Donahaye, E.J., Navarro, S. and Leesch J.G. [Eds.] (2001) Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, Fresno, CA. 29 Oct. - 3 Nov. 2000, Executive Printing Services, Clovis, CA, U.S.A pp. 227-230

REFLECTIVE COVERS TO PREVENT CONDENSATION IN SEALED STORAGES IN THE TROPICS

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ABSTRACT

A sealed structure (the 'Volcani Cube'®) that provides protection to grain without the use of chemical pesticides was used in these experiments. A major advantage of the Volcani Cube is that it can be used to safely store grain outdoors where no suitable storage buildings are available. Under tropical conditions, when grain is stored in the open with no shade, ambient diurnal temperature fluctuations, can create temperature gradients within the stack that cause convection currents to carry moisture to the upper layers of grain. To overcome this effect, an upper insulating layer of bags containing straw or husks was employed. Under tropical climates this solution enables safe storage of maize and paddy for periods of up to 3 months; for more extended periods the top moistened layer of husks should be replaced with dry material. In a search to develop an alternative inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a shade screen placed above the cube was investigated. This material described as a knitted thermal screen is formed from aluminum coated high-density polyethylene threads. Trials conducted with Volcani Cubes in tropical and subtropical climates showed that grain is protected under sealed storage by maintaining the number of live insects below the threshold of economic damage without the need for pesticides. For dry paddy, it was shown that after 5 months storage under a reflective cover, no perceptible increase in moisture content was found at the top of the stack and the grain remained in good condition.

INTRODUCTION

We first investigated the possibility of storing bagged paddy rice outdoors in Sri Lanka in the late 1980s using hermetically sealed plastic liners called Volcani Cubes to protect the grain during storage (Donahaye *et al.,* 1991). Then during the 1990s two joint R&D programs were carried out by ARO Israel, and BPRE (formerly NAPHIRE) of the Philippines to study outdoor storage of paddy and maize (Navarro *et al.,* 1996), and intermediate moisture content (m.c.) paddy rice (Donahaye *et al.* 1999). This hermetic storage technology has now been fully evaluated in the

Philippines and is being widely applied both in the Philippines and elsewhere as a viable and cheaper alternative to centralized warehouse storage, particularly in rural areas where suitable permanent buildings are not available (Alvindia *et al.* 1994; Caliboso *et al.* 1997; Navarro *et al.* 1997; Navarro and Donahaye 1998).

However, one major problem of storing grain in stacks in the open, whether under tarpaulins or inside the hermetically sealed liners that we developed, is that the heat energy from the sun rays beating down on the top of the stack during day-time, causes the top grain layers up to a depth of about 10 cm to warm up to temperatures that can reach up to 55ºC or even more, beneath the top grain surface at around mid-day. This is followed by a gradual cooling during evening and night-time so that these surface layers may cool down to temperatures that before dawn are far below the average temperature of the grain stack. This phenomenon is far more pronounced outdoors than in the warehouse where walls and roof have an attenuating influence.

This diurnal rhythm of temperature fluctuations causes temperature gradients to become established within the stack. During the night, the warm air rises, and upon reaching the cool top layer it cools down and moisture may even become deposited as dew on the top layer of bags. The m.c. of this grain increases therefore as it absorbs the condensed water. Then, as the heat of the day advances most of this moisture in the grain is once again transferred to the hot air that disperses outwards, as occurs during artificial drying with heated air.

In consequence we experience a sort of pumping effect at the top of the stack where grain moisture increases at night and decreases during the daytime. The net effect depends very much upon the regional climate. In Israel with a Mediterranean climate we have not experienced any net moisture migration to the top of stacks inside Volcani Cubes, but as soon as trials were undertaken in Sri Lanka and then in the Philippines the moisture migration phenomenon became a significant problem that needed to be addressed.

The first attempt to overcome this phenomenon was to include an absorbent blanket as part of the storage kit, with instructions that this blanket should be spread over the top of the stack before the top section of the plastic liner is placed in position. This blanket worked well but tended to be diverted to other uses rather quickly so that it was no longer available for its original purpose. Therefore standard instruction procedure was changed to include a top layer of bags containing agricultural waste material such as paddy husks or maize cobs. This method was found to protect the stack for 4 months but had the drawbacks of taking up part of the valuable space inside the cube, and requiring additional labor costs.

The recent 4 year project between ARO and BPRE was to investigate the possibility of the hermetic storage in Volcani Cubes of paddy (palay) at above critical m.c., namely from 14% to 18% m.c. Clearly, in this situation there is an even greater risk of increased moisture at the top of the stack, and if this rises above 18% there is also the added hazard of anaerobic metabolism by yeasts and bacteria. Therefore we looked for a new approach to reduce the temperature gradients within the stacks.

In our search to find an alternative inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, we studied the effect of a shade-providing cover or awning called " Aluminet" placed over the cubes. This material is described by the manufacturer as a knitted shade cloth for use as a thermal screen and formed from aluminum coated high-density polyethylene threads.

A RUNNING SUMMARY

In our first trials carried out in both countries we compared two methods of positioning this cover, which reflects the rays of the sun. In one method we placed it directly on top of the upper PVC liner of the Volcani Cube and tied it down to the tension straps that are positioned around the sides of the cube. In the second method we used spacers consisting of 20 cm sections of PVC piping to raise the reflective cover above the PVC liner. In each case we only covered half the cube so that we could make a simultaneous comparison of the temperatures in the section that was covered with those in the uncovered section. We also checked to see if the angle of the sun (in Israel) had any effect in heating the cubes. We did this by covering the north section for a week, after which the south section was covered.

At this stage our findings clearly showed that when the reflective liner was separated from the cube with spacers, there was a significant decrease in both daytime and night-time temperature gradients within the cubes, but when the reflective cover was placed directly over the PVC liner, the effect was inconclusive.

The next question that arose was: how can we best position the reflective cover over the cube? The simplest method was to pull the edges down over the sides and attach them to the straps and buckles around the cube. To our surprise this seemed to produce a greenhouse effect, trapping warm air between the two covers during the day, until at night, the warm air dissipated upwards. Consequently, it became necessary to devise a system that permits free circulation of air between the covers. We devised tent-pole spacers around the cube, or on top of the cube, though the latter tended to slide over the slippery surface of the cube under high winds. We also used four bags of straw in each corner of the cube and this provided a more stable set-up. The advantages and disadvantages of using cords attached to ground pegs were also explored, the objective being to project the awning beyond the cube so as to protect the walls as well. Anchoring the cords proved problematic in some situations, though the cube itself is always a reliable anchor.

We were able to show in field trials with reflective covers in the Philippines using dry paddy at 14% m.c. that no moisture migration to the top surface was detected at the end of the 5 month storage trial. Storage of paddy at 18% m.c. for 3 and 6 months, inside Volcani cubes provided with reflective covers showed that after 3 months there was an increase in MC at the top two layers of the stack and this was even more accentuated after 6 months. Experimental results of these trials have recently been published (Donahaye *et al.,* 2000).

Our findings have revealed the effectiveness of this relatively cheap awning in protecting stacked grain stored outdoors from moisture migration. The search for an ideal practical solution to positioning the awning has continued, and the present solution is to weld small PVC cups onto the 4 corners of the top of the cube during manufacture to house small poles that raise the awning above the cube and prevent the poles from slipping.

ACKNOWLEDGEMENTS

This research was supported under Grant No. TA-MOU-94-C12-057 funded by the U.S.-Israel Cooperative Development Research Program of the U.S. Agency for International Development.

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