Effects of Dry Heat Treatment for Seed Disinfection on Germination in Vegetables

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In the 1960s, we faced a difficulty in Japan in growing cucumbers and watermelons, due to infection of CGMMV (cucumber green mottle mosaic virus). In the 1970s, growth of watermelons was damaged by Fusarium wilt occurred in bottle gourd used widely as a root stock for watermelon plants, and that of cucumbers by angular leaf spot. In consequence of the occurrence of these diseases, the yields of these vegetables decreased and the market values of the products were reduced. These diseases were almost simultaneously prevalent all over the country. Plant pathologists showed that seed infection was the primary cause of these diseases. Thus, attention had been paid to the importance of methods for seed disinfection.

Furthermore, infection of seeds by various pathogens has increased recently in Japan because of the shortage of labor and regulation of usage of disinfection agents. Under these circumstances, the necessity for development of the methods for seed disinfection has become urgent.

Methods for seed disinfection are classified as chemical and physical ones. In the former, MMC (methoxyethyl mercury chrolide) had been widely used as the most effective fungicide. In 1973, however, the use of this chemical was prohibited, due to its toxicity. Substitutes such as Benlate T and Chemichlon G have been used as fungicide and sodium phosphate (tribasic) has been used to disinfect viruses, but they are not always effective to internally borne pathogens of seeds.

The physical methods mainly depend on a thermal effect for pathogens. For example, the hot water treatment by immersing the seeds for 20 to 30 min at about 50°C is widely used. However, this method also is not effective for viruses. In addition, it is difficult to maintain the whole of a seed lot at 50°C and to dry it rapidly without inducing germination.

On the other hand, a research on dry heat treatment was performed in 1922[10]. By dry heat treatment, it is possible to disinfect various pathogens, fusarium, other fungi, bacteria, and viruses. Nevertheless this treatment was not practical, because dry heated seeds often failed to germinate.

Research on the method for dry heat disinfection has been recently conducted in some countries, especially in Japan, where a big damage due to the seed borne diseases took place as mentioned above.

The experimental results of dry heat disinfection of vegetable seeds reported by Japanese investigators are summarized in Table 1. On the basis of these data, the dry heat treatment of seeds is carried out as a routine procedure by some seed companies, agricultural cooperatives and farmers.

In this paper, the experimental results of heat treatment of bottle gourd and other vegetables for seed disinfection will be presented together with some useful information related to dry heat treatment.

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Table 1. Examples of experiments on the heat treatments of vegetable seeds for controlling seed borne diseases

Vegetable	Pathogen concerned	Dry heat treatment		Source
		Temperature	Duration	
Tomoto	*Corynebacterium michiganense*	70°C	4-6 days	Murata et al. (1970)[3]
Cucumber	CGMMV	70°C	2 days	Nishi et al. (1967)[8]
Cucumber	*Pseudmonas lachrymans*	70°C	3 days	Umekawa et al. (1980)[9]
Netted melon	CGMMV	70°C	3 days	Furuki (1975)[1]
Bottle gourd Watermelon	CGMMV	70°C or 73°C	3 days 2 days	Nagai et al. (1974)[4]
Bottle gourd	*Fusarium oxsporum* f. sp. *lagenaria*	75°C	7 days	Kuniyasu et al. (1978)[2]

Some factors affecting heat resistance of bottle gourd seeds

It is well known that seeds with low moisture content should be stored under low temperature conditions to prevent loss of viability. Most important factors affecting heat resistance of seeds are also temperature and moisture.

As indicated in Fig. 1[5], the seeds with 1.5% moisture content (on wet weight basis) showed the highest heat resistance compared with those of seeds with other moisture content. When the moisture content was lower or higher than 1.5%, the heat resistance of seeds decreased exponentially.

Fig. 2[6] shows the heat resistance of the seeds with higher moisture content than 4%. All seeds with 8% moisture content held at 75°C for two hrs failed to germinate, whereas the seeds with 4% moisture content, held at the same temperature for 24 hrs, showed essentially no loss of germinability. When the duration time of dry heat treatment at 75°C was longer, the non-lethal moisture content of seeds declined. From these results,

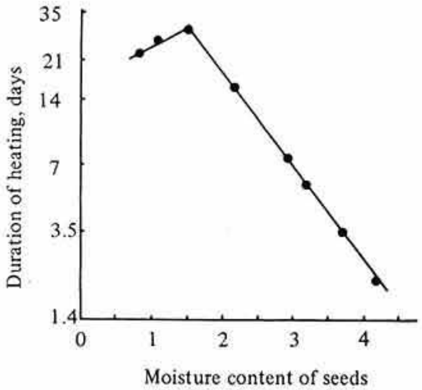

Fig. 1. Heat resistance of bottle gourd seeds expressed in terms of 50% reduction of germination (at the first count on the 4th day of germination), as effected by moisture content of seeds and duration of dry heat treatment at 75°C[5].

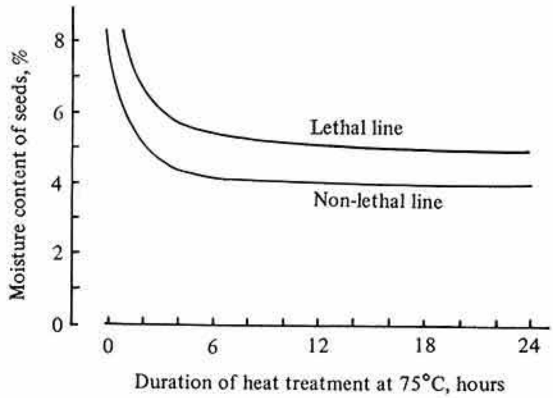

Fig. 2. Germinability of bottle gourd seeds as related to seed moisture content and duration of heat treatment at 75°C. In the zone below the non-lethal line, more than 90% of seeds were germinated, whereas all seeds were killed in the zone above the lethal line. Germinability decreased between the two curves[6].

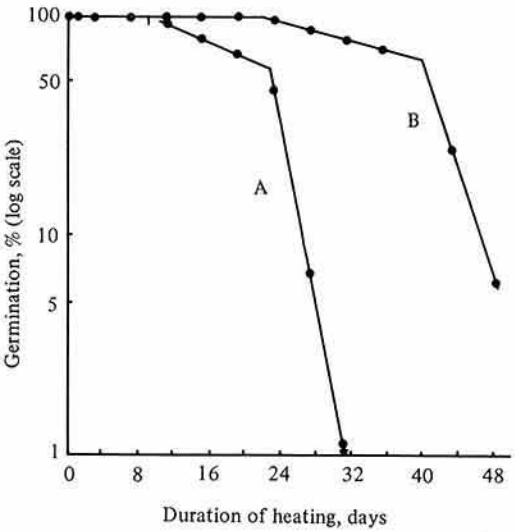

Fig. 3. Effect of heat treatment under circulating air at 75°C on the rate of germination of bottle gourd seeds with moisture content of 0.6 to 1.1%[5].
A: First count on 4th day
B: Final count on 7th day

1.5% was found to be the optimal moisture content when seeds were held at 75°C.

After the seeds were air-dried at 75°C for about 24 hrs, the moisture content of seeds reached the equilibrium with the moisture of atmosphere that is 0.5 to 2%, although the moisture content at the equilibrium is slightly higher in June–July, the rainy season in Japan. Thus, the moisture content of bottle gourd seeds could be maintained at the desirable percent, i.e. close to 1.5%, under circulating air at 75°C except the rainy season.

As shown in Fig. 3[5], the bottle gourd seeds, held at 75°C for 12 days with 0.6 to 1.1% moisture, germinated still at approximately their original level. Kuniyasu et al.[2] reported that seven days were the enough period to disinfect the fungi in bottle gourd seeds (Table 1). Therefore, the heat resistance of seeds of bottle gourd is supposed to be higher than that of the pathogens.

Other experiments[5] showed that the heat resistance of seed decreased exponentially as temperature of the treatment rose; the rate of germination of the seeds held at 90°C for five days decreased to one half of that of untreated seeds. Therefore, the upper limit of temperature of dry heat treatment for a week may be about 75 to 80°C.

Some information on practice of dry heat treatment of seeds

As mentioned above, the seeds with high moisture contents loose their germinability under high temperature conditions, while the low moisture contents can keep it under the same conditions of temperature. If the seeds containing 10% of moisture are heated at 75°C, the treatment for a few min is lethal for all seeds. In order that the seeds may be treated at high temperature without damage in viability, they should be pre-dried to a moisture level less than 5% within 2 hrs.

If a small quantity of seeds are spread out in a drying chamber used usually in laboratories in a layer of about 1 cm depth and are heated, seeds are dried rapidly. In such a case, the dry heat treatment can be performed in a drying chamber at an appropriately high temperature without pre-drying. But if a large quantity of seeds are subjected to the dry heat treatment in the same way, drying occurs slowly. In this case, pre-drying procedure at a low temperature (e.g. 40°C) is required to reduce the moisture content of the seeds to a critical level, usually less than 5%, prior to the treatment of heating at a higher temperature. By this procedure, damage by heating seeds with high moisture content can be minimized.

Vegetable crops with high heat resistance of seeds

Although the dry heat treatment is an effective method for disinfection of seeds as mentioned above, the kinds of vegetable crops to which this treatment has been applied are limited. Therefore, the possibility of the application of this method to other vegetable crops than bottle gourd should be investigated. Thus, the heat resistance of 23 common vegetables were examined under the severe

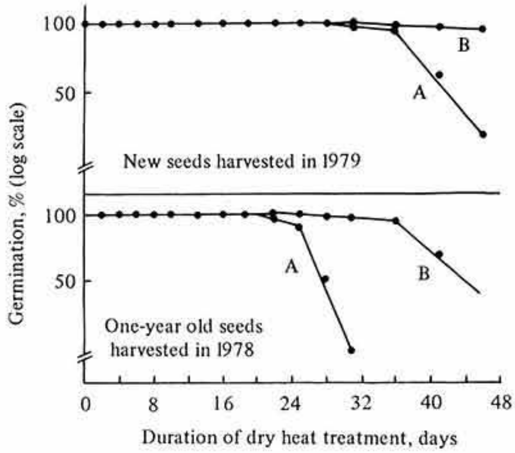

Fig. 4. Changes in the rate of germination in Chinese cabbage seeds under the circulating air at 75°C.
A: First count on 2nd day
B: Final count on 6th day

condition, that is, at 75°C for 7 days[7].

For example, the change in germinability of Chinese cabbage seeds during dry heat treatment is shown in Fig. 4[7]. It is obvious from Fig. 4 that both the new and one-year old seeds of Chinese cabbage withstood the heat treatment for longer duration than bottle gourd (Fig. 3). In Chinese cabbage, therefore, the dry heat treatment may be applicable for disinfecting seed borne diseases. The results obtained with other vegetables were summarized as follows:

1) Vegetable crops in which the dry heat treatment is applicable are:
spinach, watermelon*, cucumber, bottle gourd*, lettuce, Chinese cabbage, carrot, and tomato*.
2) Vegetable crops in which the further investigation is necessary to adopt this method are:
turnip, cauliflower, cabbage, broccoli, daikon, eggplant, pumpkin, and onion.
3) Vegetable crops to which application of this method is considered to be difficult are:
soybean, snap bean, pea, celery, green pepper, edible burdock, and Welsh onion.

* For vegetables with an asterisk, dry heat treatment is routinely performed in some seed companies in Japan for seed disinfection.

In the case of green pepper, germinability is reduced by the dry heat treatment at 73°C for 3 days. However, the treatment is still applicable, because this treatment is very effective on preventing a serious seed borne disease caused by virus.

Some problems associated with dry heat treatment

The dry heat treatment has, more or less, unfavorable effects on the seeds, resulting in the decrease in the physiological and biochemical activity of seeds. Therefore, the storage condition after treatment is important to maintain the viability.

When the seeds were subjected to a dry heat treatment, emerged seedlings occasionally showed abnormalities; a cracked hole was observed on the center of a cotyledon or one cotyledon did not develop[5,7]. Abnormal seedlings increased when the moisture of the seeds was high at the beginning of the treatment or the treatment duration was long. To avoid the occurrence of abnormal seedlings, the seeds should be rapidly dried and it is necessary to choose an appropriate temperature and duration of a dry heat treatment in vegetable crops such as daikon, cabbage, and turnip in which abnormal seedlings often appeared by this treatment.

The dormancy of bottle gourd seeds was broken by dry heat treatment[5] Seeds of many vegetables have the dormancy for several months after harvest. Dry heat treatment may also be effective in promoting the simultaneous germination of those vegetable seeds in fields.

In conclusion, the dry heat treatment is a useful and effective disinfection method of seeds for controlling the seed borne diseases in vegetables, although the treatment should be carefully performed to maintain the germinability of seeds.

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