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ASSESSMENT OF THERMO PHYSICAL SEED TREATMENTS IN CONTROLLING SEED BORNE DISEASES AND ENHANCING SEED QUALITY PARAMETERS IN VEGETABLE CROPS: A REVIEW

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ABSTRACT

Thermophysical seed treatments are an effective method to control seed-borne diseases as they use heat to kill the organisms, but not hot as much which kill the seeds. Hot water, hot air and microwave treatment of seeds and propagating materials not only control pests and diseases but also increase plant root development, bud growth and germination. Hot water, hot air and microwave seed treatments are playing a vital role in elimination of the pathogens from seed as contaminated seeds are the source of pathogen transmission. The pathogen is eradicated internally or externally from seed surface by using hot water, hot air and microwave treatments without harming germination and viability of seeds. These seed treatments are nonchemical methods and have been successfully used to control seed-borne pathogens in various crops. The hot water or hot air treatment of seeds has resulted in the removal of seed coat-related dormancy and enhanced the rate of germination due to activation of the physiological and biochemical mechanism of seeds. When compared to chemical seed treatments, thermophysical seed treatments promote the physiological and biological activity of seeds, resulting in higher seed germination and fruit yield characters while having no harmful impact on the environment.

Key words : Hot water, Hot air, Microwave seed treatment, Seed quality parameter.

Introduction

Vegetable crops are the major source of nutrition to the human beings. These crops are cultivated worldwide. The crops are affected by many pests and diseases caused by fungi, bacteria, viruses and nematodes and a major part of their produce is lost every year due to these. Many of the pathogens are seed-borne in nature especially fungi, bacteria and viruses and are therefore, carried to the fields through infected seeds. Seed-borne pathogens are present internally or externally on the seed surface and cause seed rot and damping-off diseases. Seed treatments are effective to control or eradicate seed-borne pathogens without affecting seed germination, seed vigour and seed viability. Pathogen resistance level developed due to continuous use of chemicals which developed the alternative method known as a physical seed treatment.

Physical seed treatment such as hot water, hot air oven and microwave are effective in controlling seed-borne diseases and are known to increase rate of seed germination, seed vigour and seed viability. Use of hot water and hot air treatments is recommended to disinfect the seeds. Seed treatment with chemicals does not destroy the internally seed-borne pathogen but these thermophysical seed treatments destroy the pathogen efficiently both inside and outside the seed tissue (Forsberg, 2004). Effect of different temperatures studied on different crop seeds and found that it needs to standardize temperature and duration according to seed spp. without affecting seed viability (Song and Zhen, 2008; Kou, 2008). Schirra *et al*. (2000) reported that heat applied in the form of hot water, hot air or microwave had shown a reduction in pathogen inoculums, the germ tube elongation, inoculum in form of spores and generate a physiological response of fruit tissue to reduce the pathogen inoculum. Heat treatment activates PR proteins and enzymes like chitinase, β-1, 3 glucanase significantly and increases the activity of an antifungal compound. These antifungal compounds filled those gaps which serve as an entry point of a pathogen. Thermophysical seed treatments are based on the principle of different temperatures and times that destroy the pathogen on or in the seeds without affecting seed quality parameters.

Thermophysical methods of seed treatment and their mode of action

Hot water seed treatment

Hot water seed treatment activates two major groups enzymatic activity heat shock proteins (HSPs) and pathogenesis-related (PR) proteins. HSPs are responsible for the thermo tolerance of seeds (Waggoner, 1917). Bant and Storey (1952) studied the effect of hot water seed treatments on celery seeds infected with *Septoria apiicola* and found that hot water seed treatment reduced the *Septoria apiicola* infection. Baker (1962) studied the combined effect of durations and temperatures are influenced by the number of factors like seed dormancy, seed viability and vigour and found that moisture content of the seeds is inversely proportional to the heat resistance. Cowpea seeds infected with cowpea banding mosaic virus exposed to higher temperature had shown a reduction in the virus. Higher temperatures treatment of seeds resulted in the reduction of seed viability but incubation of higher temperatures exposed seeds to lower temperature resulted in inactivation of virus (Sharma and Varma, 1975). Hot water seed treatment activates the pathogenesis-related protein. The plant defence activities are generated by pathogenesis-related (PR) proteins as these proteins are helpful in hydrolysis of fungal cells polymers (Howarth *et al*., 1993; Vierling *et al*., 1991). McGee (1995) reported that vegetable seeds treated with hot oil had resulted in the sloughing of the seed coat. Many workers have reported the effect of hot water seed treatments on seed coat impermeability to water hydration for gaseous exchange and release of inhibitors (Longer and Degago, 1996). Hot water seed treatment eradicates externally or internally seed-borne diseases but the seeds must be dried after treatment to prevent the damage caused by imbibed water in seeds (Aggarwal and Sinclair, 1997). Hot water seed treatment had shown a reduction in seed-borne bacterial diseases without adverse effects on the environment as compared to chemicals. Similarly, the hot water seed treatment effect was studied on seeds of cabbage infected with *Xanthomonas* spp. by Poschenrieder (2000) and he reported that hot water seed treatment significantly reduced the bacterial infection from seeds. Hot water treatment decreased the hardness of endosperm due to imbibition and enhanced the process of germination due to activation of germination-related activities such as gibberellic acid synthesis, protein biosynthesis and RNA synthesis (Black and Bewley, 2000). The effect of hot water treatment on tomato seedlings infected with bacterial diseases like bacterial spot and bacterial canker was studied by Melanie *et al*. (2005) and Nandini and Shripad (2015) and they found that hot water treatment at 52°C for 10 minutes reduced the bacterial diseases to a greater extent in cowpea. Floyd (2005) found that the thermo tolerance of vegetables seeds varied according to crop. Nafussi *et al*. (2001) reduced postharvest decay of *Penicillium digitatum* upon hot water treatment. Hot water treatment inhibits the activity of pathogen and developed a resistance mechanism in fruit by the formation of lignin scoparone, scopoletin content. Abdulazeez (2016) studied the effect of hot water seed treatment on the seeds of *Senna obtusifolia* at 100°C from 1 to 20 minutes and found that hot water seed treatment at 100°C for 2 to 20 minutes enhanced the germination rate by breaking seed dormancy.

Microwave seed treatment

Buffler (1993) studied the mode of action of microwave radiation and reported that the heating effect of microwave radiation is based on the law of attraction between the charged particles and polar molecules. The attraction between charged particles and polar molecules had released energy in the form of heat and the amount of heat absorbed by seed depends upon the dielectric properties of the seed and resulted in disinfection of the seed. Microwave radiation thermal involves dipole rotation and ionic polarization mechanism to heat the biological dielectric material (Bouraoui *et al*., 1993). The low power microwave radiation seed treatment enhanced the rate of germination effectively in wheat and barley (Ponomarev *et al*., 1996). Reddy *et al*. (1998) treated the mustard, wheat, soybeans and peas with microwave radiation at 2.45 GHz and found a significant reduction in the *Fusarium graminearum* pathogen infection in seeds. Microwave radiations inhibit pathogen growth at optimum temperature and duration and resulted in the reduction of host-pathogen interaction (Friesen, 2014).

Based on dielectric heating mechanism, microwave seed treatment activates various enzymes involved in seed germination thus improves the process of germination by increasing biological components synthesis (Radzevicius *et al.*, 2013). Microwave radiation in soybean seeds at 2.45 GHz for 6 to 12 minutes was found to increase the amount of lipids in the seed coat which significantly enhanced the germination (Yoshida *et al.*, 2000). In seeds of *Isatis indigotica*, treated with microwave radiation resulted enhanced activities of enzymes catalase, peroxidase and superoxide dismutase (Ping Chen, 2006). Oprica (2008) treated mustard seeds with microwave radiation at different duration and found that enzyme activity of catalase and peroxidase in seeds depends on the number of factors like age of the plants, exposure time and seed germination or ungerminated seeds. Similarly, Chen *et al*. (2009) reported that microwave radiation activates enzymatic activity to maintain the turgidity of the cell membrane and significantly increased plant resistance. Polar molecules of water interact with the microwave radiation with higher frequency resulting in the generation of heat which caused the evaporation of water molecules (Jiao *et al.*, 2012).

Hot air seed treatment

Seed treated with hot air required long-duration exposure and it is reported that after hot air treatment, seeds must be rehydrated to enhanced germination (Grondeau *et al.*, 1992). High temperature caused cell death and due to which metabolic processes in embryo responsible for germination were also reduced. Seedling length and dry weight variation observed due to inhibition of seeds supply with assimilates necessary to synthesize the storage compounds required during the germination process (Powell, 2006). Hot air seed treatment of legumes and large seed crops at specific temperature and duration, however, decreased some of the seed-borne diseases without any seed damage. Hot air seed treatment had shown a significant reduction in bacteria, fungi and viruses (Grondeau *et al.*, 1994; Ling, 2010). Viruses have been categorized by Nyland and Goheen (1969) based on their capacity to tolerate heat. Exposure time and temperature combinations have been used to kill viruses with low thermal inactivation points as low temperature was non injurious to the host (Geard, 1958). Heat treatments reduced the availability of RNA molecules in seeds, preventing virus packing and suppressing virus movement in the plant, and resulting in virus-free new growth regulation (Matthews, 1970). Couture and Sutton (1980) reported that hot air seed treatment significantly reduced the virus infection than the fungus infection of seeds in barley. The effect of hot air seed treatment was studied in legumes and it was found that due to large size seed legumes tolerate the hot air exposure for a longer duration than that of hot water treatment (Echeverry *et al*., 1983). McGee (1981) reported that hot air seed treatment affects seed viability due to long heat duration exposure and concluded that hot air seed treatment should be conducted with a proper wrapping of seeds in seed bags to maintain seed viability.

Effect of thermophysical seed treatments on seed quality parameters

Hot water seed treatment

Seeds of sunflower treated with hot water at a temperature of 80°C for 15 min resulted in 65 percent more germination as compared to untreated seeds (Akinola *et al.*, 2000). Alamgir and Hussain (2005) reported that hot water treatment of seeds lead to the higher seedling length and the variation in seed coat thickness was observed one of the reasons for seedling length differences. Okra seeds treated with hot water at 100^{o}C for 1 minutes increased percentage of germination than control (Mtui *et al*., 2010; Mohammad *et al*., 2012). Hot water treatment of tomato seeds at 48°C and 52°C had no detrimental effect on germination percent, germination rate and seed vigour including seedling radical length and shoot length and seedling dry weight (Divsalar *et al*., 2014). According to Singh *et al*. (2019), hot water seed treatment in capsicum seeds at 50 to 52°C for 30 minutes obtained the best outcomes in germination rate, seedling height, seedling dry mass, seed vigour index-I and seed vigour index-II in comparison to control seeds. High temperature results in membrane disintegration and leakage of electrolytes from cytoplasm which leads to increase in electrical conductivity (McDonald, 1999).

Microwave seed treatment

Microwave treatment of seeds can improve germination and performance because the heating action enhances the transparency of bio membranes, leading to better germination (McCormack, 2004). The effects of low power microwave radiation was studied on seeds of wheat, chickpea, green gram and moth bean by Ragha *et al*. (2011) and they found that low microwave radiation treatments increased the germination and seedling vigour of plants. Tomato, carrot and radish seeds when treated with high power microwave irradiation for 10 minutes had the best effect on seedling dry weight and seedling height of these vegetables (Radzevicius *et al*., 2013). Microwave treatment of rice, sorghum, soybean, castor, brinjal, tomato and cluster bean seeds carried at 600 W for 15 seconds increased germination, seedling length, seed vigour and reduced the fungal infestation as compared with control (Deepthi *et al*., 2014). Buckwheat seeds treated with 600 W microwaves for 10 seconds showed doubling of the germination rate after 7 days of incubation in germinator (Wang *et al*., 2018). The exposure of microwave radiations on sunflower, chickpea seeds for 10 and 30 seconds increased the germination, seed vigour-I, seed vigour-II and upgraded the health of these plant (Kanwal *et al*., 2018).

Hot air seed treatment

Shiomi *et al*. (1992) treated the seeds of cabbage with hot air at a temperature of 70°C for 7 days and reported disinfection of black rot pathogen, *Xanthomonas campestris* pv. *campestris* and influenced the germination rate. Murugesan *et al*. (2008) reported that increase in the hot air temperature activated the process of aerobic respiration in seeds which utilized the endosperm of seeds and resulted in declined germination percent. Seeds of *Solanum gilo* treated with hot air at 60°C for 40 minutes influence the seed germination rate (Umechuruba *et al*., 2013). Denton *et al*. (2013) treated the seeds of *Corchorus olitorus* with hot air at 120°C for 5 minutes and observed the best influence on germination rate as compared to other treatments. The effect of hot air was studied on seeds of wheat and corn by Jiao *et al*. (2016) and they observed a reduction in the disease incidence and both germination percentage and seed vigour increased at hot air temperature 65°C for 10 minutes as compared to the treatment at 70°C for10 minutes.

Effect of thermophysical methods on diseases incidence

Hot water seed treatment

Hot water treatment of spring wheat seeds carried at temperatures from 60°C to 80°C was found to reduce significantly the seed-borne inoculums of *Fusarium graminearum* (Clear *et al*., 2002). Raychoudhury and Lele (1966) observed that hot water treatment at 50 to 52°C for 15 to 30 minutes in tomato, brinjal, chilli resulted in higher seed germination and lowest incidence of seed mycoflora. Nega *et al*. (2002) treated the seeds of carrot, cabbage, celery, parsley and lettuce with hot water at 40°C to 60°C for 10 to 30 minutes and showed that hot water seed treatment at 50°C for the duration of 30 minutes reduced seed-borne diseases like *Septoria* spp., *Peronospora* spp., *Alternaria* spp., *Phoma* spp. significantly without affecting germination. Bari *et al*. (2003) reported that mungbean seeds treated with hot water at 55°C to 80°C for duration of 20 minutes resulted in reduced seed infection with pathogens. Hossain (2009) studied the effect of hot water seed treatment on diseases like *Phomopsis vexans* in brinjal and found that hot water seed treatment at 55°C for l5 minutes effectively reduced the disease incidence. Effect of hot water seed treatment at different temperature from 43°C to 64°C for 10 to 30 minutes was studied on *Cyperus esculentus* seed tuber by Garcia-Jimenez *et al*. (2004) and they found that hot water treatment at 53 to 55°C for 25 to 30 minutes resulted in reduction of tuber borne pathogen inoculums. Toit and Perenz (2005) studied the effect of hot water treatment in spinach seeds at 40ºC to 55 ºC for 10 to 40 minutes and reported that hot water seed treatment at 40ºC for 10 minutes eradicated the infection *Cladosporium variabile* fungus. Rahman *et al*. (2008) treated the seeds of maize with hot water at different temperatures from 48°C to 52°C and found that hot water treatments at 50°C for 15 minutes increased the seed germination and significantly reduced the infection of seed-borne pathogens *like Bipolaris maydis*, *Cuvularia lunata*, *Fusarium* spp. from seeds. Braga *et al*. (2010) found that tomato seeds treated at 55°C for 30 minutes resulted in reduction of fungi like *Rhizopus* spp., *Aspergillus* spp. and *Cladosporium* spp. without any loss to seed quality parameter. Missanjo *et al*. (2014) reported that hot water seed treatment of *Acacia polyacantha* seeds had shown the enhanced rate of germination and growth parameter at the nursery stage. Hashim *et al*. (2019) studied the effect of hot water treatment in rice seeds and found that hot water seed treatment at 50°C for 15 minutes significantly resulted in eradication of blast pathogen from rice seeds. Carrot seeds treated with hot water at 50°C for 30 to 40 minutes had shown a decrease in *Alternaria radicina* without affecting the germination of seeds (Babadoost *et al*., 2020).

Microwave seed treatment

Many researchers have reported a positive effect of microwave seed treatments on elimination of pathogens in many crops. Microwave radiation is considered as an effective nonchemical method for eradication of the fungal, bacterial and other seed-borne pathogens of various crops (Sneaman and Wallen, 1966). Cavalcante and Muchovej (1993) studied the effect of microwave radiation on morphological characteristics of fungal cell and reported that single celled spores of *Colletotrichum lindemuthianum* were more sensitive than multicellular spores of fungus. Tylkowska *et al*. (2010) studied the effect of microwave seed treatment on bean seeds and showed that microwave radiation of power 650 W reduced the incidence of *Penicillium* spp. Jakubowski (2010) investigated the effect of microwave seed treatment at 100 W and showed that microwave radiation had reduced the canker disease incidence on the potato tubers. Gaurilcikiene *et al*. (2013) treated the wheat seeds with microwave radiation at different duration from 5 to 20 minutes and found that infection of *Tilletia caries* fungus had reduced with increased duration of microwave radiations. Knox *et al*. (2013) reported that the microwave treatment at 15 seconds, 30 seconds and 45 seconds effectively reduced the *Fusarium* spp. and *Microdochium nivale* fungus infection from wheat seeds. Mancini *et al*. (2014) studied that microwave seed treatment at 800 W for 32 seconds had resulted in reduction of internally seed borne pathogens. Friesen *et al*. (2014) reported that microwave radiation resulted in eradication of the seed-borne pathogen like *Xanthomonas axonopodis*, *Pseudomonas syringae* and *Colletotrichum lindemuthianum* in bean. Mohaptra *et al*. (2014) described that microwave radiation reduced moisture content by a mechanism of dielectric heating. Taheri *et al*. (2018) found that fungus *Ascochyta* spp. penetrate the seed coat and reside inside the embryo of lentil seeds and microwave radiation for 60 seconds effectively penetrated inside the seed coat and reduced the seed infection without affecting the seed composition. Mangwende *et al*. (2020) treated *Euclayptus* spp. seeds in microwave oven at different durations and reported that microwave seed treatment at 1400 W for 120 seconds effectively reduced the anthracnose disease infection.

Hot air seed treatment

Hot air treatment was considered as effective method to destroy the pathogenic bacteria which are internally seed-borne and were not destroyed by pre-soaking or seed coating (Li *et al*., 1997). Forsberg *et al*. (2002) studied the effect of hot air seed treatment in a thin layer and fluidized bed on barley seeds infected with *Pyrenophora teres* and found that hot air seed treatment had effectively eradicated the seed-borne pathogen of barley and resulted in improved plant health. Thomas *et al*. (2004) studied the effect of hot air heat treatment on lupin seeds and found that *Colletotrichum lupini* seed infection reduced significantly at a temperature range of 60°C to 80°C without affecting seed germination. Ling (2010) treated the tomato seeds with hot air and found that thermophysical hot air treatment at 72°C or 80°C for 48 to 72 hour reduced seed-borne Pepino Mosaic Virus with the least effect on seed germination as compared to hot water treatments and chemical treatments. Gama *et al*. (2014) treated the seeds of fennel with hot air at 70°C temperature for different durations and found that thermophysical treatment at 70°C for 12 days was effective to control the infection of *Alternaria* spp. fungus. Sun *et al*. (2015) found that hot air seed treatment of melon at 75°C for 72 hour was effective to eradicate the bacterial fruit blotch caused by *Acidovorax citrulli* from seeds. Shi *et al*. (2016) treated cucumber seeds with hot air at 70°C for 40 to 90 minutes and evaluated that hot air treatment at 70°C for 90 minutes had reduced the activity of internally seed borne pathogen. Jiao *et al*. (2016) studied the effect of hot air seed treatment on corn seeds and found that hot air treatment at 65°C for 10 minutes influenced the physiological and bio enzymatic activity of seeds by inhibiting the *Aspergillus flavus* fungus growth.

Conclusion

It concluded that thermophysical seed treatment have resulted in better seed germination and controlling disease incidence in nursery and field conditions at optimum temperature and duration and there is great need to standardized the temperature and duration according to crop. It is better to use thermo physical seed treatments for better seed germination and to control disease incidence in nursery. Among hot water hot air and microwave seed treatment hot water is regarded best method and easiest method for seed treatment and controlling disease incidence in nursery.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable

Credit authorship contribution statement

Romika Thakur: Idea of article, Literature search, analysis and interpretation of results, Conceptualization, Methodology, Investigation, Formal analysis & Writing Original Draft. (First Author)

Abhishek: (Corresponding Author) Idea of article, Literature search, analysis and interpretation of results, Conceptualization, Methodology, Investigation, Formal analysis & Writing Original Draft.

Pradeep Kumar Singh: Supervision in Study, Review &Editing. (Co-author)

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Perspective of study : The details obtained from the literature about the effect of hot water, hot air and microwave seed treatments in vegetable crops have been reviewed in this review paper. Chemical seed treatment and continuous use of chemicals in comparison to thermophysical seed treatment have harmful impact on the environment. The use of chemicals in controlling plant diseases result in environmental pollution, health hazard and also farmers have to pay a high price. Less chemical use is recommended to conserve important soil microbes and natural biodiversity. So, it is better to use less expensive, less risky, nonchemical and eco-friendly methods of seed treatment. To avoid chemical entry into the seed, various thermophysical seed treatment methods have been developed to control seed-borne diseases.

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