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Hot Water Seed Treatment: A Review

Suryapal Singh, Harshita Singh and Narender K. Bharat

Abstract

In present day agriculture, use of chemicals for crop production is discouraged. Hence, other alternative treatments for disease control must be developed, and hot water treatment is one of them. It is a feasible practice, both financially and time wise. Hot water soaking is a very age-old practice, efficient in destroying pathogens borne both outside the testa and inside the seed testa by using temperature hot enough to kill the organism but not quite hot enough to kill the seed. Extensive research work has been reported on hot water treatment in vegetables. Therefore, an attempt has been made to review the information available regarding the effect of hot water treatment on growth, disease incidence and yield of vegetables.

Keywords: hot water treatment, capsicum, seed-borne disease

1. Introduction

In the present age when the crop production is protected by chemicals and threat of disease due to exposure to these chemicals is at a rise, organic farming is getting momentum. This organic farming is regulated by certain certifications including chemical-free state of agriculture farm. In this condition use of chemicals will not help farmers for these certifications; rather, there is rejection of the produce. Here it becomes pertinent to involve those practices which are natural and can help control diseases naturally. Priming and pelleting are commonly used practices for seed treatment to enhance the production of *Capsicum*, but some chemicals are involved in it. *Capsicum* is in great demand as it is a vegetable with very rich contents of vitamins and minerals and is cooked in combination and individually as per the taste of consumers. Rejections of pesticide, insecticide and chemical sprayed crop attracted the attention for the present review where hot water seed treatment is controlling the diseases in bell pepper. Pepper (*Capsicum annuum* L. var. *grossum*) is commonly known as *Capsicum*, *Shimla Mirch*, green pepper, cherry pepper or bell pepper, and it belongs to the solanaceous group of vegetables. *Capsicum* is one of the most important vegetable crops grown extensively throughout the world especially in the temperate countries [1] and has attained a status of high value crop in recent years because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid and other vitamins and minerals [2]. Fruits of sweet pepper are either used as salad or cooked as vegetable or processed and is appreciated worldwide for its flavour, aroma and colour. It contains several bioactive substances like capsaicin, vitamin E, pro-vitamin A, carotenoids, flavonoids and other secondary metabolites with antioxidant properties [3]. In the states of Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Darjeeling District of West Bengal and hills of UP,

bell pepper is grown in summer, whereas in the states of Karnataka, Tamil Nadu, Bihar and Maharashtra, it is grown in the autumn season [4]. In India, bell pepper covers an area of 29,800 ha with 171,370 tonnes production and productivity of 5.75 tonnes/ha [5]. Sweet pepper is a warm-season crop, which grows well under an extended frost-free season, with the capability of producing high yields of exceptional quality. The best temperature range for sweet pepper growth is 20–25°C, whereas the best germination temperature is 29°C. A temperature of less than 29°C reduces the growth of seedling, leading to increased exposure of seedlings to insects, diseases or salts, resulting in damaged or dead seedlings [6]. High temperatures adversely affect the productivity of many plant species of which sweet pepper is of no exception.

High humidity in the environment and moist soil together with optimum temperature result in high incidence of various diseases. Diseases like bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*), *Cercospora* leaf spot (*C. capsici*), anthracnose (*Colletotrichum capsici*) and virus diseases are seed borne in nature. To avoid the occurrence of such diseases, seed treatment with various chemicals has been recommended from time to time [7]. But in present day agriculture, use of chemicals for crop production is discouraged. Hence, other alternative treatments for disease control must be developed. One such treatment is with hot water which is economically as well as temporally feasible. Farmers, along with a little technical assistance, can easily adopt this treatment. This treatment is also successful for destroying viruses like *mosaic virus* that affect bell pepper. It is very efficient in destroying pathogens borne both outside the testa and inside the seed testa. In this area no such work has been done in the case of bell pepper.

2. Disease of sweet pepper

Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*), bacterial wilt (*Pseudomonas solanacearum*), anthracnose/ripe fruit (*Colletotrichum* spp.), *Cercospora* leaf spot/frog eye leaf spot (*C. capsici*), bacterial canker (*Clavibacter michiganensis*) and viruses like Tomato spotted wilt virus (TSWV) are some of the most important diseases of sweet pepper that cause huge economic losses to the farmers. Seed-borne diseases of bell pepper are the most important problems in organic farming systems because of the limitation in chemical control methods. For the successful management of any disease under normal conditions, sanitation, elimination of primary source and chemical protection at initial stages are some of the measures recommended. Various workers are now engaged in developing and testing the non-chemical methods for seed-borne diseases of vegetables including bell pepper.

3. Seed technology

Seed is the primary and essential starting point of a wide range of horticultural crops, including the majority of vegetables. The high-quality seeds of vegetable varieties that display early, consistent, dynamic seedlings and better- and good-quality fruits from individual seed sown at favourable or unfavourable conditions have increased significantly in recent years. Seedling emergence and field stand establishment is one of the problems faced by the growers, especially in early planting where adverse conditions are prevailing (low temperature and high soil moisture). Delayed, erratic germination and emergence, poor stand, slow early seedling growth rate and non-uniform maturity often limit crop production even

under optimum environmental conditions [8–10]. Extensive seed germination and seedling appearance has increased the occurrence of pre-damping off mortality caused by soil-borne fungi [11]. This also leads to establishment of weeds in the fields even before the crop seedlings are mature enough to be cultivated, competing with the main crop for nutrients, and moreover, they hinder the processes of fertilisation, chemical application and mechanical harvesting.

4. Hot water treatment

The most appropriate seed treatment with respect to least damage, economy, efficiency and application is hot water soaking. It is an old-age practice based on treatment with hot water whose temperature is high enough to kill the pathogen but not high enough to harm the seed, hence a very good technique to control many seed-borne diseases [12, 13]. Heat treatment may be applied for agricultural commodities by (1) immersion in hot water, (2) exposure to vapour heat, (3) exposure to hot dry air, (4) treatment with infrared radiation or (5) microwave radiation. Hot water treatments of seed and plant material are classical thermophysical methods of plant protection and are more eco-friendly and effective than chemical treatments.

Hot water treatment can be damaging or not practical for seeds of peas, beans, cucumbers, lettuce, sweet corn, beets and some other crops [12, 14, 15], but it is highly recommended for pepper, eggplant, tomato, cucumber, carrot, spinach, lettuce, celery, cabbage, turnip, radish and other crucifers. It may also severely damage old seeds, and therefore, a small sample of any seed lot over 1 year should be first treated and then tested for germination to determine the amount of injury that may occur. Hot water treatment is recommended for seeds with surface or deep-seated infections. Effective treatment temperature and duration have to be found out for every vegetable crop and the relevant pathogens. The principle is to eliminate the pathogens as far as possible without decreasing germination of seeds. For example, just a 5-min difference in treatment time can lead to diverse differences in the germination rate of cabbage seed.

A number of tests and studies of heat treatment must be undertaken to optimise the time and temperature that are most adaptable to the seeds to be treated and the pathogens to be killed before practical application. Susceptibility to heat damage may differ among different varieties of plant species [16, 17]. The time/temperature combination for a given plant seed depends on many factors interacting with the heat susceptibility of the host, viz., conditions of external layers, dormancy, moisture content, age and vigour [18]. Particularly, it has long been known that the smaller the initial water content of seeds is at the time of heating, the greater the resistance to high temperatures [19]. Two major groups of proteins may be activated by the hot water treatments that induce fruit resistance: heat shock proteins (HSPs) and pathogenesis-related (PR) proteins. HSPs are believed to play a major role in thermotolerance [20–22]. Among the PR proteins, most characterised enzymes chitinases and β -1,3-glucanases hydrolyse polymers of fungal cell walls and are, therefore, thought to be involved in the plant defence mechanism against fungal infection [23, 24].

5. Effect of hot water treatment on different vegetables

Nega et al. [15] stated that even with longer treatment times, hot water treatment with a temperature of 40°C had no significant effect on the seed-borne pathogens. However, on all the crops investigated, hot water treatments at temperatures

50 or 53°C for 10–30 min had a good phytosanitary effect. In the majority of cases, these treatment conditions did not affect seed germination. Therefore, to reduce the effect of higher temperature like 53°C on germination, comparatively shorter treatment time must be used, especially on sensitive crops like cabbage, etc. The treatment of 50°C for 30 min is optimal against *Phoma lingam* on cabbage. They also observed that on crops like carrot, cabbage and parsley treatments at temperatures 50–53°C for 10–30 min gave a good elimination of *Alternaria* species.

In the past, Walker [25] observed complete abolition of *P. lingam* from cabbage seeds with treatment at 50°C for 30 min. Clayton [26] recorded similar results for 25 min as well as for 30 min at 50°C. Bant and Storey [27] showed good effects of hot water treatment against *S. apiicola* on celery in field trials. In the view of lack of alternatives, this treatment has proved to be an efficient method on celery and parsley seeds against the *Septoria* species [28] and that too with well-known yield increase. Due to the rapid spread of bacterial diseases like those caused by *Xanthomonas* species [29], hot water treatment has emerged as an important method to control seed-borne bacterial diseases because of lack of chemical or other well-established treatments [30, 31]. The documented efficiency of this treatment on cabbage and cauliflower against *X. campestris* pv. *campestris* is between 25 and 90%. The treatments differ between 50°C for 10–60 min [32–34] and 52°C for 30 min [35].

Melanie et al. [36] demonstrated the efficiency of hot water treatment method in reducing bacterial diseases like bacterial spot and bacterial canker in tomato under greenhouse as well as open-field conditions. They also observed that after treating, seedlings from the same seed lots with hot water did not get diseased in the greenhouse or fields. In plots/fields established from hot water-treated seed, the occurrence of bacterial canker was less extensive, and yields were higher than the plots/fields established from non-treated seeds. Also, fruits from non-treated seeds were considerably smaller than fruits from treated seeds. Reduced infection frequency of bacteria responsible for bacterial canker and bacterial leaf spot was observed in tomato seeds after hot water treatment with increased fruit size and yield.

Hot water treatment of seeds of okra (*Abelmoschus esculentus*) at 52°C for 30 min resulted in the improved crop, both in greenhouse and field conditions. The improvement was with respect to increase in fruit number, leaf number, fruit length and girth, total number of seeds per fruit, seed weight and plant biomass. The hot water treatment of seeds also reduced the frequency of mycoflora infection in the seeds, hence enhancing the vigour index and germination percentage of the seedlings [37]. After soaking carrot seeds in hot water at 52°C for 25 min, the bacterial pathogen (*Xanthomonas hortorum* pv. *carotae*) in and on the carrot was killed [38]. On the other hand, Nandini and Shripad [39], observed that hot water treatment at 52°C for 10 min was effective in controlling the bacterial blight of cowpea with minimum number of infected seedlings and percentage of seedling infection. Germination was also not much affected as compared to control (58 vs. 76.00%).

The effects of hot water treatments of carrot seeds on seed-borne fungi, germination, emergence and yield were studied by Hermansen et al. [40] where the seeds infected with *Alternaria dauci* were hot water treated at temperature ranging from 44 to 59°C at intervals of 5°C for periods of 5–40 min. Treatment of carrot seeds with hot water at 44, 49 and 54°C improved germination rate and reduced the occurrence of *A. dauci*. Hot water treatment at 54°C for 20 min inhibited *A. dauci* without negatively affecting germination rate or yield. Ranganna et al. [41] demonstrated that the potato tubers can safely be stored without sprouting for 12 weeks at 8 or 18°C, if treated with 57.5°C hot water for 20–30 min.

Hot water treatment of seeds was also observed to be helpful in controlling seed-borne pathogens in sweet pepper. Aguilar et al. [42] observed that hot water treatment of bell pepper at 45°C for 15 min or 53°C for 4 min before storing them at 8°C reduced the occurrence of fungal infections. Several hot water treatments of bell pepper seeds resulted in considerable drop-off in seed viability but had no effect on seed vigour [43]. No study can be found in the literature that attempted to arrive at the optimum time-temperature combination for sweet pepper. Therefore, the effect of hot water treatments of sweet pepper seeds on seed viability and seedling vigour needs to be investigated (Table 1).

Causal agent	Host	Thermotherapy tested	Result	Ref.
<i>Clavibacter michiganensis</i> subsp. <i>michiganensis</i>	Tomato (<i>Lycopersicon esculentum</i>)	Hot water treatment at 53, 54 and 55°C for 10–60 min	Germination remained unaffected up to 55°C for 30 min; bacteria were recovered after 30 min at 53 and 54°C and not after 40 min	Bryan [44]
<i>C. m.</i> subsp. <i>michiganensis</i>	Tomato	Soaking infected seeds 30 min in hot water at 56°C	Plants develop significantly less disease than when no seed treatment is used; seed germination is slightly reduced	Shoemaker and Echandi [45]
<i>P. s.</i> pv. <i>phaseolicola</i>	Bean (<i>Phaseolus vulgaris</i>)	Hot water treatments: 50°C for 45–60 min	Reduction of bacterial number by 98–100% but 45% reduction in seed germination for 60 min soaking with naturally infected seeds	Tamietti [46]; Tamietti and Garibaldi [47]
<i>P. s.</i> pv. <i>pisi</i>	Pea (<i>Pisum sativum</i>)	Dry heat at 65°C for 72 h and soaking in water at 55°C for 15 min	Significant reduction of pathogen contamination but germination lowered 5–20%	Grondeau et al. [48]
<i>P. s.</i> pv. <i>tomato</i>	Tomato	Infected seeds are subjected to hot water treatment at 48°C for 60 min	Pathogens are killed, and germination is not affected	Devash et al. [49]
<i>Xanthomonas campestris</i> pv. <i>campestris</i>	Cabbage, cauliflower (<i>Brassica oleracea</i>)	Hot water treatment at 50°C for 30 min	Pathogens are eliminated successfully by this treatment to prevent seedling infestation	Shekhawat et al. [34]
<i>X. c.</i> pv. <i>carotae</i>	Carrot (<i>Daucus carota</i>)	Hot water treatment (52°C for 10 min)	Can prevent pathogen infestation	Ark and Gardner [50]
<i>X. c.</i> pv. <i>cucurbitae</i>	Pumpkin (<i>Cucumis pepo</i>)	Hot water treatment at 54 and 56°C for 30 min	Greatly reduces the level of seed infestation but does not completely eliminate it	Moffett and Wood [51]

Adopted from Grondeau et al. [52].

Table 1.
 Thermotherapy to free seeds from pathogenic bacteria.

6. Conclusion

High incidences of disease in consumers leading to fatal diseases like cancer have attracted the attention of researchers. The causative agents were explored, and the focus was indiscriminate use of chemicals starting from seed treatment to crop productions. The residual effects of pesticides, herbicides and other chemicals are long lasting, adversely affecting the health of consumers. Some mechanism and treatments are needed to address these problems. Hot water treatment is one such mechanism which has been reviewed in the chapter to help the consumers taking care of all the public health issues. The present study provides easy to practice technique to farmers without involving cumbersome techniques to farmers to protect the capsicum against bacterial, viral and fungal diseases, leading to optimal productions without harming the interest of consumers.

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