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"DOUBLE-LOW": A SYNTHESIS OF CONTROLLED ATMOSPHERE AND FUMIGATION TECHNIQUES FOR STORED GRAIN CONSERVATION

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ABSTRACT

This presentation describes the "Double-Low" standard grain storage technique, a practical method based on scientific principles for the integration of controlled atmospheres and fumigation (CAF) in the control of storage pests. The "Double-Low" technique is threefold: 1) a grain bulk sealing system including structural sealing of warehouse walls; 2) pesticide dosage facilities, phosphine generators, fumigation duct systems, and integration of fumigation with CA protection; and 3) a monitoring system for grain temperature and relative air humidity. Using this method reduced the total annual losses of grain in storage for the Szechwan Province from 0.35% to 0.05%, with improved phosphine fumigation efficiency. This method has also been shown to retard grain quality deterioration.

INTRODUCTION

The Szechwan basin lies in the central part of south west China and has a sub tropical humid climate. The basin is surrounded by mountains and a plateau and in its eastern region is characterized by plains and hilly land. Between August and September, maximum temperatures may rise above 40°C, and relative humidity is usually about 85% along the Yangtze river valley. The geographical environment, climate, and poor quality of warehouses have made it especially difficult to store grain in this region. Ten years ago, the control of insect pests in storage was based on fumigation treatments using phosphine. Yet, these failed to prevent the insects from becoming resistant even when dosage levels were raised. However, over the past ten years considerable progress has been achieved by the introduction of the "Double-Low" technique, a combination of controlled atmospheres and fumigation.

PRINCIPLE OF THE "DOUBLE-LOW" TECHNIQUE

Grain taken into storage is immediately sealed hermetically. As the grain from the fields is at high temperatures, and contains many field fungi, aerobic respiration is rapid, the oxygen content decreases and carbon dioxide content increases. When the CO_2 level rises above 3% to 5%, the respiration of insect pests is stimulated. At this point, if a low dosage of aluminium phosphide (AlP) is applied, the activity of the pests can be controlled effectively .

METHOD OF APPLICATION OF THE "DOUBLE-LOW" TECHNIQUE:

Hermetic seal

First the storage system is made air-tight including walls and floor using coating materials and plastic liners, and the level of hermetic seal of the empty warehouse is tested.

After the warehouse is filled, the grain surface is levelled off and sealed using strips of PVC liner 90 cm wide that are heat-welded together, and at the junction with the walls, are pressed into plastic notches in the walls. Gastightness of both the grain bulk liner and the whole warehouse are tested using a U tube manometer and a suction blower. Air is pumped from the bulk to create a negative pressure. If a pressure drop from 50 mm to 5 mm water gauge can be maintained for over 150 seconds, the system is considered to be sufficiently airtight.

Our trials have shown that O_2 levels of wheat and rice in such warehouses may decrease to 5% and 12% respectively, and that these "low-oxygen" conditions can be maintained for 20 days, during which time the fumigant (AlP) is applied.

Pesticide application

Before pesticides are applied, it is important to know the distribution of the insect pests. This has been done for bulk paddy and wheat using the GJ-89-1 pest tester which is a "tool" for studying insect ecology (Ya-Nan *et al.*, 1992). The dominant species among the insects of newly stored wheat is *Sitophilus zeamais*, which accounts for some 87% of the infestations. Other species are *Liposcelis* sp., *Sitotroga cerealella, Bracon hebetor,* and mites (*Acarus* and *Tyrophagus* spp.), that account for 8.7%, 2.01%, 0.8%, and 0.7% of the infestations, respectively. The distribution of *S. zeamais* is mainly over the grain surface and to depths of up to 2 m.

For newly stored paddy, there are five species, the major species being the predatory bug *Xylocoris* sp. that accounts for 74.2% of the infestations. The other four species are *Acarus* sp., *Tyrophagus* sp., *Liposcelis bostrychophilus*, and *S. zeamais* constituting 9.5%, 9.3%, 5%, and 2% of the infestations, respectively. As in the wheat bulks, *S. zeamais* is usually

distributed over the grain surface and up to depths of 2 meters, while *Xylocoris* is dispersed over the middle and lower portions of the bulk.

For effective pest control, insect distribution and temperature fluctuations during the year should be taken into consideration when making decisions on fumigant application. For fumigation of the lower part of the grain bulk, when insects are present only in the mid and lower regions and temperatures in the bulk are relatively high, two methods of application are advocated:

1) *Application of phosphine from a generator.* The total dosage is calculated on the basis of AlP pellets at 2.5 g/m^3. The pellets are placed in a reaction vat and when moisture is absorbed from moist sand in the vat, the phosphine is released. This produces a positive pressure within the generator that drives the gas past a filter into a distributor and then into the grain bulk where it distributes itself, normally reaching all parts within 4 hrs and producing an even distribution within 10 hrs (Anon. 1993a). Concentrations will then be maintained for a further 10 days. Results have shown that insects at all developmental stages are killed in this process.

2) *Application by means of "aeration duct fumigation".* The calculated dosage of AlP pellets is placed into inverted U-type aeration ducts (Anon. 1993b). When enough moisture has been absorbed by the pellets, a small air-blower (30W) is activated (at 6 hr intervals) and blows the phosphine from the duct into the grain bulk. Results have shown that at a dosage of 1.9 g/m^3, concentrations at the upper level of the bulk can reach 0.03 mg/L, and this level can be maintained for 34 to 57 hrs or up to 70 hrs. In the lower levels of the grain bulk, the highest concentration of phosphine recorded was 0.9 mg/L and average concentration was 0.202 mg/L, while a concentration of 0.03 mg/L could be maintained for 80 hrs, and after 120 hrs the concentration was about 0.01 mg/L. These results show that the chosen dosage of 2 - 3 g AlP/m^3 is sufficient for both adults and larvae.

When there are high insect infestations in the top and middle layers, fumigation may be employed in conjunction with a residual insecticide. Usually malathion is employed. This is blended with bran to provide a concentration of 1% a.i. and then the required dosage is spread over the grain surface to produce a 30 ppm concentration (w/w) at the surface layer. Generally this procedure is accompanied by fumigation applied to the mid and lower regions of the bulk and provides an effective means of combating insect resistance.

Monitoring System

An automatic monitoring system for temperature and moisture based on a microcomputer has been widely used in Szechwan Province. Thermistors are used for temperature measurement. In the grain bulk, sensors are located

at vertical distances of 50 cm, and at horizontal distances of not more than 1.5 m. The sensors are connected through a switch network to a computer. This system has demonstrated strong disturbance resistance, low power dissipation, high reliability, and versatility in function. The system has facilitated the monitoring of temperatures and moisture fluctuations in grain storages.

ACHIEVEMENTS OF THE "DOUBLE-LOW" TECHNIQUE

To date more than 60% of the grain storage facilities have adopted the "Double-Low" technique, since its first introduction into Szechwan Province in 1976. The "Double-Low" technique involves an airtight bulk stack in which the gas composition is modified, thereby restraining grain respiration and depressing fungal development.

Over the past 10 years, the total amount of AlP has been reduced by 600 tons, in comparison with use under the regular fumigation method. Furthermore, stored grain losses have decreased to 0.05% using the "Double-Low" method as compared with 3.5% by conventional means.

In the "Double-Low" technique, because the AlP is applied beneath the plastic seal, the phosphine concentration in the grain bulk is 22% higher than by the usual fumigation method, and the effective concentration can last for up to 102 hrs.

Reduction in fumigant usage has reduced the dangers of pollution and increased work safety.

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