Sci. Rep. Fac. Agr. OKAYAMA Univ. (61), 5 − 8 (1983)

Use of Solar Heat to Control Stored-Product Insect Pests: Bean Depth[a)]

Toshiharu YOSHIDA and E. M. GICHUKI
(*Laboratory of Applied Entomology*)

Received November 1, 1982

Summary

Temperature in layers of different thicknesses of Azuki beans was measured and it was found that layer thickness was a very important factor to consider when an attempt is made to disinfest grains using solar heat. Thin layers of up to 3.0 cm required 1.5 hours to reach the temperature of 55 °C, that is fatal, if exposure is done for 4 to 5 hours, deduced from the literatures, while still a thinner layer of 1.5 cm required only 30 minutes and a 4.5 cm thick layer never reached that temperature. The 1.5, 3.0 and 4.5 cm thick layers reached highest temperature of 78, 67 and 51 °C respectively. The 1.5 and 3.0 cm thick layers maintained temperature above 55 °C for 4 hours 50 minutes and 4 hours 20 minutes respectively. The 3.0 cm thick layer, therefore, seems the best and most practical.

In general it is considered that very thick layers need a long time for the temperature to rise and do not reach so high, but keep the highest temperature attained for a fairly long time. On the contrary very thin layers have the temperature rise quickly but lose the heat rather rapidly. Therefore very thick or very thin layers being not convenient for solar heat disinfestation of insect pests, a suitable depth of grains need to be selected.

Introduction

The use of heat to dry and control insect pests in grains has been investigated by many authors (WENHOLZ, 1917[9)], MOOKHERJEE et al, 1968[5)], and YOSHIDA, 1974[10)], among others). However, though solar heat is possibly the first method ever to have been used by man to dry and control insects in his grains, but until recently, its manifold use in daily life and industry has not been thoroughly investigated. Generally, the use of heat from the standpoint of safety, effectiveness and utility during the season when control measures are most needed is superior to either fumigation or freezing (PEPPER and STRAND, 1935)[8)]. In connection with energy economy solar heat being a useful source of energy and the safest and easiest to manipulate led us to investigate its use by small scale farmers to dry and disinfest their grains in the developing countries. This method for pest control in stored products appears to be a very appropriate alternative to the sometimes hazardous chemical method or the utilization of other sources of heat which would invariably be more expensive.

In the present paper the variation of temperature with depth of beans being disinfested was investigated. Some authors when working on the problem of grain disinfestation using heat have considered the importance of using thin layers of grains (MANTER, 1917[4)] and CHAPMAN, 1921)[3)] but data on temperature variation with depth of grains being disinfested is lacking.

Materials and Methods

Three different weights, 524 gm, 348 gm and 174 gm of Azuki beans, *Phaseolus angularis*

a) Research supported by Research Grant No. 411913 from the Japanese Ministry of Education.

Wight, were put in each plastic container (sides 2 mm thick) measuring 11.5 cm square and 4.5 cm deep to a depth of 1.5 cm (hereafter called A), 3.0 cm (B) and 4.5 cm (C) respectively

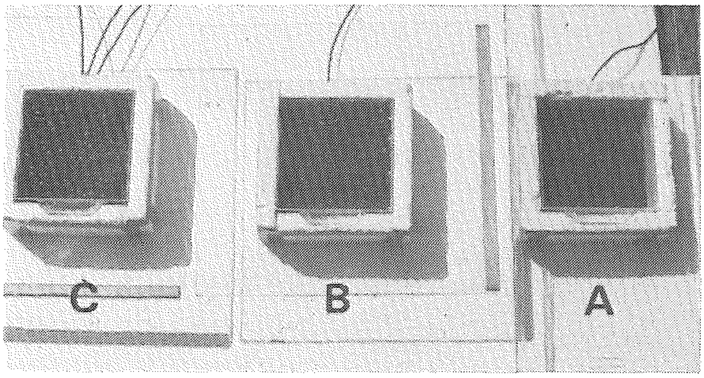

Fig. 1 Three plastic containers. Azuki beans at different depth were put in; A—1.5 cm, B—3.0 cm, and C—4.5 cm deep.

(Fig. 1). The moisture content of the beans was about 15%. The sides of the containers apart from the top were insulated with a white plastic foam (2.0 cm thick) generally used for packing. Temperature detectors were inserted inside the beans and put at the bottom of each container. In addition two more temperature detectors were put in the C container full of beans at the top of the beans (about 0.5 cm deep) and the middle of the beans (about 2.25 cm deep). Also air temperature under a shade was monitored by another detector. All the containers were put on a white plastic foam sheet (2.0 cm thick) and placed on a granite pavement in a courtyard surrounded by buildings. The temperature was charted using a digital thermocouple (EH 106—06, product of CHINO Factory Ltd.). The experiment was carried out on the 13th of September 1982 from 10.30—17.00 hours. It was a fine day just after a typhoon.

Results

The temperature records are graphed in Fig. 2. Container A which had beans 1.5 cm deep attained the highest temperature of 78 ℃ and the 55 ℃ level 30 minutes after exposure but gave off the heat relatively more quickly later in the day (1 in Fig. 2). The middle container B in Fig. 1 which had beans 3.0 cm deep attained highest temperature of 67 ℃ and the 55 ℃ level 1.5 hours after exposure and kept the high temperature for a considerably long time (2 in Fig. 2). The last container C full of beans attained highest temperature at the bottom of 51 ℃ and the 55 ℃ level was not attained during the exposure period (5 in Fig. 2). The middle detector in container C attained highest temperature of 54.5 ℃ but the 55 ℃ level was not attained (4 in Fig. 2). The top detector in container C attained highest temperature of 60 ℃ and the 55 ℃ level 1 hour 10 minutes after exposure but gave off the heat most quickly and the temperature fluctuated within a narrow amplitude (about 1 ℃) although the line in Fig. 2 was drawn neglecting that factor (3 in Fig. 2). Making a comparison of the temperature trends among the three different depths in container C, we can observe that the temperature at the top of beans rises most quickly and reaches the highest temperature but drops rather rapidly. In the middle, the temperature rises slowly and does not reach the level of the top detector but persists at its high temperature for a longer time, while at the bottom, temperature rises most slowly and is kept at the highest temperature attained for a fairly long time. The air temperature measured under the shade (6 in Fig. 2) fluctuated little between 25 ℃ and 27 ℃ although the line was drawn neglecting that fluctuation.

In the course of the experiment, a few water droplets started forming on the inside of the glass cover of A and B containers later in the day. At 13.00 hours about two third of the glass

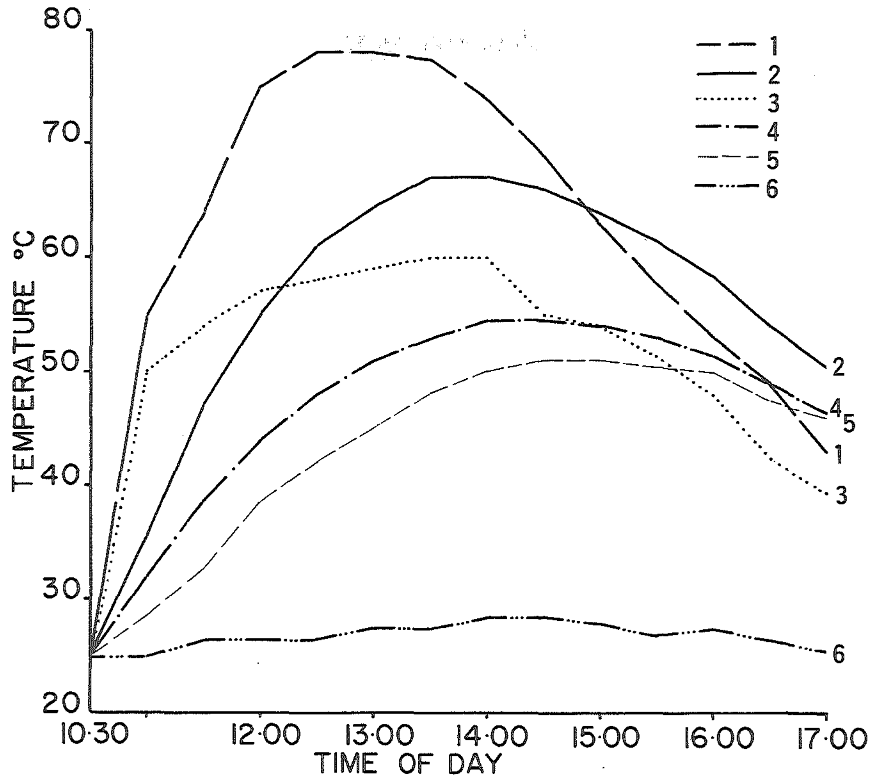

Fig. 2 Temperature variations with bean depth and time of day. Temperature under the shade is also shown as control. The numbers in the figure show the temperatures: 1, at the bottom of 1.5 cm depth container A; 2, at the bottom of 3.0 cm depth container B; 3, at the top, 4, at the middle and 5, at the bottom of 4.5 cm depth container C; and 6, under the shade.

cover of the A container and one third of the B container were dim with moisture but the cover of the C container was clear. Also a shadow was formed in the A and B containers which covered more beans as the sun went down although the C container had no shadow. At 15.20 and at 17 hours, half and all of A container was shadowed respectively.

Discussion

For a practical purpose the following several factors should be considered; first, the temperature-rising speed, second, the highest temperature reached, third, the period maintained at the highest level, and fourth, the bulk of beans that could be exposed at the same time. In general the quicker the temperature rises, and the higher the level is attained, and the longer that level is maintained, and the greater the bulk of beans that can be exposed at the same time, the more facile the infestation can be controlled.

For the azuki bean weevil, *Callosobruchus chinensis* (L.), the adult is killed by the temperature of 50 ℃ in 5 minutes (YOSHINO and HARADA, 1936)[11] and OOSTHUIZEN (1940)[6] reported that beans spread in thin layers in an oven and heated to a temperature of 48.9—62.8 ℃ for several hours or exposed for 1 hour in open sunlight when temperature under the shade was about 37 ℃ was sufficient to kill all the weevils. Our unpublished laboratory results indicate that a temperature of 55 ℃ kills larvae and pupae of the weevil in 4 hours. For the southern cowpea weevil, *Callosobruchus maculatus* (F.), all stages are killed by a temperature of 63.3 ℃ in 15 minutes (PADDOCK and REINHARD, 1919)[7] and larvae are killed in 20 minutes at a temperature of 51−53 ℃ (BREITENBECHER, 1923)[2]. BACK (1940)[1] reported that a temperature of 60 ℃ for 5 minutes was not sufficient to kill the southern cowpea weevil but all stages were killed in an oven of 60 ℃ for 10 minutes. MOOKHERJEE et al (1968)[5] found that a temperature of 55 ℃ for 4−8 hours was sufficient to kill the weevil. Our unpublished laboratory results conform to these results. On the basis of these results it may be concluded that a temperature of 55 ℃ for 4−5 hours is sufficient to kill all the weevils. Increasing the temperature to above 60 ℃ would require about 1 hour which was attained by the middle container B. It can be stated in this connection that the bean layer thickness of 4.5 cm is not practical for sterilization purposes as the bottom temperature does not reach a sufficient height although a large bulk of beans can be exposed at the same time in that case. Hence, the middle container B having a depth of 3.0 cm seemed to be the best and most practical.

Acknowledgement

The authors wish to express their gratitude to Dr. K. MIURA of our College for his valuable suggestion. Also the authors are grateful to JICA and Jomo Kenyatta College of Agriculture and Technology who sent the junior author, E. M. GICHUKI to Okayama University. In this connection the permanent address of the junior author is Jomo Kenyatta College of Agriculture and Technology, P. O. Box 62000, Nairobi, Kenya.

References

1) BACK, E. A. : USDA Farm. Bull. **1275**, 1−37 (1940)
2) BREITENBECHER, J. K. : Proc. Okla. Acad. Sci. **3**, 32−35 (1923)
3) CHAPMAN, R. N. : Univ. Minn. Agr. Exp. Ata. Bull. **187**, 1−76 (1921)
4) MANTER, J. A. : J. econ. Ent. **10**, 190−193 (1917)
5) MOOKHERJEE, P. B., M. G. JOTWANI, T. D. YADAV, and P. SIRCAR: Indian J. Ent. **30**, 107−202 (1968)
6) OOSTHUIZEN, M. J. : Fmg. in S. Afr. **12**, 1 (1940)
7) PADDOCK, F. B., and H. J. REINARD: Tex. Agr. Exp. Sta. Bull. **256**, 1−92 (1919)
8) PEPPER, J. H. and A. L. STRAND: J. econ. Ent. **28**, 242−244 (1935)
9) WENHOLZ, H. : Agr. Gaz. N. S. W., Sydney **28**, 229−243 (1917)
10) YOSHIDA, T. : Sci. Rep. Fac. Agr., Okayama Univ. **43**, 11−17 (1974)
11) YOSHINO, S. and T. HARADA : Nojikairyoshiryo **106**, 8−9 (1936)

太陽熱による貯穀害虫の駆除
暴露時の豆の深さ

吉田敏治・E. M. GICHUKI
(岡山大学農学部応用昆虫学研究室)

省エネルギー技術，発展途上国での中間ないしは適正技術（オルターナテイブ・テクノロジー）の開発を目差して，太陽熱を利用した貯穀害虫の駆除法の近代化を図ろうとし，太陽にさらす時の豆の厚さが各層での温度変化にどうひびくかを調べた．暴露時の豆の深さが深いほど温度上昇に時間がより長くかかり，また到達した最高温度はより低かった．しかし，一端上昇した温度は深さの浅い場合より，より長く保持された．従って，中間の厚さ（この場合 3 cm）でさらすのが最もよいことがわかった．