THE POSSIBLE ROLE OF AERATION IN THE CONTROL OF STORED PRODUCT INSECTS IN WARM CLIMATES

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ABSTRACT: The role of aeration in reducing the temperature in the grain bulk, and thus controlling of insects in stored grain, is reviewed. The scarcity of cold ambient air being the limiting factor in the application of this technique in warm climates, is emphasized. A review of recent commercial scale aeration trials in several sub-tropical countries, and the application of results obtained in practice, is given.

The possibility of using cold ambient air, available at nights or in cool seasons prevailing in some tropical and sub-tropical climates, is considered. A detailed survey of meterological data in every given grain storage site is essential, before deciding on the installation of grain aeration systems.

Suggested air flow rates and techniques for the operation of the aeration system are briefly discussed, taking note of the advantage of aerating flat storage structures to make possible the use of larger air volume rates.

The economic aspects of application of aeration in tropical and sub-tropical countries are most significant, and it is emphasized that this treatment can be justified only in large, commercial grain storage sites.

The aeration of grain with refrigerated air, when and where cold ambient air is not available, by use of grain chilling units, is also discussed. The limitations, such as cost and energy requirements, in applying this method, are noted.

Considering further benefits of grain aeration and stressing its advantage as a non-chemical treatment for the preservation of grain, the need for research and development on this technology, in tropical and sub-tropical countries, is urged.

The subject of aeration of grain in warm climates is controversial. It is a well-known fact, that many grain silos in the tropics are equipped with modern aeration installations, although very little is known about the operation of those aeration systems, regarding the benefits this technique offers for the preservation of grain in these climates.

In discussing this subject, two basic postulates should be stressed: Firstly - mechanical aeration can be efficiently applied only in large scale commercial bulk storage of grain. Secondly - only the movement of selected ambient air can improve the grain bulk storability. Since the main purpose of aeration is to reduce the grain temperature, the "selected" air should be cool, and here we come to the main problem, namely the availability of cool air in tropical and subtropical climates, and how to utilize the same for the aeration and cooling of grain.

EXPERIENCE GAINED IN SUBTROPICAL CLIMATES: Before furthering our exploration of the possibilities of aeration in the tropics, it is necessary to define clearly, what we expect from such a treatment, as far as insect control is concerned. Firstly, we are interested in reducing the temperature of the grain bulk. Here, we may benefit from the data given by Burges and Burrell, 1964 (Table I) giving "safe temperatures" - from insect attack. It can be deduced from this table, that if the temperature of the grain bulk

TABLE 1. Optimum temperature for rapid insect growth, and the temperature at which the development cycle takes 100 days on one of the best foods for each species. (From Burges and Burrell, 1964).

Species	Optimum temperature °C	Safe temperature °C (from oviposition to adult in a mean of 100 days)
Oryzaephilus surinamensis (L.)	34	19
Sitophilus granarius (L.)	28-30	17
Cryptolestes ferrugineus (Steph.)	36	20
Tribolium castaneum (Herbst.)	36	22
Tribolium confusum J. du V.	33	21
Trogoderma granarium Everts.	38	22
Sitophilus oryzae (L.)	29-31	18
Rhyzopertha dominica (F.)	34	21
Cryptolestes pusillus (Schonherr)	32	19

can be maintained under 18°C (65°F), the hazard of significant damage due to insect infestation would be negligible. The second basic element in the technology of Aeration Cooling is the fact that large grain bulks are self-insulating bodies, and thus the reduced grain temperatures, obtained by aeration, can be maintained for considerably long periods of time.

We know today that the above is not only a theory, but quite an accepted practice. Experimental work on aeration has been carried out in subtropical climates and the results are being applied on a large commercial scale.

This work began quite simultaneously in the middle sixties, in Australia and in Israel. J. W. Sutherland (1968) reports on work done in Victoria, in 1963, 1964 and 1965. Summing up-aeration of a 100,000 bu. grain store resulted in reduction of the grain temperature from 32°C to 9.5°C during the first year of aeration (1963), in about 1100 h. Shorter aeration times were required to obtain these low temperatures during the two following years [2]. More information on the same subject is given by W. B. Elder [3,4,5].. in which other aeration experiments are described and technical improvements of this aeration procedure, such as automatic monitoring systems, are suggested. In every case, prevention of insect infestation is proved, without the use of toxic chemicals, as a result of this aeration cooling of the grain bulk.

Very similar results we obtained from trials, carried out by our group in Israel. Apart from the work published by Navarro et al (1969) [6], in which 1140 tons of grain in a bin were stored for about 2 years and kept practically free from insect infestation due to operation of the aeration system, many further experiments were carried out and results reported. One of the experiments [7] points out the advantage of the selective use of the ambient air: (Fig. 1). In a metal bin containing 510 tons of wheat, the grain temperature was reduced from 34°C to 15-20°C during December and January (winter months) using 155 hrs of aeration only.

In further experiments [8], the suppression of insect population in local wheat, in a bin of 180 tons capacity, by aeration, during a period of 10 months, was recorded. As mentioned before, aeration for cooling of grain is and has been used at practically all grain storage sites in Israel over the last 10 years, with very satisfactory results, and I cannot see any reason why this technology should not be more widespread in other subtropical countries.

AERATION IN THE TROPICS: The feasibility of using aeration for the prevention of insect damage in tropical climates remains still unclear. Although speculation cannot replace real experimental work on a specific location, it can be of some help.

Since the first basic, essential, condition for the application of aeration is availability of low ambient temperatures, it is, therefore, necessary to determine the maximum permissible temperature which will result in suppression of insect infestation in the stored grain bulks. As mentioned before, this would be less than 18°C (65°F), or in terms of wet-bulb temperatures, which more correctly take into account the ability of the ambient air to cool grain - this limit should be 14.6 - 15.8°C.

Thus the question is: are these relatively low temperatures available in tropical climates? Without delving into the details of climatology and geography, we can make use of Glenn T. Trewartha's map of Types of Climates, in which a simplified classification of climates is shown [9].

According to this map, we cannot expect to find the required temperatures in the Tropical Rainforest climate, where average temperatures range from 25-28°C and neither seasonal nor diurnal changes in temperature are significant. Therefore, it can be safely stated that in this climate, the application of aeration for cooling is not feasible.

In Tropical Savannah Climates, constantly high temperatures are still characteristic, but here we have a "cooler dry

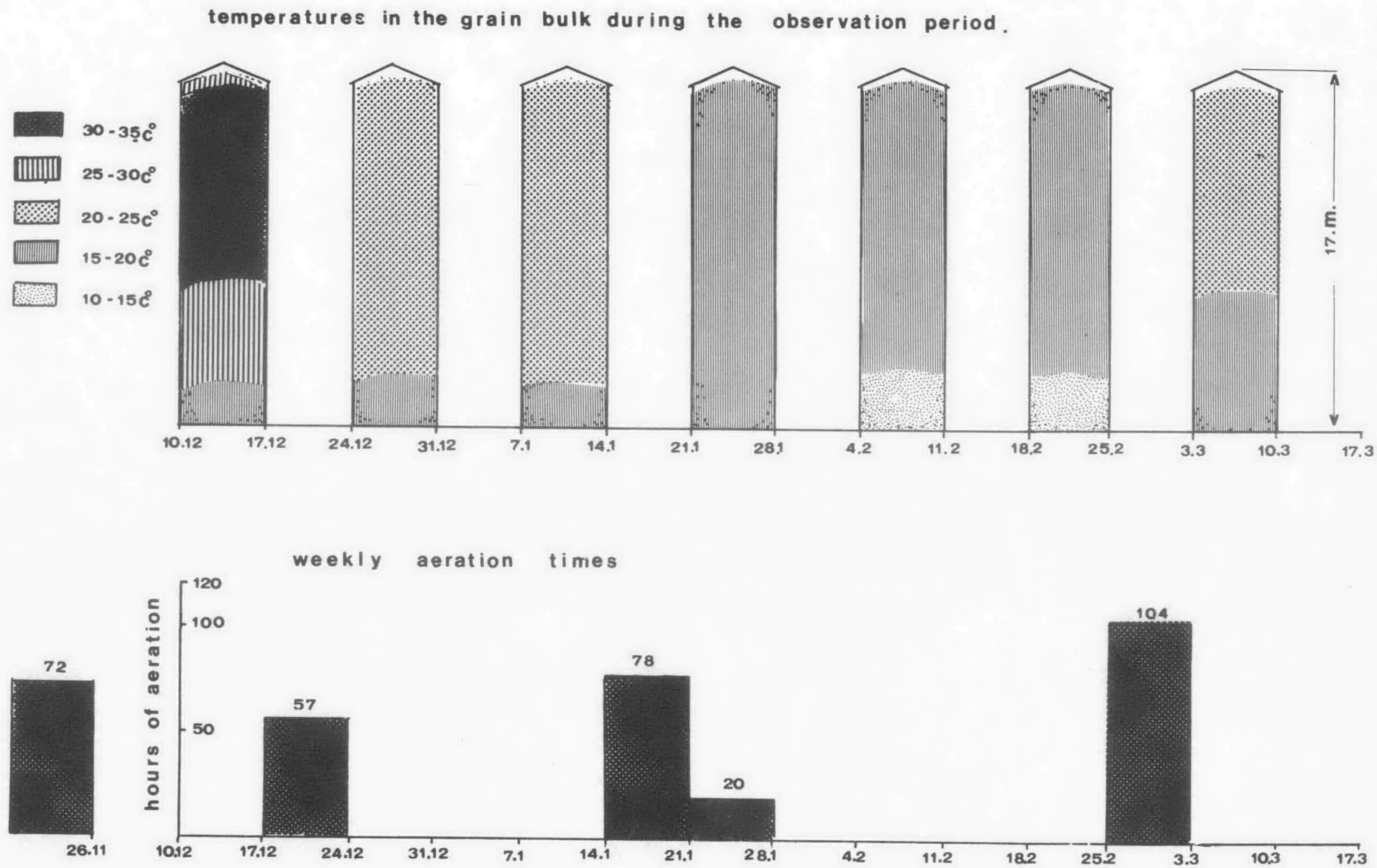

FIGURE 1. The Effect of Aeration On Cooling Of the Grain Bulk At "Massuot Yits-Hak"

season", in which temperatures of 16°C at night are not infrequent. This type of climate prevails in enormous areas between the tropics and further analysis of climatic conditions at given locations should be made, in order to decide about the feasibility of grain aeration. In the Tropical and Subtropical Dry Climates, Threwartha distinguishes between Low Latitude Deserts and Steppes. Characteristic of the desert are the annual ranges in temperature in two distinct seasons, which average 35°C in summer, and about 12°C in winter (January, Sahara, Aswan). There are also large diurnal changes of temperatures, so that night temperatures can sometimes fall to nearly 0°C. In Steppes, which usually margin the Desert or Savannah Climates, low temperatures are available, similar to those mentioned above. In short, both in Deserts and Steppes, relatively cold ambient air is available, and a more detailed examination of the climatic elements at given grain storage sites, may show the availability of excellent conditions for aeration cooling.

In the tropics, we can find low air temperatures also in so-called Highland (Upland) climates. For example, in typical Upland Savannah Climate (near Sao Paulo, Brasil) at about 800 m. altitude, temperatures of 10-12°C prevail during several months of the year. Uplands can be found in different tropical regions and as a simplified rule, for every 1000 m. of altitude there is a fall of about 5°C in comparison with the surrounding lowland. Thus, in the Upland areas of Kenya of between 1000 and 1800 m altitude, minimum temperatures of 5-11°C are available, and consequently favourable conditions exist for aeration cooling of grain. The above review shows clearly that in large areas in the tropics favourable conditions for the operation of aeration systems exist. However, a thorough survey at every given grain storage site is essential before deciding on the installation of grain aeration systems.

SUGGESTIONS FOR THE PLANNING OF AERATION SYSTEMS IN WARM CLIMATES:

Based on the experience gained in subtropical countries, some useful suggestions for aeration of grain in warm climates can be given:

1. Selecting the ambient air - As mentioned above, air of less than 18°C (or 14-16°C wet-bulb approximately) should be introduced in the grain bulk, and the lower the temperature, the better the results. As recommended by Holman [10], the ambient temperature should be at least 5.6°C (10°F) lower than the temperature of the grain bulk, in order to prevent the entry of high humidity into the bulk. The use of the ingenious "disc calculator", proposed by Australian scientists [4,5] is recommended. The selection of air of proper wet-bulb temperature which will result in reducing the grain temperature to desired levels, is made easy by this "disc calculator".
2. Air Flow rates - Owing to the scarcity of cold air in the tropics, higher air flow rates should be used in order to shorten, as much as possible, the aeration time required to cool the grain. In Fig. 2, the calculated approximate aeration

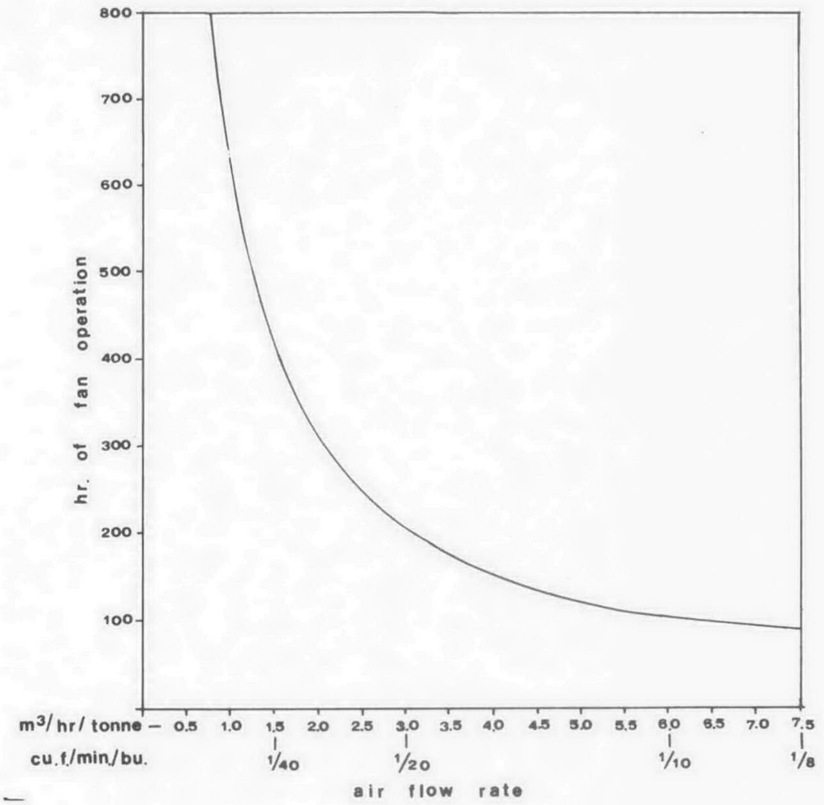

FIGURE 2. Aeration Cooling Time Required (Approximate), For Reducing Grain Temperature From 27°C to 15°C (At 50 °/o RH).

cooling time for reduction of grain temperature from 27°C down to 15°C is shown. It is clear that in order to obtain efficient short-time cooling, air flow rates higher than 1/10 cfm/bu ($6m^3$/hr/ton) should be used. In this respect, aeration of flat storage structures is advantageous, since in such structures larger air flow rates can be used, without the need for increasing considerably, fan horse power. In these cases, air flow rates of 1/5 cfm/bu (12 m^3/hr/ton) and higher can be used and thus the shortest possible aeration time can be obtained.

3. Accounting for Air Density in Upland Climates - In estimating the air volumes and the time required for aeration at given storage sites in Upland regions, it is usefulto note that air density decreases according to altitude. Table II shows calculated air densities and aeration times required at different altitudes. It can be seen that at 4,000 m. altitude, about twice as long a time is required for the introduction of the same air volumes into the grain mass, as compared to that time required at sea level.

From the above discussion it can be concluded that Aeration Cooling of grain is feasible even in tropical countries, where ambient air of low temperature is available for periods of time sufficient to reduce the grain bulk temperature below a certain limit, at which stored products insects cannot cause significant damage. Moreover, today, possibilities exist of introducing cold air even in climates where low air temperatures are scarce or not available. In such cases, aeration can be effected by using refrigerated air obtained from grain chilling units. Experimental work on this subject has already been done in Queensland, Australia

TABLE II. Estimated Aeration Time Required To Reduce Wheat Grain Temperature From 27°C To 15°C At Different Altitudes. (Air Flow Rate 0.1 c.f.m./bu) (60 m^3/hr/ton)

Altitude (m)	Atmospheric Pressure (mm Hg.)	Air Density (Kg/m^3)	Aeration Time Required (hr.)
	760	1.22	100
1,000	720	1.16	105
2,000	600	0.95	127
3,000	510	0.82	149
4,000	420	0.67	182

[11] and in Israel [12], and the results obtained are promising. The chilling of grain still poses serious problems of economics, energy consumption, maintenance etc. However, in some tropical regions this might be one of the very few possibilities for maintaining the storability of grain in large commercial silos. In this review aeration cooling of grain is proposed, as a nonchemical method for the prevention of insect damage. However, from the above, it should not be deduced that aerated grain storage in warm climates can do entirely without chemical treatments. The periphery of the grain bulks regains very soon the ambient temperature and insects (especially grain moths) could become a serious problem. In this case a surface treatment with suitable insecticide is an absolute necessity.

This paper is, in fact, a speculation about the possibilities of using grain aeration for insect control in warm climates, based on know-how gained in this field in several subtropical countries. However, its real aim is to promote the very much needed research on this subject at as many as possible sites, in countries with tropical and subtropical climates. The results of such experimental work,if positive, could provide a very effective means of preventing heavy storage losses in the precious grain stocks of these parts of the world.

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