are often associated with a commodity.
Rare or Absent Pests -	those that are rarely found in or are absent from a commodity.

The percentage of maize, paddy, rice, sorghum and millet at risk to damage by insect pests are presented graphically in Appendix II.

Paddy:

Unhusked rice (paddy) is usually considered more resistant to insect attack than most other cereals. Moisture content is particularly important and field infestations of S. cerealella are the main problem. This pest is of major importance in areas yielding over 80% of paddy production. Infestations occur particularly during after harvest but do not persist in storage. The initial attack, however, allows other species such as O. surinamensis and to a lesser extent T. castaneum to become established. These species may also be prevalent as a result of husk damage or breakage of grain during harvesting or threshing, for example from combine harvesting. Where infestations of S. cerealella do persist in storage, they occur primarily in the surface layers and particularly around the edges of bulk stored paddy. Bagged paddy is less liable to attack, especially if stored in close-woven bags.

S. oryzae and R. dominica may cause serious damage in parboiled paddy and in varieties less resistant to attack particularly at comparatively high moisture contents. R. dominica predominates in the drier batches when these are left undisturbed for long periods. There is considerable confusion as to the relative roles of S. oryzae and S. zeamis. S. oryzae appears to be the dominant species in the dry areas and S. zeamais in the warm moist areas. S. zeamais, for example, is not common in the Middle East or in India where 5. oryzea is

predominant, whereas in Southeast Asia, S. zeamais is particularly abundant in milled rice and maize. The occurrene of field infestation, the greater mobility or S. zeamais, the rapid turnover a stocks in mills and the associated production of maize appear a probable combination of factors that, together with high local temperatures and humidities, would favour this. However, it has been demonstrated in Indonesia that S. oryzae appears the dominant species on paddy (Haines, 1981; Haines and Pranata, 1982).

Most other species are of little consequence except that occasional outbreaks of C. cephalonica and T. granarirm may occur.

Rice:

Milled rice is particularly susceptible to insect attack. It is used to store the grain as paddy and process or mill it as required, keeping the storage period of the processed product to a minimum.

S. oryzee is the perdominant species. It has been recorded as a major pest in areas that yield 80% of rice production. S. zeamais has not received a high rating as a pest but, as with paddy, its real importance is probably much greater than appreciated because of its being confused with 5. oryzae particularly in eastern Asia and in Central America and the Caribbean.

B. dominica has been recorded as a major pest in areas yielding approximately half of rice

production but because of the limited storage periods usually involved, this species would not be expected to cause damage of the same order as 5. oryzae. S. oryzae. C. cephalonica and T. castaneum have frequencies of occurrence similar to R.. dominica, and would be of greater significance. O. surinamensis and E. cautella must also be taken into account as significant pests though they do not occur as frequently as the species listed earlier.

Rice bran is a commodity notoriously susceptible to storage pests. It provides a serious source of infestation in many rice mills- T. castaneum is the principal species involved.

Maize:

World production of maize is of the same order as rice (considered as dehusked paddy) and not substantially less than wheat. The export trade is second only to wheat but because maize has a greater association with subsistence farming and local animal feeding, a lower proportion enters international trade. The two grains together account for approximately 80% of the world export trade in cereals.

Maize, more than any other cereal, is subject to field infestation. The only other cereals in which field infestation is problem today are the sorghums and paddy where infestations primarily concern S. cerealella attacking unthreshed grain left drying in the field after harvest. Maize, in addition to being attacked by S. cerealella, is heavily attacked when standing in the field at early stage of ripening by Sitophllus zeamais. This species may complete one or even two life cycles before harvest. Such field infestations which are often

accompanied by a complex of Nitidulidae, Lathridlidae, Mycetophagidae and sometimes in later stages species such as T. castaneum, reflect varietal varietal characteristics of the maize plant such as husk length, and their effect may be augmented, sometimes independently, by damage from birds and field crop insects such as Heliothis. The problem may be accentrated by crib drying and storing of maize cobs.

As with sorghum, varietal differences in hardness of the grain also can have a marked influence on severity attack.

Sitophilus oryzae is again the most important pest. S. Zeamais is considerably less important though its importance probably would have been somewhat not separating it from S. oryzae in some maize-producing countries where it is known to be a pest were taken into account. The pattern of occurrence of the two species conforms reasonably with what could be expected from climatic considerations-in the warmer often more humid areas, S. aramais is more important than S. oryzae (e.g. Australia, Philippines, Malaysia, Burma, Zambia, Nigeria and El Salvador), with S. zeamais becoming less important as the humidity decreases (e.g. Egypt, India and Botswana), or the temperature decreases (e.g. Argentine, Canada, Czechoslovakia), Both species appear absent in very hot areas such as in the Sudan but in most instances the lower itmperature limits for maize appear not to preclude either species being present at least as pests of minor importance. S. granarius can also be regarded as a significant pest of stored maize particularly in these cooler areas, and in storage of imported maize in countries which it cannot be grown.

S. cerealella is of comparable importance to the Sitophilus spp. As with sorghum stored on the head, maize stored on the cob is liable to reinfestation in storage increasing the potential of the species. The larger grain size and hence intergranular spaces of maize allow some movement of S. cerealella in shelled grain and thus increase the chance of reinfestation in grain bulks. This is not common with the smaller more tightly-packed grains but when it occurs infestations are usually confined to the surface and the periphery of bulks.

A list of the important primary and secondary pests for maize, as well as groundnuts, mungbeans and soyabeans is given in Table 2.

COMMODITY	CLASSIFICATION	SCIENTIFIC NAME COMMON NAME
MAIZE	Primary Pests	Sitophilus zeamais Motschulsky - Curculionidae (COL)
		"Maize Weevil"
		Sitophilus oryzae (Linnaeus) - Curcu - lionidae (COL)
		"Rice Weevil"
		Rhyzopertha dominica (Fabricus) - Bostrychidae (COL)

		"Lesser grain borer"
		Sitotroga cerealella (Oliver) - Gele - chiidae (LEP)
		"Angoumois grain moth"
	Secondary Pests	Tribolium castaneum (Herbs") - Tene - brionidae (COL)
		"rust-red flour beetle"
		Cryptolestes ferrugineus (Stephens) - Cucujidae (COL)
		"rusty grain beetle"
		Cryptolests pusillus (Schonherr) - Cucujidae (COL)
		"flat grain beetle"
		Oryzaephilus surinamensis (Linnaeus) - Silvanidae (COL)
		"saw-toothed grain beetle"
MAIZE	Secondary Pests	Oryzaephilus mercator (Fauvel) - silva- nidae (COL)

		"merchant grain beetle" Latheticus oryzae Waterhouse - Tenebrioni - dae (COL)
		"long-headed flour beetle"
		Palorus spp.
		P. ratzeburgi (Wissmann) - Tenebrionidae (COL)
		"small eyed flour bettle"
		P. subdopressus (Wollaston) - Tenebrioni dae (COL))
		"depressed flour bettle"
		Ahasverus advena (Waltl) - Silvanidae (COL)
		"foreign grain bettle"
		Carpophilus spp. - Nitidulidae (COL) "dried
		fruit beetles"
		Lasioderma serricome (Fabricus) - Ano - biidae (COL)
		"cigarette beetle"
		Lophocateres pusillus (Klug) - Trogositidae

		(COL) "Siamese grain bettle"
		Tenebroides mauritanicus (Linneaeus) - Trogositiae
		(COL) "The cadelle"
		Typhaea stercorea (Linnaeus) - Mycetopha-gidae (COL)
		"hairy fungus beetle"
		Corcyra cephalonica (Stainton) - Pyrali - dae (LEP)
		"Rice moth"
		Ephestia cautella (Walker)- Pyralidae (LEP) "Tropical
		warehouse moth" or "almond moth"
		Plodia interpunctella (Hubner)- Pyra Lidae (LEP)
		"Indian mealmoth"
		Several other minor secondary pests.
GROUNDNUTS	Primary Pests	Caryedon scrratus (Oliv) - Bruchidae (COL)

		"ground nut borer"
		T. castaneum (H)-"rust-red flour bettle"
GROUNDNUTS	Primary Pests	O. mercator (Fauv.) - "merchant grain beetle"
	Secondary Pests	O. surinamensis (c)-"saw-toothed grain beetle"
		A. advena (Walt)-"foreign grain beetle"
		Cryptotestes spp.-"flat grain beetle"
		T. mauritanicus (L)-"cadelle"
		Wechobia rufipes (Degeer) - Cleridae (COL)
		"redlegged horn beetle" or "copra beetle"
		C. cephalonica (Staint.)-"Rice moth"
		E. cautella (Walker)-"Tropical warehouse moth"
		some minor pest species
PULSES	Primary Pests	Callosobruchus analis (Fabricus) - Bru - chidae (COL)
		"cowpea weevil"
		Callosobruchus chinensis (Linnaeus)- Bruchidae

		(COL) "cowpea weevil"
		Callosobruchus maculatus (Fabricus)- Bruchidae (COL)
		"cowpea weevil"
		Acanthosselides obtectus (Say) - Bruchi - dae (COL)
		"dried bean beetle"
		Zabrotes subfasciatus (Boh)- Bruchidae (COL)
		Sitophilus oryzae (L)- "rice weevil"
		Secondary Pests L. Serricurne (Fab)-"cigarette betle"
		Stegobium panecium (Linnaeus) - Ano - biidae (COL)
		"Biscuit beetle"
		T. castaneum
		Various minor pest species.
SOYBEANS	Primary Pests	Callosobruchus spp.-"bean weevils"

	Secondary Pests	T. castaneum ((H)-"rust-red flour beetle"
		P. interpunctella (Hub)-"lndian mealmoth"
		A few minor pest species

***Source: Dr. C. P. Haines, BIOTROP, Indonesia.**
****Special pulse feeding strain-cultured on mungbeans.**

The occurrence of Sitophilus oryzae which is capable of attacking pulses has also been recorded by Pemberton and Rodriguez (1980) on carob pods from Portugal. Carobs are normally very susceptible to storage pests which predominanty attack dried fruits, since the pod contains a high sugar content. Certain strains of S. oryzae are also konwn to breed on other pulaes and legumes, such as yellow split peas (Coombs, et al., 1977).

Distribution of stored products insects In Southeast Asia:

Systematic surveys of the presence and distribution of stored products insects has not been attempted on a regional basis in the ASEAN countries. Separate surveys however have been completed on a national basis in the Philippines (Morallo-Rejesus, 1978); Indonesia (Prevett, 1975; Morallo-Rejesus and Pranata, 1978; Haines and Pranata, 1982); Thailand (Chuvit, 1976) and Malaysia (Champ and Dyte, 1976; Lim and Tan, 1978), but no data is available for Singapore.

SOURCES OF INFESTATION

A. CROSS INFESTATION

This may be defined as the infestation of one commodity by movement of insects and mites from one commodity to another. This happens when sound grains are stored side by side with infested materials or by loading both products into the same hold of a ship or the same railroad car.

B. RESIDUAL INFESTATION

Residual infestation results from attack by insects which have remained in the structure of the store, vessel or vehicle after the removal of a previously infested commodity. Grains that have collected in corners, cracks and crevices in walls, floors and ceilings of a warehouse, or in the holds of a bulk tanker or railroad vehicle support insect populations that are capable of reproducing in large numbers and infesting clean grain.

Residual infestation and the potential it creates maybe of greater significance than insects within the bulk, which can be effectively treated or processed before insect numbers develop into large populations. Once insects become established in stores or within the fabric of storage structures, they maybe extremely difficult or impossible to eradicate unless the entire building can be effectively fumigated. This would be relatively expensive and may not be practicable if a sufficient level of gastightness cannot be maintained within the

storage structure. The costeffectiveness of the treatment also may not be warranted if cross-infestation from adjacent storages (who are not prepared to carry out extensive pest control measures) cannot be prevented.

(i) Infestation arising from the use of infested containers

Bags and sacks and other repeatedly used containers are often infested by insects. Of these, jute bags are most often infested by flour beetles, warehouse moths, tropical warehouse moths or rice moths. The receival of infested stocks without inspection or the recycling used sacks that are not adequately cleaned and treated with either a fumigant or impregnated with a residual insecticide, further compound the problem and reduce the efficiency of control measures.

(ii) Intestation arising from mills

(iii) Combine harvesters, field bins, augers and transportation equipment

After use, this are usually left in the field for several months and pockets of infestation may occur inside the machinery.

(iv) Grain elevators and related conveyance machinery

C. INFESTATION BY FLIGHT AND CRAWLING OF INSECTS

Some stored grain insect pests are capable of flight and infestations are frequently initiated in this manner. All moths and many beetles move to stored products by flight. Some species also crawl into new uninfested stored products, but migration by crawling is confined within narrow limits.

Field infestations have been dramatically reduced by the adoption of combine harvesting in many Western countries. In the Southern states of the US, cereals especially corn is at risk in the field to such pests as Sitophilus zeamais, Sitotroga cerealella, Sathrobrota rileyi, Nemapogon granella, Araecerus fasciculatus and Carpophilus dimidiatus among others, the first two being the most dominant and serious.

Field activity of S. zeamais and S. cerealella has also been reported in the Southern parts of the USSR (Trisuyatkii, 1966) as well as in the Northeastern states of USA following mild winter conditions (Cotton, 1964). Both species commonly occur in maize grown in the coastal region of NSW, Australia (Greening, 1978), while Sitophilus oryzea infested 9-17% of sampled standing heads of wheat in Queensland during October and November (Rossiter, 1970).

Field infestations can be curtailed by growing corn varieties that possess tight husk characteristics, disposing of infested grain in farm storages before the corn reaches the silking stage in the field, early harvesting, application of recommended grain protectants, drying and shelling and storing corn in tight bins or containers adaptable for fumigation.

Both S. zeamais and Rhyzopertha dominica have been shown to infest sorghum in the field. Preharvest spraying with either Tetrachlorvinphos, Pirimiphosmethyl or Malathion (in order of effectiveness) during the dry or wet season harvest afforded protection is storage for 3 and 2 months, respectively, without any further post-harvest treatment (Caring and Morallo-Fejesus, 1976).

D. NATURAL SOURCE OF INFESTATION

Infestation may also arise from natural sources including nests of birds, rodents, spiders and insects.

FACTORS GOVERNING THE DEVELOPMENT OF INFESTATIONS

The likelihood of a pest infestation developing and the severity of the infestations are determined both by the location of the stored grain habitat and by the specific features of the habitat itself.

(a) Important characteristics of the stored grain 'habitat'

i) Size of the grain bulk is of critical importance. Small bulks are very much subject to the vagaries of their immediate surroundings. Other things being equal conditions tend to become more stable as the bulk grows larger-the effect of climate within a bulk is tempered and the relative importance of mass immigration and emigration declines due to the

insulating properties of bulk grain. If it is not moved or aerated, conditions in bulk will be largely governed by the temperature and moisture content of the grain when it was placed in storage.

ii) Shelter offered -masses of grain kept in tightly sealed containers are less subject to the vagaries of climate and less susceptible to mass invasions by biological agents (or to mass exports of the same).

iii) Climate- local conditions of temperature and moisture have the profoundest influence on the susceptibility of grain to infestation and the course of events in these infestations. Generally pest control is much more difficult and grain deteriorates more rapidly in warmer-moisture areas than in drier cooler regions. But as pointed out in (i) and (ii) the effects of climate may be greatly altered both by the size of the bulk and the degree of shelter offered by the particular habitat.

iv) The duration of stay of the grain- if the grain only stays a very short time in the habitat, then organisms infesting the grain will be subject to considerable disturbance and the dynamics of infestation will be greatly altered. While ephemeral habitats may serve as sites for initiating infestation they are not places where pest numbers increase to any extent; rather these are often places which test the survival capacity of the pest. It is only in undisturbed sites, preferably sheltered and preferably with at least modest quantities of grain that infestations can develop to damaging levels.

v) Proximity of sources of infestation. Some habitats such as poorly-cleaned storages may have adjacent sites harbouring numerous pests which can quickly invade incoming grain. Other habitats may be far from any such reservoirs and hence, other things being equal, should present less difficulty from a control point of view.

(b) Important ecological characteristics of storage insects

i) In the protected environment of grain, insect mortality is low in the immature stage. As a result, their capacity for increase is great.

ii) As the temperature inside stores is usually higher and more stable than the external environment, the effective temperature is more conducive for the development of storage pests than for field pests. Furthermore, many of stored product pests have originated from tropical or sub-tropical regions, thus they are capable of reproducing continuously throughout the year.

iii) Stored grains are usually hard and are relatively dry (as food for pests grains are usually stored at between 9 and 14% m.c., depending on the type of grain, whereas growing plants are at about 90% m.c.). The important pests are adapted to feed on hard food and to survive on a very low water content in their diet. They are quite sensitive to grain moisture content and equilibrium relative humidity.

Both (ii) and (iii) are optimized in the humid tropics for the rapid development of stored

grain pests, i.c. temperatures between 27 and 32C and equilibrium relative humidities between 70 and 75%. As a result storage insects are able to develop at more-or-less the same rate throughout the year. Most of the important pests have generation times of between 3 and 6 weeks on most products in tropical stores, i.e. between 8 and 16 generations per year.

iv) Insects that are small in size are extremely suitable for living in stockpiles of grain. Light affects different species, and different stages of development, although they commonly prefer darkness. There are many of the adult species that have already lost their flying ability.

v) The movement of infested parcels of grain and grain products in international trade has provided an effective means of ensuring the widest possible geographic spread of storage pests since cereals were first harvested. The continued introduction of the major pest species into climates outside their normal distribution, ensures also that all these species may be found in all parts of the world.

Because of the bulk and relatively low value of cereals, international transport is almost exclusively by sea although rail and road transport may become significant in limited areas. The infestation which occur in ships originate either in the commodity before loading or from cross-infestation from residues of previous cargoes or other infested cargoes being carried. It is often difficult, however, to determine the precise origin of particular

infestations.

DYNAMICS OF THE GRAIN COMMUNITY

Clearly the amount of damage done to a bulk of grain is dependent upon the number and kind of pests present in the grain and the time available for these organisms to do the damage. Accordingly it is not unreasonable to center one's understanding of the events in grain around the population dynamics of the pest.

An insect population in bulk grain experiences a certain rate of population growth (or decline as the case may be) and the population acquires a particular structure. Different stages of insect may be more damaging to grain than others. Growth rate and composition are products of factors influencing survivorship of adult and developmental stages, rate of development to maturity and the egg laying schedules to females. The insect population is influenced both by its environment-physical and biological conditions in its surroundings-and by its own size and composition. Depending on the species, insects may feed on whole grains, frass from other insects, fungi, grain particles and dust or other insects. In addition, the metabolic heat of insects and the water released by them encourages their own growth and that of other pests (mites, fungi and other insects). The chain of cause and effect is complete when insects influence the very factors which had affected their population growth.

The dynamic processes associated with the growth and development of stored grain insects

is summarized in Table 3.

Table 3. Processes associated with various developmental stages of an insect population infesting stored grain. The operation of each process is influenced by environmental conditions and the effect of each process is to change conditions In the bulk as It alters the size and composition of the Insect population

Influence of abiotic environmental factors on pests of stored grain

(a) Temperature

Below a certain minimum threshold temperature insects do not complete development from egg to maturity and the pest population cannot increase. At temperatures only slightly above their threshold, say within 4-5C, mortality rates are extremely high for virtually all stages of development. Most species do not multiply fast enough to become a pest until temperature is somewhere between 3-6C above the minimum threshold for development.

The highest rate of oviposition usually occurs at a temperature about or just below the developmental optimum. Temperature has a profound impact on insect and mite locomotion, the net effect being that insects tend to move out of areas where temperature is unfavourable and relocate in more favourable zones.

Temperature effects on a pest is not always direct. Different members of the ecosystem have different temperature optima, hence temperature influences processes such as competition, predation and ecological succession. Temperature is also the main variable determining the rate of population growth, insect activity, the liberation of heat and moisture and the production of frass and other waste products which lead to grain deterioration.

The effects of temperature are graphically illustrated in Fig. 1, using Tribolium castaneum (Herbst) as the example.

In general, the higher the temperature, the shorter the developmental period. The most favorable temperature for development and reproduction is about 28C. Below 21C and above 35C reproduction almost ceases. Developmental period from egg to adult becomes longer and the number of eggs laid fewer, at lower temperatures. At higher temperature, the life cycle becomes shorter while the oviposition rate increases. Rice weevils, for insxance, complete their life cycle in 25 days at 30C while they take about 94 days at 18C. Most insects grow more quickly at 2932C

At a temperature over 34C, insects usually cannot develop. Lesser grain borers and Khapra beetles will however continue to develop at 34C and 40C, respectively.

The lower temperature limit for insect development depends on the species. It is 14-15C for the rice weevil while it is 18-19C for the rust-red flour beetle. These limits are the most important factor affecting the geographical distribution of stored insect species.

(b) Moisture

Different developmental stages of insects, mites and fungi have different susceptibilities to aridity or excessive moisture. Generally the dormant stages-eggs and pupae for insects, eggs and resting stages of mites, and spores of fungi can best resist desiccation while active feeding stages may die out if conditions are too dry. Tolerance depends on the species-some insects may increase even at a R.H. of 10-30%, while miters and other insects require at least 65% R.H. and fungi at least 70% R.H. (Ideal range for reproduction and development in storage insects in 65-80% R.H.).

Insects depend primarily on their food supply for moisture to carry on their life processes. Stored product insects can develop on food with moisture content as low as 2 to 14%. Moisture requirements vary with species. Generally, optimum grain moisture for development and reproduction is 14-18%. Most species do not develop below 10% m.c.; some exceptions are the Mediterranean flour moth and Khapra beetle can develop on food with negligible moisture content (down to 2%), weevils cannot live on grain containing moisture of less than 10% and lesser grain borers can subsist on grain with 9% moisture content while the confused flour beetles can live on 2% moisture grain.

Moisture and temperature interact to provide conditions favorable for multiplication and survival of stored product insects. As temperature is increased, insects are able to reproduce in grain of lower MC and when moisture is increased, they can multiply at lower

temperatures.

(c) Gas concentrations

Metabolic activities of grain, but to a much greater extent of mites, insects and especially fungi may cause local reduction in the concentration of oxygen and increases in carbon dioxide. As grain settles, intergranular passageways become constricted or even blocked if dust or grain particles are present. Low levels of oxygen and high levels of carbon dioxide cause metabolic stress on insects, mites and aerobic microorganisms generally increasing mortality while lowering fecundity and rates of development. If oxygen should drop below 2.5% conditions become lethal for insects, but fungi can survive with levels lower than 1 % O2.

Figure 1. The influence of temperature on the rate of development of stored product insects, exemplified here by the flour beetle Tribulium castareum (Herbst). Shaded zones allow survival but are either too cool (left portion) or too warm (right portion) to allow rapid population growth.

Source: ADAB International Training Course on the Preservation of Stored Cereals, Selected Reference Papers, Part I (1975).

Table 4. Lower limits of relative humidity, temperature, optimal range of temperatures and

degree of hardiness of pests of stored grain, together with estimate of maximum rate of increase per lunar month

Insect	Min. Rel. Humidity %	Min. Temp. C	Opt. Temp. C	Maximum Rate of Increase +
Acarus siro	65	7	21-27	2,500
Ephestia kuehniella	1	10	24-27	50
Ephestia elutella	30	10	25	15
Ptinus tectus	50	10	23-25	4
Endrosis sarcitrella	80	10	24-26	30
H.pseudospretella	80	13	24-26	2
Sitophilus granarius	50	15	26-30	15
Sitotroga cerealella	30	16	26-30	50
Gnathocerus cornutus	40	16	24-30	15
Stegobium paniceum	60	14	25-28	7.5
Sitophilus oryzae	60	17	27-31	25
Ephestia cautella	25	17	28-32	50

Plodia interpunctella	40	18	28-32	30
Corycra cephalonica	30	18	28-32	10
Dermestes masculatus	30	20	30-25	30
Oryzaephillus mercator	10	20	31-34	20
Cryptolestes turcicus	50	21	30-33	50
Oryzaephilus surinamensis	10	21	31-34	50
Tribolium confusum	1	21	30-33	60
Lasioderma serricorne	30	22	32-35	20
Necrobia rufipes	50	22	30-34	25
Tribolium castaneum	1	22	32-35	70
Cryptolestes ferrugineus	10	23	32-35	60
Trogoderma granarium	1	24	33-37	12.5

*** Minimum temperature at which epidemic increases may occur, i.e.3-5C above the development minimum.**

+ Maximum rate of increase for stable age population per lunar month.

Source: Howe (1965).

Influence of biotic environmental factors on pests of stored grain

(a) Food:

Grain itself is just one of several resources used by pests for nourishment-in addition they may feed on damaged grains, grain particles and dust, fragments of insects and mites, including frass and cast skins, dead and living arthropods and fungi. Thus, fungus beetles and certain moths show marked preference for mouldy grains or frass from other insects; certain mites make their living by feeding on other mites, and flour beetles supplement their diet by feeding on the dormant stages of their own and other species.

Stored grains are an ideal food source for stored product insect pests, providing the essential elements required for continued growth and development. Levels of carbohydrates, proteins, fats and vitamins required varies with the species concerned. The Indian meal moth, warehouse moth, Mediterranean flour moth, and saw-toothed grain beetle cannot live in artificial diet containing carbohydrates of less than 20%, while the confused flour beetle and cigarette beetle can live on foodstuff with less than 2% carbohydrates.

The saw-toothed grain beetle can grow with 2-3% protein of artificial diet and hide beetles need at least 20% protein. Insects need 10 kinds of essential amino acids: arginine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, trytophan and saline.

Some Insects utilize fats in food materials as their source of energy, and some, such as the warehouse moths and tropical house moths, fats are indispensable. Their adults will partially or completely lack scales on their wings or fail to emerge from pupae if fats are not available.

Most of the vitamin B group such as thiamine (B.), riboflavin (B2), pyridoxine (B6), nicotinic acid, patothenic acid, biotin, folic acid, and choline are indispensable to all insects.

However, the saw-toothed grain beetle, drugstore beetle and cigarette beetle can live on food materials without some B group vitamins, not because they can dispense with these vitamins, but because they have in their bodies some intercellular symbiotic microorganisms which are able to synthesize and supply such vitamins. Vitamins A and C are not required by any of the stored products insects.

(b) Competition

At low and moderate population densities members of a given species will improve conditions for their fellows. Initial attacks on hard grains may make things easier for the next, while heat and moisture released by metabolic activity may push temperature and moisture into more favourable zones or at least encourage the growth of other species. Beyond optimal population densities, the scramble for food, for mates and for oviposition sites enhances mortality, lowers rates of development and leads to lower fecundity.

Members of various species residing in stored grain have considerable influence on the welfare of other consumer species. Thus as a larva Tribolium castaneum, the fulur beetle benefits from encounters with eggs of say Ephestia cautella the moth, which it feeds on, but as an adult the beetle may get injured by a larval moth. Insects and mites may lower the fecundity of the other species simply by mechanical disturbance-jostling-or by releasing noxious chemicals. Feeding and release heat, water, and waste by some consumers may pave the way for succession by other consumers, or species may engage in a scramble for resources causing such depletion that other consumers die out or are forced to leave the locality.

The competition for food is more severe between species which have the same nutritional and ecological requirements. Parasites (mostly hymenopterous) and predators have, to some extent, helped in reducing insect populations. Some insects such as Tribolium spp. or flour beetles exhibit cannibalism.

TYPES OF DAMAGE

A. Direct damage

1. Reduction or loss in weight:

The direct feeding of insect pest on stored grains results in food and weight losses. A rice weevil will eat 14 milligrams of a rice kernel weighing about 20 milligrams during its

developmental period from egg to adult. However, this results in the commercial loss of the whole rice kernel.

Weevils, which feed mainly on the carbohydrate portion of a maize, remove a considerable amount of the calorie potential but little of the protein and vitamins which are mainly in the germ and bran. In legumes, in which the protein and vitamins are more evenly distributed throughout the grain, infestation of beetles, which can be responsible for consuming up to 50% of peas and beans of which some 25% of the dry matter is crude protein, can cause a loss of about 12% of the available protein.

2. Reduction or loss of seed viability:

A seed grain which has been attacked by a germ feeder will not germinate. Examples are Triblim spp., Cryptolestes spp., Tenebroides mauritanieus, Ephestia spp.

B. Indirect damage

1. Quality loss

a) Nutrient loss. When grains are attacked by insect species which feed selectively on the germ leaving the endosperm almost untouched, food loss is not apparent; weight loss is also small compared to loss of loss of vitamins, proteins, etc.

b) Heating and spotlage. Heating from insect infestation accelerates further infection by microflora and bacteria. This results in spoilage of grain which often causes more serious economic damage than loss in weight by insect consumption.

c) Contamination, tainting or discoloration. Contamination and tainting of foodstuffs with frass materials such as insect fragments, excrete, secretions, webbings and dusts also contributes to a deterioration in quality. Insect secretions or entomoxins, such as quinone, may also prove to be serious contaminants.

d) Production of off-flavors and odors. Cereal, after prolonged storage, but particularly when ground into a meal or flour or when infested by insects, show an increase in free-fatty acid content (FFA). If, prior to milling, the maize has been attacked by adults of Tribolium castaneum, the initial faa of the resultant meal is much higher than that of uninfested meal, and the FFA rises to a much higher level.

2. Monetary loss

Financial losses are not simply in terms of that lost in reduction in weight, but also the downgrading or absolute rejection through the presence of live insects or signs of their activity. The cost of any applied control measures, as well as all the agricultural inputs invested in growing the grain, become important "hidden'' costs if grain is consumed or destroyed by insects before reaching the consumer.

3. Loss of goodwill

A country loses its goodwill and earns a bad reputation if its produce are of low quality, insectinfested and contaminated by toxins, insect, excrete, etc.

STRATEGY FOR SURVIVAL

Successful storage pest insects have adopted strategies that can be summarized as being opportunist. By a variety of biological mechanisms, all these species are capable of very rapid population growth when they invade a batch of grain in a suitable condition. Most pest species have potential rates of increase of between 20 and 60 times per month under optimum conditions (See Table 4). We should consider what this means by thinking about a pest with a 40-times-permonth rate of increase: One gravid female invading the grain can lead to 40 individuals after one month, 1600 individuals after two months, 64,000 after three months, 2,560,000 after four months.

Fortunately, at some point in the development of the population, natural or artificial (pest control) factors operate to control the increase. If pest control is not applied, the commonest natural limiting factor is competition for available food while other forms of competition or disturbance, presence of fungal growth and mycotoxins, parasites, predators and pathogens, pheromones and defensive secretions from other species, and cannibalism become contributory factors in suppressing insect populations.

Levels of temperature and moisture liberated by the development of an insect population often becomes excessive for the survival of the pests, eventually forcing the insects to relocate themselves elsewhere, thus increasing the hotspot to a point where adults can only survive in the superficial layers or on the surface. The very success of a species or species complex within a population may very well form the basis for its own extinction.

As well as being opportunists in taking advantage of abundant food placed in a store, most major pest species also have a survival strategy for the time when the food is removed. in many cases, this involves the establishment of small residual populations which immediately have the potential to infest a new batch of grain entering the store. Another survival strategy found in many primary pests is their ability to disperse to ripening grain in the field. Finally, many species rely on human distribution and transportation to implant them in another storage locality. The use of second hand untreated sacks helps promulgate and distribute major storage pests, and is perhaps one of the major causes of cross-infestation.

As mentioned previously, storage insects have become adapted to surviving in a low moisture ensvironment relative to their field pest counterparts. Any significant changes in temperature and relative humidity (which are functions of the equilibrium moisture content of different grains) will have a critical effect on the rate and development of insects, as well as the composition or species complex constituting a pest population.

It must be emphasized that the accepted level or "safe moisture content" to which grain

should be dried does not prevent attack by insect pests, and in fact a relative humidity of 70% is well within the tolerance of most major pest species. Oftentimes in the humid tropics, grain possesses a moisture content somewhere within the 70-75% e.r.h. range. At the higher levels, the development of storage fungi is delayed, but has the deleterious effect that many major insect pests develop much more rapidly and many minor insect pests that are inhibited at 70% r.h. attain pest status.

If grain is not fully dried to the safe moisture levels, then

i) the slightly softer grain allows attack by many pests that initially cannot develop on sound, undamaged kernels.

ii) higher humidity becomes more favourable to a wider range of pests, and

iii) presence of slight but significant fungal growth allows rapid increase of certain pests that require a certain proportion of fungus in their diet. Finally, it should be noted that drying must be uniform throughout a batch of grain. The presence of a few grains that are not fully dried can allow the rapid development of some insects consequently producing more moisture, and allowing the development of pests in grains that were originally dry but have absorbed the extra moisture. The infestation ''hotspot" can thus expand from a very small volume and become a serious problem throughout the entire batch of grain unless some measure of control is implemented to reduce the population and disperse increased moisture.

REFERENCES

CARINO, F. O. and B. MORALLO-REJESUS. (1976). Control of Sitophilus zeamais and Rhyzopertha dominica by pre-harvest sprays and sack treatment with three insecticides in three sorghum varieties. Phil. Agric. Vol. 60 (1976) 3 and 4, AugSept 81-95.

CHAMP, B. R. and C. B. DYTE. (1976). Report of the FAO global survey of pesticide susceptibility of stored grain pests. FAO Plant Protection Series, No. 5. Rome, 1976.

COOMBS, C. W., C. J. BILLINGS and J. E. PORTER. (1977). The effect of yellow split peas (Pisum sativum L.) and other pulses on the productivity of certain strains of Sitophilus oryzae (L) and the ability of other strains to breed thereon. J. Stored Prod. Res. 13, 53-58.

COTTON, R. T. (1964). Controlling the Angoumois grain moth. Northwest Miller 271, 19-23.

DAVEY, P. M. (1965). Insect pests of stored products in the tropics and the commodities and conditions in which they occur TSPI (N) 377-386.

GREENING, H. G. (1979). Observations on the occurrence of insect pests of stored grain in New South Wales, Australia, Cont. to the Symposium on Protection of Grain Against Insect Damage. Moscow, 1978. CSIRO Div. of Ent. by D. E. Evans.

HAINES, C. P. and R. l. PRANATA. (1982). Results of a survey of the insects and arachnids

associated with stored products in some parts of Java. Paper presented at the Reg. Grains Post-Harvest Workshop Jan. 19-21, Chiang Mai, Thailand (Proc. in press).

HAINES, C. P. (1981). Paddy losses to insects: notes on selected problems of insect ecology, damage, inspection, loss assessment and varietal susceptibility. Paper presented at GASGA Seminar on "Paddy Deterioration in the Humid Tropics" Oct. 11-17,1981. Bagulo, Philippines (Proc. in press).

HOWE, R. W. (1965). A summary of estimates of optimal and mininal conditions for population increases of smoe stored products insects. J. Stored Prod. Res. 1:177-184.

KOHLMEYER, R. W. (1981). The agricultural market place of the 1980's.

MORALLO-REJESUS, B. (1978). Stored grain pest problems and research needs in Southeast Asia. SEARCA professorial lecture in Entomology, July 21, 1978. 41 pp.

PEMBERION, G. W. and A. DE RODRIGUEZ. (1980). The occurrence of a strain of Sitophilus oryzae (L.) (Coleoptera: Curculionidae) breeding in Portuguese kibbled carobs. J. Stored Prod. Res. Vol. 17, pp. 37-38.

ROSSITER, P. D. (1970). Field infestation of the rice weevil in wheat. QLD J. Agric. Anim. Sci. 27, 119-121.

TRISVYATSKII, L.A. (1966). English translation by D.M. Krane. Vol. 1-3 Nat. Lending Lib. Sci. Tech. England, 1969.

FURTHER READING

Setected Reference Papers (Part I) of the International Training Course in Preservation of Stored Cereals. Office of the Australian Development Assistance Bureau, Canberra, Australia.

"Stored Grain Insects", USDA Agricultural Research Service Handbook, No. 500.

"Common Insect Pests of Stored Food Products - A Guide to their Identification", Edited by Paul Freeman, Brit. Museum (Nat. Hist.) Econ. Series No. 15.

"Pests of Stored Products", by J. W. Monro. and "Pest Control in Buildings" (a guide to the meaning of terms) by P. B. Cornwell, Rentokil Library Series.

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

The biology of some important primary, secondary and associated species of stored products coleoptera

Contents - Previous - Next

INTRODUCTION

The beetles comprise the largest natural order in the Animal Kingdom with a total of no less than 250,000 described species, of which more than 600 have been associated with stored food products throughout the world. Some, through the agency and dispersal by man in international trade have attained cosmopolitan distribution and constitute the major cereal pests that attack stored cereals and grain legumes.

Ever since man began storing food reserves in granaries during biblical times, various beetle species have become established pests and have continued till the present day as one of the most profound causes of grain loss in storage. Adults of the "cigarette beetle", "humpbacked spider beetle" and "weevils" were discovered in 1390 BC from the tombs of Tutankhamen, and no doubt the association of stored grain beetles with man extends even further back during the neolithic phase of human prehistory (earliest records are of flour beetles in an Egyptian tomb dating back to 2500 BC).

CHARACTERISTICS OF THE ORDER

Small to large insects, forewings modified to form horny wingcovers or elytra, which meet along a straight mid-dorsal line. The hind wings are membranous, folded away beneath the elytra, some times reduced or even absent in Sitophilus granarius. The mouthparts are adapted for biting and chewing. The prothorax is larger and more developed than the other thoracic segments extending dorsally as a single shield called the pronotum. Metamorphosis is complete, i.e. egg to larva to pupa to adult. The larvae, have well developed heads and mouthparts and are of three main types (a) campodeiform; elongate and active with well developed antennae and mouthparts, often carnivores e.g. Carabidae, Staphylinidae (b) scarabaeiform; crescentic, bulkier and less active, usually herbivores e.g. Anobiidae, Bruchidae and (c) apodous scarabaeiform; grub-like, with reduced antennae and mouthparts which live within the food source e.g. Curculionidae. The pupae of Coleoptera are mostly exarate but some are found within earthen cells and a few within cocoons (pharate) formed within the cast skin of the final larval instar. They are morphologically diverse and have invaded land, air and aquatic habitats with great success. Their hard cuticle is of particular value in surviving both biological and physical hardships as well as their ability to enter into facultative diapause under adverse conditions. Many are important to man as pests of growing crops, timber, skins and hides, textiles, furniture, structures and of stored foods and drugs. Some others, such as blister beetles (Meloidae) are directly injurious to mankind by their toxic secretions.

A diagrammatic representation of a typical beetle adult and the various larval forms is given in Figures 1 and 2.

The classification of stored products insects has been described elsewhere, especially with reference to primary and secondary grain pests. It has been established that Rhyzopertha dominica

Fig. 1. (A) Dorsal view of a beetle. (B) Ventral abdominal view of a Carabid beetle. Diagrammatic. After Hinton and Corbeth (1972)

Fig. 2. Three forms of insect larvae; (A) campodeiform; (B) scarabaeiform; (C) legless or apodous scarabaeiform; (D) cruciform. After Monro, J.W. "Pests of Stored Products."

(F) cannot penetrate sound paddy husks in the early larval stages, but gains access through the presence of minute cracks. Species such as R. dominica and Trogoderma granarium Everts can be considered intermediate between the two classifications, since only the late instars can penetrate undamaged grains (Evans, 1975). It also appears that both Sitophilus oryzae (L.) and Sitophilus zeamais Motschulsky are also not true primary pests of paddy due to the female's inability to penetrate sound husks, and since feeding is directly related to oviposition, egg-laying is inhibited unless some physical defect exists. However, these defects are apparently not uncommon an observation based simply on the frequency of occurrence of weevil infestations in paddy, especially after further husk damage has been inflicted by the feeding activity of the lesser grain borer or Sitotroga cerealella Oliver, the Angoumois grain moth.

Very little attention has been focussed on some secondary pests such as Lophocateres

pusillus (Klug) and Cryptolestes spp (especially C. pusillus (Schon.) and C. ferrugineus (Stephens)), which are commonly found in moderate to large numbers on paddy in the humid tropics, sometimes even outnumbering the acknowledged primary pests. They are often assumed to cause little damage but it would seem apparent that such large and abundant populations maybe utilizing whole paddy, since the early instar larvae of these beetles would be certainly capable of gaining entry through defects necessary for the entrance of R. dominica.

Once husk and kernel damage has been initiated by the primary grain feeders, the extent of damage caused by these and other secondary pests of milled rice would be quite significant, especially in longterm storage.

The physical condition of a grain mass, its temperature and moisture content considerably affects its suitability as a habitat for a given species because each has its own particular temperature and humidity limits and optima. The activities of pests such as S. oryzae and R. dominica often change the temperature and moisture content of bulk grain causing heating and moisture migration and thereby initiating a succession of consumers within the storage ecosystem resulting in grain deterioration.

The major coleopteran families that we are concerned with in stored products entomology are listed in Table 1 (in alphabetical order).

MAJOR STORED PRODUCTS BEETLE FAMILIES

1. ANOBIIDAE

Adults are small, subcylindrical (wood boring) oval or nearly globular (general feeders) with the prothorax more or less covering the deflexed head. The stored products members of the family have 11-segmented antennae with a loose 3-segmented serrate club. The elytra completely cover the abdomen and there are 5 visible abdominal sternites. All tarsi are 5segmented with segments 1-4 decreasing in length.

A family which are damaging to wood i.e., Anobium puncatatum, the furniture beetle, and Xestobium rufillosum, the death watch beetle. The family is related to the Bostrychidae and the Ptinidae and although cosmopolitan, is best represented in temperate regions. The larvae are scarabaeiform, fleshy and have enlarged terminal segments; and can be disinguished from allied members of Ptinidae by possessing minute spinules on some of the folds of the thorax and abdomen. Two species Lasioderma serricorne and Stegobium paniceum are of importance as stored product pests.

(a) Lasioderma serricorne (F.). The tobacco or cigarette beetle.

Small (2-2.5 mm), oval, brown or dark brown beetle. Antennae serrate throughout; absence of line of punctures or striae on the elytra and lack of spinules on abdominal larval segments distinguish if from other anoblids infesting stored products.

The eggs are laid singly in crevices of folds in the substrate. The fleshy larvae, which are

distinctly hairy, pass through four instars. Newly hatched larvae cannot attack undamaged grain but enter small holes in search of food thus gaining entry to packaged goods such as cigarettes. The larvae pupate, when mature, within a rather flimsy cell amongst the substrate of within a grain or bean. The adult, lives only about 25 days producing some 100 eggs at 30C and 70% R.H.

Table 1. Major coleopteran families.

FAMILY	COMMON NAME	NUMBER OF DESCRIBED SPECIES		
		TOTAL (WORLD)	STORED PRODUCT	
Anoblidae*	Furniture, tobacco			
	and biscuit			
	beetles	1000	15	(2)
Anthicidae	Incidental pests	1800	2	
Anthribidae	Coffee bean borers	2400	1	
Bostrychidae*	Wood borers	434		(3)
Bruchidae	Bean weevils	1200		(11)
Carabidae	Ground beetles			
	(predatory)	25000	(4)	

Cleridae	Chequered beetles			
	(mainly predatory)	3400	10	(4)
Colydiidae	Incidental pests:			
	biology unknown	1400	3	
Cryptophagidae	Fungus beetles	800	25	
Cucujidae*	Flat grain beetles	500	15	(4)
Curculionidae*	"Weevils"	60000	30	(4)
Dermestidae*	Hide and Leather			
	beetles	600	55	(13)
Histeridae	Carrion feeders	2500		(1)
Languriidae	Mexican grain beetle	400		(i)
Lathridiiae	Plaster beetles	520	35	(7)
Mycetophagidae	Fungus beetles	200	5	(2)
Nitidulidae	Sap feeding beetles	2000	16	(4)
Ptinidae	Spider beetles	500	24	(8)
Silvanidae*	Secondary grain			
	feeders	400	15	(4)

Staphylinidae	Rove or cocktail			
	beetles; Biology variable	27000		
Tenebrionidae	Darkling beetles	15000	100	(14)
Trogossitidae	Secondary grain			
	feeders (germ)	600		(2)
(Ostomatidae)	Some predatory			

*** Represents major stored products pests families. Numbers in parenthesis are the more commonly encountered species.**

When humidity is not limiting the life-cycle can be completed in the range of 20C to 37.5C although the optimum is about 32.5C. High humidities retard development and increase mortality as do humidities lower than about 70% R.H.

By day, the adult beetle shuns light, hiding in crevices, but flies readily at dusk in warm conditions and is attracted to artificial light.

L. serricorne attacks an extremely wide range of stored products throughout the tropics and subtropics and is particularly damaging to tobacco, cigars, cigarettes, cocoa-beans, spices and various seeds such as coriander and caraway, cereals and cereal products.

(b) Stegobium paniceum (L.). The drugstore beetle

Small (2-3.5 mm), cylindrical, light brown beetle which resembles L. Serricome but whose last three anthennal segments are very long and elytra striated.

The life-cycle is similar to L. serricorne: the egg is followed by 4-6 larval instars, the last of which constructs a cocoon within which it pupates. After eclosion, the adult remains in the cocoon for several days before emerging and does not feed. At 20-25C and 60-80% R.H., each female lays about 75 eggs and has a life-span of about 40-90 days.

The life-cycle can be completed over 15-34C, development taking 40 days at about 30C and 60-90% R.H. At 20C development takes about 100 days at 90% R.H. and 130 days at 60% R.H.

The adult cannot fly and dispersal therefore depends on passive distribution during the movement of goods. S. paniceum is cold-hardy and can survive winter conditions in temperate regions.

S. paniceum is a cosmopolitan pest of more temperate than tropical climates infesting almost any dry animal or plant products, particularly in pharmacies where it eats drugs and in premises where it attacks breakfast foods, biscuits, etc.

2 ANTHRIBIDAE

(i) General characters

Adults infesting or associated with stored products resemble Bruchid bean weevils. The antennae are 11-segmented, thread like or filiform with a loose 3segmented club, rarely with a compact club. All tarsi are 5-segmented (the fourth segment being minute and more or less completely sealed in a dorsal groove (or apical emargination) of the third segment which is nearly always broadly dilated. Mostly of tropical distribution, associated generally with old wood dead branches and fungi.

(a) Araecerus fasctculatus (Degeer). The coffee bean weevil.

Small (2.5-4 mm), dark brown pubescence.

The eggs are laid within the endosperm. The larva is spodous scarabaeiform similar to Sitophilus. In maize of highs moisture content, the female lays about 80 eggs in a life-span of some 60 days.

The optimum range for development is 28-32C but the speed of development and mortality are much influenced by the moisture content of the grain. Thus, at 27C and 80% R.H. the life-cycle is completed in 43 days in maize and 66 days in cocoa. The lower limits for development are about 20C and 60% R.H.

A. fasciculatus, which is now more or less cosmopolitan, especially in the tropics where it

attacks a wide range of stored commodities, such as coffee and cocoa beans, nutmegs, ginger, maize and dried fruit, particularly when such produce is not properly dried. It will also attack the fallen fruits of the custard apple, bananas and cotton balls.

It is a strong flier and is frequently seen in cornfields in Southern USA on exposed and damaged ears. It lays eggs in the soft kernels and continues to breed after the corn has been harvested and placed in storage. However, it is considered a minor pest since it does not cause significant damage once the corn becomes too hard to be attractive. In the humid tropics, it is considered a major pest of cassava, attacking whole tubers and chips while they are still being dried.

3. BOSTRYCHIDAE

(i) General characters

Prothorax coarsely tuberculate and concealing the deflexed head. Antennae terminate in a loose 3segmented club.

A cosmoplitan family of mainly wood-boring beetles which, particularly in the tropics and subtropics, attack felled timber or dry wood and, occasionally, unhealthy trees.

Besides Rhizopertha dominica, only Prostephanus truncatus (Horn), the larger grain-borer, which attacks corn, grain and tubers in the Southern states of USA, central and south

America and Dinoderus minutus (F.), the bamboo borer, which attacks bamboo, grain, flour, tobacco and spices in the tropics and warm temperate areas are of any significance as pests of stored products.

P. truncatus previously regarded as having a restricted distribution to the Americas, has now been recorded in Africa, in the Tabora region of Tanzania and has now spread to Neighbouring

Tribolium castaneum (Herbst) The rust-red flour beatle

Rhyzopertha dominica (Fabricus) The lesser grain borer

Sitophilus oryzae (L.) The rice weevil

Acanthosselides obtectus (Say) Dried bean weevil

Cryptolestes pusillus (Schonherr) The flat grain beetle

Tenebroides mauritanicus (L.) The cadelle

Lasioderma sericorne (F.) The tobacco or cigarette beetle

Oryzaephilus surinamensis (L.) "The saw-toothed grain beatle"

Guinea, Togo, Kenya, Burundi, Benin and Ghana. The "greater grain borer" or "Scania beetle", is capable of boring through the husk sheath of maize, and losses reported in 3-6 months storage were 10% and sometimes as high as 30% in sample that had a moisture content of only 11% m.c.

Rhyzopertha dominica (F.). The lesser grainborer.

Small (2.5-3 mm) dark brown cylindrical beetle with head concealed by thorax which has many small tubercles. The elytra have clear rows of regular punctures.

The female lays her eggs in clusters on the grain in cracks and crevices or singly amongst the grain dust and frass produced by the adults. The newly hatched, white, cylindrical larva, may enter the grain directly or feed amongst the dust until it reaches the third of the four larval instar when it usually enters grain and eventually pupates. More than one larvae may be found within a single grain. Adults live for 2-3 months and females produce 200 to 400 eggs depending on conditions. Under optimum conditions of population density, temperature, moisture and presence of damaged and cracked grains, the adults can survive almost 5 months and produce approximately 600 eggs. The adults feeds voraciously, leaving characteristic holes with ragged edges in the grain, and produces floury dust and frass.

The life-cycle can be completed over 20-38C, although the optimum is between 32C and 35C. Development is completed in 25 days at 34C and 84 days at 22C (both at 70C R.H.) and ceases below 18C. Moisture levels have a considerable influence on the biology of the pest,

where few eggs are laid in grain of less than 8% moisture content although, in contrast to grain weevils, oviposition is little inhibited until moisture content is less than 9%.

The adults are strong fliers and move freely from one store to another. Within a grain mass the species disperses rather slowly but is generally found in the driest part of the grain mass.

R. dominica is particularly well adapted to breeding in warm dry climates and is of particular importance in countries such as Australia and India. It is most important in wheat, rice, paddy, millet and of lesser importance in sorghum and is known from other cereals such as maize. Of little importance in milled products.

4. BRUCHIDAE

(a) General characters

Adults are small,- strongly convex beetles, densely clothed in hairs which are usually coloured and form distinctive patterns (generally variable and cannot be used for species differentiation). The last abdominal segment is large, more or less vertically inclined, and conspicuous beyond the shortened elytra. The eyes are large, and with exception of the genus Caryedon, the eyes are u-shaped or emarginate. The antennae are 11-segmented without a club, usually filiform with some segments compressed while in the males of some Callosobruchus, they are pectinate (comb-like) or flabellate (spoon-like). The tarsi are distinctly 4-segmented with the third segment broadly dilated and deeply emarginate. The

hind femora are somewhat thickened or strongly enlarged and each bears one or more teeth. Bruchid larvae on hatching have three thoracic legs (a Chrysomeloid character) but after the first moult they become apodous (a Curculionoid character). Despite their common name, the bean weevils do not possess the elongate rostrum or snout of the true weevils.

Several species of bruchids are primary pests of stored beans, peas and other legumes.

Multivoltine species

(a) Acanthoscelides obtectus (Say), Dried bean weevil,

Adults are form 3.2 mm to 4.0 mm long and grey in colour with light and dark markings on the wing covers. The hind femur has one large and two small teeth which are of taxonomic importance in this genus.

This beetle is an important primary pest of pulses, especially of Phaseolus spp. beans. In all but the cool temperate regions of the world it attacks beans ripening in the field before harvest as well as in store. The larva develops entirely within a single grain, eventual,y forming a pupation chamber just under the seed coat, at which stage the infestation becomes evident as a characteristic circular 'window' on the surface of the grain. The adult which emerges from the chamber is short-lived and does not feed, and the female lays its its eggs rapidly; the eggs are laid freely among the grains, in contrast to other pest bruchids which cement their eggs to the seedcoat. A generation takes about 4 weeks at 30C and

development is possible in temperatures down to 15C.

(b) Callosobruchus chinensis (L.), "Cowpea beetle".

Antennae of the males are pectinate to strongly pectinate, whlist on the female they are subserrate. The apical tooth on the inner carina of the hind femur (which are bicarinate in this genus) is long, narrow, parallel sided and blunt at the apex. Adults generally 2.5-3.5 mm in length with typical white markings on the scutellum.

This bruchid beetle is an important primary pest of pulses in tropical and subtropical climates, originating from the orient but now found in many other areas. Pulses are often infested in the field before harvest as well as in storage. The larva develops entirely within single grain, eventually forming a pupation chamber just under the seedcoat, at which stage the infestation becomes evident as a circular 'window' on the surface of the grain. The adult which emerges from the chamber (leaving a large round hole) is short-lived and does not feed, and the female lays its eggs rapidly; the eggs are cemented firmly to the outside of the grain and the larva hatches through the 'floor' of the egg straight into the grain. After the larva has hatched the eggcase is clearly visible as a small creamish-white spot on the surface of the infested grain. The other major pest species of Callosobruchus have a similar life-cycle and cause nearly identical damage. One generation is completed in 25 days at 30C, and females lay more than 100 eggs, usually in less than one week.

(c) Callosobruchus analis (F.)

C. analis differs from all other members of this genus by having a tooth on the inner carina of the hind femur which is relatively small and sometimes absent.

The eyes tend to be flattened and less prominent. Adults range in size from 2.5-3.5 mm. This bruchid is a primary pest of pulses in many parts of tropical Asia and has been reported on grain, soyabeans and groundnuts (probably incidental pest) from India, Burma, Hongkong, Indonesia but rarely E. Africa. Generally less common than C. chinensis, but causes identical damage. Optimum conditions for development are 30-32C and 70-90% R.H.

(d) Callosobruchus maculatus (F.), "Southern cowpea beetle"

The antennae of both sexes in this species are subserrate. The elytra are brown with two medio-lateral black spots (sometimes inconspicuous in males); apical tooth on inner carina of hind femur straight. Slightly larger varying from 3-4.5 mm. Adults live for 710 days only, the female lays about 80 eggs, and one generation takes 21 days (32.5C and 90% R.H.).

This bruchid beetle is an important primary pest of pulses in tropical and subtropical climates, probably originating from Africa but now nearly cosmopolitan in all warm regions of the world except India where it is not common. Pulses are often infested in the field before harvest as well as in store. Certain types of pulses, particularly cowpeas, are more susceptible to attack by this pest than are other pulses. The life-cycle is similar to that of C. chinensis, and the damage caused is identical.

(e) Callossobruchus rhodesianses (Pic), "Cowpea beetle".

Adults 2.5-3.5 mm in length; antennae of males serrate while on females sub-serrate. Colour of apical half of elytra black or nearly black in females, brown in males. Apical tooth on inner carina acute and curving towards apex.

This bruchid is a primary pest of pulses in central and southern Africa and has not been recorded outside this continent (before 1976). Pulses are often infested in the field before harvest as well as in pulses have dried. The life-cycle is similar to that of C. chinensis but is completed in 26-28 days at 30C and 70% R.H.

Zabrotes subfasciatus (Boheman).

This bruchid beetle is an important primary pest of several pulses but is particularly associated with the many varieties of common beans (Phaseolus vu/garis). It is particularly common in central and South America but is also found in several other tropical or sub-tropical regions (central Africa, Madagascar, the Mediterranean, and India). The pulses are often infested in the field before harvest as well as in store.

Smallish bruchids (2-2.5 mm long) with long, filiform antennae, black with basal segments reddish yellow. The dorsal surface of adults usually variegated dark and brown while the base of the pronotum has a large patch of whitish hairs also exist as a broad transverse patch on the elytra.

Caryedon serratus (= C. gonagra F.). "Groundnut borer".

The eyes of this species are large and not emarginate. The hind tibiae are strongly curved. Adults are larger (4-7 mm) and cosmopolitan in distribution.

This beetle is a primary pest of groundnuts in many parts of the tropics. It can be a serious pest, especially on groundnuts that are inshell (because of its size it cannot penetrate so easily between the grains of shelled groundnuts). Infestations normalty start in the groundnuts soon after harvest, often while they are being dried. The larvae spend most of their life within the pod but when they are fullygrown they leave the seeds and cut exit holes in the pods. Pupation occurs within a thin paper-like cocoon that is usually formed on the outside of the pod but occasionally protrudes through the exit hole. The adults generally live and lay eggs within the surface layers of a bulk of groundnuts: up to 25 cm into the bulk in groundnuts in shell, much less in shelled groundnuts.

5. CUCUJIDAE

(i) General characters

Small adults (1.5 to 2.5 mm) which are flattened, reddish-brown, Il-segmented filiform antennae which may display a thickening of apical segments in some species. The prothorax possesses an entire, sub-lateral ridge (carina) on both sides which are more or less parallel. Torsal segmentation are 5-segmented in females while in males the front and mid-tars) are

5segmented and the hind tarsi are 4-segmented. Some members are often predatory but in Cryptolestes, the genus of importance in stored products, predation and grain feeding both occur. They closely resemble each other in appearance, while determination of species is based on characteristics of the genitalia and antenna: body length ratios of the males. (C. turcicus are as long or longer than the body, C. pusillus are only 2/3 as long as the body while C. ferrugineus are only 1/2 as long as the body).

(1) Cryptolestes ferrugineus (Stephens). The flat or rusty grain beetle.

Very small (1.5 mm) reddish-brown flattened beetle with long filiform antennae.

The eggs are placed in crevices within the grain or dropped loosely. The elongate larva has pronounced tail-horns and feeds preferentially on the germ of the grain. It passes through four instars and pupates in a gelatinous cocoon which is usually covered in food particles. Cannibalism occurs under crowded conditions. After a pre-oviposition period of two or three days, the female lays approximately 400 eggs and lives for 6-9 months at 32C and 70% R.H.

The life-cycle can be completed over the range of 20C to 42.5C and the optimum for both development and population increase is about 35C, when development is completed in 21 days (about 100 days at 20C). Development is retarded and mortality increased at low humidities but the rate of population increase is still considerable at 40% R.H. This species is cold-tolerant and can overwinter without difficulty in very cold conditions.

The adult flies actively at temperatures above 21C and warm grain, i.e. above 30C is preferred.

By virtue of its wide tolerance of temperature and humidity, C. ferrugineus is a cosmoplitan and important secondary pest of cereals, cereal products and oilseeds in temperate, sub-tropical and tropical regions and is often associated with or follows infestations of primary pests.

(2) C. pusillus (Schonherr), The flat grain beetle.

The optimum conditions for increase are about 35C and 90% R.H., development being completed in about 27 days under such conditions. It is not tolerant of low temperatures or of low humidities less than 60% R.H.

A cosmopolitan pest attacking a similar range of commodities to C. ferrugineus but only abundant in the tropics. It is apparently unable to survive in sound uninjured grain, but is commonly associated with the more vigorous primary grain pests such as the rice weevil. It is also a scavenger, the larvae feeding on the remains of dead insects, and is most often associated with grain and meat that is in poor condition.

The larvae are particularly attracted to the wheat germ, and in infested grain, many kernels are found uninjured except for the removal of the germ.

(3) C. turcicus (Grouvelie)

Optimum conditions for increase are about 28C and R.H., when development takes about 38 days, but the life-cycle can be completed between 17C to 37C at 90% R.H. At lower humidities survival is reduced and approaches zero at 50% R.H. The species is cold tolerant and is most abundant in flour mills in temperate regions where it is often confused with C. ferrugineus which occupies the same niche in the sub-tropics and tropics.

(4) C. pusilloides (Steel & Howe).

Optimum conditions for increase are about 30C and 90% R.H., when development is completed is completed in about 23 days. Development is completed over 15-35C at 90% R.H. However, survival is reduced and approaches zero at 50% R.H. and is restricted to tropical and sub-tropical regions in the southern hemisphere where it attacks a similar range of products to C. ferrugineus.

6. CURCULIONIDAE

The Curculionidae or true weevils form the largest single family in the Animal Kingdom. Many species are pests of growing crops of many kinds throughout the world, and approximately 30 species have been recorded in stored food products, three of which are of extreme importance.

Adults may be distinguished from all other stored products species by having the head produced in front of the eyes to form a well defined snout, the antennae are geniculate (elbowed) and clubbed, and all tarsi are 4-segmented. The larvae are apodous scarabaeiform, stout and slightly curved, and are creamy white with a pale brown or yellowish head.

Three species of Sitophilus are important pests of whole cereals, however, they are of little significance as pests of milled cereals because the larvae require a hard substrate in which to develop. As primary pests, these weevils are of additional importance in that their entry into whole grains provides access for secondary pests such as Tribolium spp. The role of the immature stages in the formation of 'hotspots' and in moisturemigration is also noted.

(1) Sitophilus granarius (L.), The granary weevil.

Small (2-4 mm), polished, uniformly chestnut brown to black weevil. Thoracic punctures oval and rather shallow. Male distinguished by shorter and more deeply pitted rostrum than female.

The females bores a hole in a grain with her mandibles, lays her egg at the bottom of the hole which is then sealed with a gelatinous plug.

After four moults, the larva pupates within a single grain. If several eggs are laid within a single grain usually only one larva reaches the pupal stage due to cannibalism of the

supernumerary eggs. Newly emerged adults spend some days within the grain before chewing their way out. Providing that temperature and moisture levels are favourable, the female lays about 250 (maximum 360) eggs during her life-span of about six months.

The life-cycle can be completed over the temperature range of 12-32C, the optimum lying between 26C and 30C. Development is completed in 26 days at 30C and 144 days at 15C (both at 70% R.H.). The moisture content of the grain greatly influences both oviposition and the development of the immature stages. Thus, eggs are seldom laid in grain of less 9% moisture content and are most numerous in grain of 14-16% moisture content.

The larvae produce much metabolic heat and moisture during their development where the heat generated may contribute to the formation of 'hotsports' with spot temperatures of 38-42C forcing the adults to migrate to cooler areas (generally towards the surface).

The adults have no functional wings under the elytra and their dispersal is therefore passive.

S. granaries is typically a pest in rather cool areas because the developmental threshold and temperature optima are lower than those of other Sitophilus spp. A wide range of cereals are attacked particularly wheat, oats, barley and rye.

(2) Sitophilus oryzae (L.), The rice weevil.

Small (2-3 mm), brown to black weevil with two paler reddishbrown patches on each elytra.

Prothoracic punctures round and rather deep, except for a smooth narrow strip extending down the middle of the upper (dorsal) side. Punctures on the elytra are narrowly separate, as compared to S. granaries, which are widely separate.

Life-history and biology essentially as for S. granaries. However, the female is more fecund and lays about 380 eggs (maximum 576) during her lifespan of about five months. The life-cycle can be completed over the temperature range of 14-34C; the optimum for development and survival is 27-31 C i.e. somewhat higher than the granary weevil. Development takes 25 days at 29C and 220 days at 15C (both at 70% R.H.). Few eggs are laid in grain of less than 10.5% moisture content and mortality of the immature stages are increased in grain with less than about 13% moisture content.

The heat and moisture produced by the immature stages is of considerable importance in the development of 'hot-spots' and moisture migration.

The adults have functional wings and their dispersal depends on flight as well as passive dispersal in trade. In contrast to S. granarius, the rice weevil with its greater tolerance of temperature exceeding 30C, is typically a pest of warm temperate and tropical zones. It attacks wheat, barley, paddy, rice, millet, sorghum and maize amongst other grains but is of little importance in milled products.

(3) Sitophilus zeamais Motschulsky, The maize weevil.

Small (3 mm) but somewhat larger than S. oryzae from which it cannot only be distinguished by examining the genitalia. Often confused with S. oryzae or referred to as S. oryzae 'large-strain'. Although generally darker than the rice weevil the variation that exists within each species makes separation on external characters alone rather inaccurate.

Life-history and biology essentially similar to S. oryzae but is about 1.5 times more fecund than S. oryzae with a life-span of five months. S. zeamais will oviposit in much moister grain, e.g. ripening maize, than S. oryzae and ovipostition is inhibited in grain of less 12.5% moisture content.

The life-cycle is completed in 37 days at 25C and 110 days at 18C (at 70% R.H.) which is somewhat longer than in S. oryzae.

S. zeamais is an active flier resulting in many field infestations in areas adjacent to infested storages.

S. zeamais occurs throughout the warm humid areas of the world and will attack a wide range of cereals although it is particularly a pest of maize. It will breed in rice and wheat but a true assessment of its pest status is confounded by the confusion that exists in early reports as regards to the separation of the species.

(4) Caulophilus latinasus (Say), The broadnosed weevil (= C. oryzae (Gyllenhal)).

Small (3 mm) dark-brown broad-nosed wevil. The life-cycle is essentially similar to the members of Sitophilus spp. The female lays an average 136 eggs over four months-the total life-span being about five months. Development is completed in 26 days at 28C and 76 days at 17C.

In warm weather, the adult may fly into maize fields where it attacks, damaged or exposed cods before the grains are hardened. C. latanasus breeds in stored maize, chick peas, millet and root crops such as sweet potatoes but is only of importance in the southern states of USA.

7. DERMESTIDAE

Adults are small to moderately large beetles densely covered with hairs or scales which are often conspicuously coloured. The head is small and somewhat deflexed and in some species (Anthreninae) bears a medium ocellus. The antennae are 5 to 11segmented, short with a distinct and often large club. The elytra completely cover the abdomen and there are five visible abdominal sternites. All tarsi are 5segmented.

Approximately 600 species have been described, and roughly 55 species have been reported as injurious to stored products. The larvae are general feeders and scavengers of dried organic matter of animal origin, particularly skins, furs, woollens and textiles, dried fish, dry carcasses and insect remains, while the adults are commonly found on flowers (necessary in the females of some species for egg maturation). Stored foodstuffs such as bacon and cheese

are also infestible items to members of the genus, Dermestes, while Anthrenus spp., as well as Trogoderma versicolor Creutz., are troublesome as pests of insect collections in museums.

Certain species however, vary their diet by feeding on farinaceous materials, and may therefore be frequently found in flour mills, farm storage and central collection bulk storages, or any similar places where grain or grain products are being stored or processed. These include members of the genera Trogoderma, Anthrenus and Attagenus.

(1) Anthrenus flavipes (Le Conte), The "furniture carpet beetle".

Small (2-3.5 mm) oval and strongly convex beetle with characteristic but variable dark, yellow and white patterns on dorsal surface.

The active larvae, which vary in colour from white through yellow to dark red, are clothed in dark hairs and bristles and moult 6-12 times or more. The pupa is formed within the last larval skin and the young adult remains for up to two months before emerging. The female lays up to 100 eggs during a life-span of up to one year and the adults feed on pollen or nectar.

At temperatures between 25-26.7C the life-cycle is completed in 160-360 and in 70-80 days at 35C.

A. flavipes is a serious pest of woollen-fabrics, silks, furs, skins, leather and horn. It will also

eat old grain, insect specimens, dried blood, glue and many other animal products or remains.

(2) Anthrenus and Anthrenocerus species.

A. verbasci (L.), the "varied carpet beetle" and A. museorum (L.), "the museum beetle", have similar biology and habits to A. flavipes but are temperate species. A. verbasci may be found as a scavenger in mills and is similar in appearance, biology and habits to A. scrophulariae (L.). Anthrenocerus australis (Hope) is indigenous to Australia which has been carried in trade to Britain where it attacks wollen goods, hides and food residues.

(3) Attagenus megatoma (F.), The black carpet beetle.

Small to medium (2.8-5.0 mm) beetle, head and thorax black, but the wing covers are black or dark reddish brown covered with short hairs. The larvae are characteristic and easily recognized by reddish or golden brown colour covered with short scale-like hairs with a tuft of long caudal hairs at the rear of the body.

The biology and life-history are similar to that of Anthrenus spp. Adults feed on pollen and nectar and produce 60-80 eggs over a lifespan of about one month. The number of larval instars and the speed of development depends greatly on temperature, humidity and diet. On fishmeal, the life-cycle is completed in 918 months at 26C but can extend for 3 years under cooler and less favourable conditions. The larvae shun light and tend to bore deeply

into the food source.

A. megatoma is a cosmopolitan pest particularly in materials of high protein content such as bone and fish meals, grain residues, wool, hair, fur and dead insects. The borings of the pest frequently provide immediate access for more damaging pests.

The larvae are often found in abundance in cracks in the floors of warehouses where foodstuffs have accumulated.

(4) Dermestes maculates (Degeer), The hide or leather beetle.

Large (5.5-10 mm) black beetle with white markings on the side of the thorax and abdomen. Apices of elytra pointed.

At 23C and 70% R.H., there were 5-7 instars when the larvae were reared on fish-meal diet of 46% moisture content compared with 9-13 instars at 7.5% m.c. The larvae attack skins and hides from the flesh side burrowing actively and often cause much additional damage to timber structures when they seek pupation sites.

The optimum temperature range is 30-35C. At 90% R.H. development takes about 4 weeks at 32C and 14 weeks at 20C, but may sometimes extend over some years under field conditions. D. maculatus is cosmopolitan and serious pest of hides, skins, furs bones, horns and hooves and foodstuffs such as dried fish.

(5) Other Dermestes species.

D. ater may be found with D. maculatus and is more usually a scavenger on carrion and dead insects. D. lardarius the "larder leetle" may be encountered as a domestic pest in temperate regious. D. frischli and D. carnivores have similar habits to D. maculatus.

(6) Trogoderma spp. complex.

Some of the members of the genus Trogoderma are highly important stored product pests.

The "Khapra bettle", Trogoderma granarium Everts., is one of the most damaging pests of stored products of agricultural origin throughout the world. Indigenous to the Indian sub-continent, Khapra beetle has become established in some Asian, Middle-East and African countries, being distributed mainly by shipping and international trade through the agency of man, since this beetle has limited mobility.

Species differentiation of Trogoderma; espeally larvae can be extremely difficult. For example T. variabile Ballion is difficult to recognize because of its variable appearance. T. glabrum (Herbest) and T. inclusum Le Conte are very similar and are often found in similar situations, the differences in the eyes and antennae can only be observed microscopically. All species of Trogoderma posses a median ocellus or simple eye on the forehead (of frons). Anthrenus species also posses a median ocellus, but differ from all other dermestids by possessing grooves in the prothorax in which the clubs of the antennae can be retracted

which is characteristic of this genus.

(A) Trogoderma granarium Everts, "The khapra beetle".

i) Adults

Khapra beetles are small oblong oval insects appoximately 1.75 to 3.5 mm in length with the males tending to be slightly smaller than the females. The elytra are almost unicolorous, brown to brownish black with the body densely clothed in fine yellowish hairs and the eyes are evenly rounded.

The antennae club in T. granarium E. is 4-5 segmented in the males, while the female club is 3 segmented. In T. glabrum (H), the male club is 5-6 segmented and the females are 4 segmented.

Trogoderma species however, exhibit considerable variation in size, colouration and patterns, and therefore if confirmation of any diagnostic separation is required, morphology of the male or female genitalia must be used.

ii) Larvae

The separation of Trogoderma larvae based on morphology is also extremely difficult, and are often confused with one another or misidentified, due to broad variation in form.

Members of Anthreninae (the sub-family to which Trogoderma and Anthrenus belongs) possess hastisetee, which are unique spearshaped hairs on the body, while native Trogoderma endemic to Australia, possess fiscasetae, which somewhat resemble a twig basket in shape. Anthrenus larvae have 3 short and dense tufts of spear-headed setae inserted on membranous areas behind the 5th to 7th tergites, coverging over the dorsum, while Trogoderma have spear-headed setae on the distinctly sclerotized parts of the tergites without obviously converging over the dorsum. Larvae of Attagenus spp. differ by having fine hairs extending posteriorly to form a caudal brush.

Larvae of Trogoderma are generally 6 mm long, and varies in colour from whitish-yellow, when young, to reddish-brown, when mature, and is clothed in transverse bands of hairs. The young larvae feeds mostly on grain debris or damaged grains but the large larva is able to bore into grains and therefore, is often regarded as a primary pest.

iii) Biology

Although adults possess functional wings they do not readily fly, and only live for a short period (5 to 10 days). During this period, adult females lay an average of 50 eggs loosely in the foodstuff but may lay over a hundred at temperatures exceeding 35C. On the other hand, larvae can live for several weeks, but are also capable of living for more than seven years, without food, and have been reported surviving in grain at near freezing temperatures. This ability to enter into a "facultative diapause" enabling them to survive

unfavourable conditions, whether high or low temperatures, food or water shortages, is instrumental in their ability to "spontaneously reappear" after attempts to control them. During diapause, the larvae have also been reported as being able to rouse itself, search for better food and shelter, and then resume its diapause again.

The number of instars varies considerably according to the prevailing conditions and at 38C and 50% R.H., 4-5 instars are common but as many as 15 have been recorded under unfavourable conditions. Pupation occurs in the last larval skin, while the adult remains quiescent for some time before emerging, and requires neither food nor water to attain full fecundity and longivity.

The optimum temperature range is 33-37C; the lower and upper limits being about 22C and 43C. Development is completed in 25 days at 35C and 48 days at 25C. The most favourable humidity range is 45-75% R.H. but development can still be completed at only 2-3% R.H. However, as implied previously the developmental rate varies enormously according to prevailing conditions and consequently the life-cycle may extend over 2-3 years.

The habit of larvae seeking shelter often makes them difficult to detect, and they may burrow into materials that are not generally infested in search for pupation sites. They often damage sacking, weakening it and causing it to tear easily. Because of the long body hairs, they may be inadvertently carried on clothing or even adhere to rodent's fur, which aids in dispersal (a phenomenom coined phoresy).

Khapra beetle has been occasionally recorded in Great Britain, Ireland, Italy, Jamaica, Japan, Mexico, North Western Europe, Philippines and Thailand (up until 1979).

Wheat, barley, rice and spices seem to be the most attractive commodities, but the Khapra beetle also feeds on almonds, walnuts, spaghetti and egg noodles, tapioca, dried beans, powdered skim milk, oilseed cake, fishmeal, and to a lesser extent, dried fruits. The developing larvae are the damaging trophic phase, and causes damage which is essentially similar to Rhyzopertha dominica Fabricus, the "lesser grain borer"

(B) Trogoderma inclusum (LeConte), The larger cabinet beetle.

This species is somewhat larger than the khapra beetle and, as an adult, may be recognized by the notch in the inner margin of the eye. T. inclusum may be encountered in grain and cereal products but is seldom regarded as a pest. However, it and several other Trogoderma species may be confused with the khapra beetle. For conclusive identification, consultation with an expert taxonomist familiar with the genus is imperative.

Continue

Contents - Previous - Next