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Effect of Thermophysical Methods of Seed Treatments Like Hot Water, Hot Air and Microwave Seed Treatment on Seed, Seedling Quality Parameters and Disease Incidence in *Solanum melongena*

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Research Article

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Keywords: *Solanum melongena*; Diseases incidence; Hot air seed treatment; Hot water treatment; Microwave seed treatment; Seed quality parameters; Seedling growth parameters

ABSTRACT

Objective: *Solanum melongena* is cultivated mostly as rainy season crop. High rainfall hinders the seed germination and enhances the process of disease infection. Thermophysical methods of seed treatment have resulted in higher seed germination and less seed borne diseases without any environmental and health hazards as compared to chemical treatment. The aim of study was to standardize the temperature and duration of thermophysical seed treatment on seed quality parameters in brinjal.

Methods: The present investigation was carried out in the Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh during January 2021 in laboratory conditions and March 2021in field conditions. Hot water, hot air, microwave seed treatment and untreated seeds were tested for their effect of seed quality parameters and disease incidence in brinjal under laboratory conditions and nursery conditions.

Conclusions: Hot water treatment at 49°/60 minutes and 50°C/30 minutes, hot air treatment at 72°C/48 hours and 74°C/36 hours and microwave seed treatments at 10 seconds and15 seconds resulted in higher speed of germination, germination Percent, seedling length, seed vigour-I and seed vigour-II. These standardized treatments along with untreated were used in nursery conditions. In nursery conditions highest seedling growth was recorded in T_2: Microwave 15 seconds whereas speed of germination, speed of 50% germination, total emergence percent and less disease incidence was recorded in T5: hot water seed treatment at 49°/60 minutes.

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INTRODUCTION

Brinjal (*Solanum melongena L.*), is one of the important vegetables of tropical countries like India. It is native to Southern India and ranks 4th important vegetable crop. In Himachal Pradesh, it is cultivated as rainy season crop. Disease incidence gets high as a result of high rainfall. Major diseases of brinjal are seed borne like damping off; Phomopsis blight [1]. The use of chemicals in controlling plant diseases result in environmental pollution. Thermophysical seed treatments are effectively control seed-borne diseases as they use heat to kill the organisms but not hot as much which kill the seeds [2] .The hot water seed treatment has significantly regulated the gaseous exchange, water uptake and it is regarded as antimicrobial against plant pathogenic fungi [3]. Seeds of Phaseolus vulgaris treated with microwave at power 650 watts for 15 to 120 seconds and reported that microwave treatment at shorter duration significantly enhanced the germination percentage [4]. Heat treatments of hard coated seeds also make the seed permeable to water and induce the germination [5]. The investigation was carried to standardize the temperature and duration of hot water, hot air and microwave seed treatment on seed quality parameters in brinjal cultivar Pusa Purple Cluster.

MATERIALS AND METHODS

The first experiment was carried in laboratory conditions to standardize the temperature and duration of hot water, hot air and microwave seed treatments in brinjal. Under laboratory conditions experiment was laid out in completely randomized design comprising four replications as per ISTA guidelines. Seeds of brinjal were treated with the different levels of temperature and duration of hot water, hot air and microwave seed treatments using thermostatic hot water bath, hot air oven and microwave oven respectively. Hot water bath works thermostatically controlling temperature with time. The seeds were pre- soaked in distilled water for 15 minutes. Pre-soaked seeds wrapped in muslin cloth and placed in a beaker of water and that beaker was placed in thermostatic hot water bath for required period as per the treatment detail (49˚C/30 minutes, 49˚C/45minutes,.....,52˚C/60 minutes). At the end of the treatment, seeds were shade dried. Total hot water seed treatment combinations were 12+1 (Control)=13. Hot air electric oven with forced air circulation system was used and temperature was set through digital PID controller. After the desired temperature obtained, the seeds were kept in kraft paper bags and subjected for heating to different treatment combination such as 70˚C/24 hours, 70˚C/36 hours,.....,76˚C/48 hours. Total hot air seed treatment combinations were 16+1 (Control)=17. Microwave seed treatment was carried in microwave oven of 900 watts power supplied by magnetron operating at 2450 MHz frequency. Seeds were placed in sterilized open glassware petriplates and subjected to different period of exposure of 5, 10, 15 and 20 seconds at micro power level 900 watts. After the treatments, seeds were taken out and used for study of further seed quality test. Seed quality parameters were worked out on procedure as given below under laboratory conditions.

The details of the experiment in laboratory conditions are as under:
Crop: Brinjal
Cultivar: Pusa purple cluster
Number of replications: 4
Design: Completely randomized design

The details of the experiment in nursery conditions are as under:
No. of treatments: 7
No. of replications: 3
Design: Randomized completely block design

Germination percentage

The germination test was carried out as per the ISTA guidelines (Anonymous, 1996). Four hundred seeds from each treatment and the tests were carried out in 4 replications, having 100 seeds each. The seeds were allowed to germinate using paper towel method at 25˚C ± 2˚C in seed germinator. The first and final counts of seeds were taken at 7th and 14th day of the test. Germination percentage was calculated by using the formula given below

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds used}} \times 100$$

Seedling length (cm) and seedling dry weight (mg)

Ten normal seedlings were selected at random from each replication and used to work out the seedling length. Total seedling length was worked out by taking the total length of seedling from the tip of the primary leaf to the tip of the

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primary root with the help of scale. The length of seedling was measured on 14th day of germination test and these seedlings were used to work out seedling dry weight (mg) and seedlings were kept in oven at 80˚C for 48 hours for drying.

Seedling vigour index- I and Seedling vigour index- II

Seedling Vigour Index- I (SVI-I) and Seedling Vigour Index- I (SVI-I) was calculated as per the formula given by Abdul-Baki and Anderson [6].

SVI-I = Germination (%) x Seedling length (cm)

SVI-II= Germination (%) x Seedling dry weight (mg)

Electrical conductivity (S/m)

About 2 g seed sample was weighed and immersed in 250 ml distilled water at 25˚C ± 1˚C for 24 hours. Thereafter, seeds were removed with a clean forcep and water left was considered as leachate. Then, electric conductivity meter was warmed for 30 minutes. Firstly the conductance of leachate was measured .Then the electrical conductivity of the leachate was calculated as:

Actual EC of leachate =EC of seed leachate−EC of distilled water

Two best treatments on the basis of performance under laboratory conditions from hot water, hot air and microwave along with untreated (control) were used for nursery rising. In nursery conditions experiment was laid out in Randomized completely block design with three replications.

The various observations recorded in nursery as per procedure given below:

Total emergence percent – It was calculated by using formula given below

$$\text{Emergence (\%)} = \frac{\text{Number of seedlings emerged}}{\text{Total number of seeds used}} \times 100$$

Speed of germination

The number of seedlings emerged were counted on each day from when the emergence started and speed of germination was calculated using the formula by Maguire (1962).

$$n_1/d_1+n_2/d_2+n_3/d_3+\ldots\ldots\ldots\ldots\ldots\ldots+n/d$$

Where, n=number of emerged seedling, d=number of days

Speed of 50% germination

The number of seedlings emerged were counted on each day until the 50% germination and speed of germination was calculated.

$$n_1/d_1+n_2/d_2+n_3/d_3+\ldots\ldots\ldots\ldots\ldots\ldots+n/d$$

Where, n= number of emerged seedling, d= number of days

Disease incidence (%)

The incidence of various diseases like damping- off and viruses was recorded in nursery by using the formula given below:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of diseased seedling per plot}}{\text{Total number of seedling per plot}} \times 100$$

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RESULTS AND DISCUSSION

The data presented in Table 1 revealed that the germination percentage ranged between 74.50 to 85.25 % under different hot water seed treatments Hot water seed treatment at 49°C for 60 minutes and 50°C for 30 minutes were recorded with 85.25% and 83.75% germination, respectively. The value of hot water seed treatment at 49°C for 60 minutes was found statistically at par with hot water seed treatment at 50˚C for 30 minutes. The untreated seeds had showed intermediate germination (81.00 %). Hot water seed treatment at 52°C for 60 minutes and at 52°C for 45 minutes was recorded with lowest germination. Hot water seed treatment affected seedling length (cm) after germination and the seedling length (cm), in general, ranged between 7.10 and 13.47 cm under various treatments. In the seeds treated with hot water at 49˚C for 60 minutes highest seedling length (13.47 cm) was recorded which was followed by seeds treated with hot water at 50˚C for 30 minutes. The values of both treatments were statistically at par with each other. Seeds treated with hot water at 52˚C for 45 minutes and 52˚C for 60 minutes were recorded with inferior seedling length. The values of seedling length of both treatments were statistically at par with each other. Untreated seeds had showed an intermediate seedling length of 10.82 cm. A significant difference in seedling dry weight was observed when seeds were treated with hot water for different temperatures and durations. The range of seedling dry weight (mg) in different hot water treatments varied between 11.30 to 16.15 mg. Hot water seed treatments at 49˚C for 60 minutes and 50˚C for 30 minutes was recorded with 16.15 mg and 15.80 mg seedling dry weight, respectively and both treatments were found statistically at par with each other. Seeds treated at 52˚C for 60 minutes produced the lowest seedling dry weight followed by seed treatment at 52˚C for 60 minutes. Both the treatments were statistically at par with each other. The seedling dry weight under untreated control was 13.88 mg. The data on seedling vigour index – I (Length) ranged from 528.39 to 1148.70 under various treatments. The highest seed vigour–I (1148.70) was recorded in hot water seed treatment at 49˚C for 60 minutes, which was statistically at par with hot water seed treatment at 50˚C for 30 minutes. Seeds treated with hot water at 52˚C for 60 minutes and 52˚C for 45 minutes were recorded with inferior seed vigour index- I and both treatments were statistically at par with each other. The control demonstrated an intermediate seedling vigour index-I (876.05). In general, the seed vigour index–II (Mass) was between 842.50 and 1375.85. The highest seed vigour index-II (1375.85) was obtained at 49˚C for 60 minutes and the second highest was recorded at 50˚C for 30 minutes. The values obtained under these parameters were statistically at par with each other. At 52˚C for 60 minutes, the lowest seed vigour-II (842.50) was recorded as compared to control. Electrical conductivity (S/m) of hot water treated seeds was observed from 0.51 to 0.85 S/m. Electrical conductivity was recorded highest (0.85 S/m) at 52˚C for 60 minutes which was found statistically at par with hot water seed treatment at 52˚C for 45 minutes and 52˚C for 30 minutes in which 0.82 S/m and 0.79 S/m electrical conductivity was recorded, respectively. The lowest electrical conductivity 0.51 S/m, 0.56 S/m and 0.57 S/m was recorded in control, at 49˚C/30 minutes and 50˚C/30 minutes, respectively. The values of electrical conductivity in these treatments were found statistically at par with each other. Hot water seed treatment makes hard seed coat impermeable to water hydration for gaseous exchange and release of inhibitors, which resulted in enhanced germination percent of seeds [7]. Our laboratory results for electrical conductivity are similar to Rajatha *et al*. [8]. Who reported that higher temperature increased the electrical conductivity of seeds and declined the germination percent and viability of the seeds? The electrical conductivity of seeds increased with temperature. The reason might be high temperature results in membrane disorganization which had resulted in increased leakage of electrolytes from the cytoplasm and leads to increased electrical conductivity.

Table 1. Effect of different hot water seed treatments on seed quality parameters in brinjal.

Treatment	Germination (%)*	Speed of germination	Seedling length (cm)	Seedling dry wt. (mg)	SVI–I (Length)	SVI–II (Mass)	Electrical conductivity (S/m)
49˚C/30 minutes	77.50 (8.86)	12.91	9.87	13.42	765.47	1040.99	0.53
49˚C/45 minutes	78.75 (8.93)	12.10	10.26	13.67	807.27	1077.40	0.54
49˚C/60 minutes	85.25 (9.28)	15.40	13.47	16.15	1,148.70	1375.85	0.56
50˚C/30 minutes	83.75 (9.20)	15.36	12.60	15.80	1,055.47	1322.05	0.57

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50°C/45 minutes	80.00 (9.00)	13.98	10.11	14.60	810.51	1167.84	0.61
50°C/60 minutes	79.75 (8.98)	13.51	9.32	14.15	743.10	1128.95	0.68
51°C/30 minutes	79.50 (8.97)	13.51	9.15	13.81	727.55	1097.08	0.70
51°C/45 minutes	79.25 (8.95)	13.26	9.12	13.66	723.17	1082.84	0.72
51°C/ 60 minutes	79.00 (8.94)	13.16	9.07	13.27	716.67	1049.10	0.73
52°C/30 minutes	78.75 (8.93)	12.99	8.62	13.25	679.50	1042.90	0.79
52°C/45 minutes	76.50 (8.80)	10.90	7.18	11.33	550.01	866.70	0.82
52°C/60 minutes	74.50 (8.68)	10.33	7.10	11.30	528.39	842.50	0.85
Control	81.00 (9.05)	12.21	10.82	13.88	876.05	1125.87	0.51
C.D (0.05)	0.17	1.20	1.06	1.24	85.62	106.56	0.07
*The values in parentheses are square root transformed values; **The values in parentheses are angular transformed value; SVI–I: Seed Vigour I; SVI–II: Seed Vigour II; cm: centimetre; S/m: Siemen/metre; mg: milligram							

Data depicted in Table 2 showed that the germination percentage of hot air treated seeds ranged from 59 to 78.25%. Amongst all hot air seed treatments, seeds treated at 72°C for 48 hours recorded with highest germination (78.25%) and seeds treated at 74°C for 24 hours were recorded with second highest germination.

Table 2. Effect of different hot air seed treatments on seed quality parameters in brinjal.

Treatment	Germination (%)*	Speed of germination	Seedling length (cm)	Seedling dry weight (mg)	SVI – I (length)	SVI- II (Mass)	Electrical conductivity (S/m)
70°C/24 hours	72.50(58.38)	7.77	6.99	8.01	505.70	581.16	0.55
70°C/36 hours	74.50(59.68)	8.22	7.14	8.17	532.19	608.59	0.57
70°C/48 hours	74.50(59.67)	8.46	7.24	8.53	538.79	635.08	0.62
70°C/60 hours	69.50(56.49)	6.80	5.99	7.48	415.93	519.96	0.65
72°C/24 hours	73.00(58.71)	8.23	7.20	8.63	526.69	631.42	0.68
72°C/36 hours	74.75(59.84)	8.29	7.34	8.66	548.21	647.27	0.70
72°C/48 hours	78.25(62.21)	9.48	8.55	9.54	670.18	746.35	0.72
72°C/60 hours	70.00(56.81)	6.15	7.18	7.24	501.95	506.34	0.80
74°C/24 hours	76.25(60.84)	9.01	8.53	9.44	650.43	720.13	0.81
74°C/36 hours	73.50(59.02)	6.24	7.24	7.64	532.18	561.38	0.83
74°C/48 hours	71.50(57.79)	5.38	7.00	7.46	497.98	533.45	0.86
74°C/60 hours	67.75(55.41)	5.12	6.90	7.21	467.70	489.46	0.87
76°C/24 hours	71.75(57.91)	5.24	7.00	8.45	501.53	607.40	0.89
76°C/36 hours	66.50(54.64)	5.15	6.68	8.00	442.85	532.68	0.94
76°C/48 hours	63.75(53.00)	3.59	6.60	7.19	420.90	458.42	0.96
76°C/60 hours	59.00(50.19)	3.56	5.53	5.05	325.95	298.13	1.00
Control	82.00(64.90)	13.46	10.87	13.68	891.67	1122.19	0.51
C.D (0.05)	2.13	1.01	0.96	0.82	69.29	69.78	0.11

These two treatments were found statistically at par with each other. Seeds treated at 76°C for 60 hours and 76°C for 48 hours were recorded with lower germination than control as well as other hot air treatments. Under different treatments seedling length range was observed from 5.53 to 10.87 cm. In hot air seeds treatment at 72°C for 48 hours highest seedling length (8.55) was recorded and it was further followed by 8.53 seedling lengths at 74°C for 24 hours. The values

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of both hot air treatments were statistically at par with each other. Seeds treated at 76°/60 hours were recorded with minimum seedling length (5.53 cm). The control recorded a seedling length of 13.68 cm. The different treatments had showed significant difference in seedling dry weight. The data of seedling dry weight was ranged from 5.05 to 13.68 mg. The maximum seedling dry weight was recorded at 72°C/48 hours and 74°C/24 hours. The Inferior seedling dry weight was recorded 5.05 in hot air seed treatment at 76°C for 60 hours as compared to control. Seed vigour index–I (Length) in general, ranged from 325.95 to 891.67. The superior seed vigour index-I was analyzed 670.18 and 650.43 at 72°C for 48 hours and 74°C for 24 hours, respectively. The recorded data of highest seed vigour –I for both treatments were found statistically at par with each other. Seeds treated at 76°C for 60 hours were obtained with lowest (325.95) seed vigour index–I as compared to control. The seed vigour index-II was recorded highest for same treatments in which seed vigour- I was recorded. The data for seed vigour index–II (Mass) in general, ranged, from 298.13 to 1122.19. The maximum seedling vigour index-II was recorded 746.35 for hot air seed treatment at 72°C/48 hours which was statistically at par with hot air seed treatment at 74°C for 24 hours the lowest seed vigour-II was observed at 76°C for 60 hours as compared to untreated seeds. Higher hot air temperature declined the germination percentage due to loss of moisture content in the treated seeds. The germination percentage of seeds gradually increased at low temperature due to loss of seed coat related dormancy. According to Chun *et al*. [9]. Observed that the germination rate of radish seeds declined with the higher hot air temperature at 76°C for 48 hours due to loss of moisture content. In hot air seed treatments electrical conductivity (S/m) ranged from 0.51 to 1.00 S/m. Hot air seed treatments at 72°C for 48 hours and 74°C for 24 hours was recorded with 0.72 S/m and 0.81 S/m electrical conductivity, respectively. The highest electrical conductivity was recorded 1.00 S/m in hot air seed treatment at 76°C for 60 hours followed by 0.96 S/m at 76°C for 48 hours and 0.94 S/m at 76°C for 36 hours. The values of electrical conductivity in all these treatments were found statistically at par with each other. As control seeds were not treated with different temperatures, therefore it was recorded with the minimum electrical conductivity (0.51 S/m), which was statistically at par with 0.55 S/m, 0.57 and 0.62 S/m. The electrical conductivity 0.55, 0.57 and 0.62 S/m were recorded at 70°C for 24 hours, 70°C for 36 hours and 70°C for 48 hours, respectively. Farooq *et al*. who observed that seeds treated at higher temperature resulted in a higher loss of leachates whereas seeds treated at lower to medium ranged temperature did not result in leaching of the solutes from the membrane, but it was found to be enhanced the seed quality parameters [10].

Data depicted in Table 3 presented that the highest germination percentage (93.25%) observed when seeds were exposed to microwave for 10 seconds and second highest germination was observed at 15 seconds. However, the treatments for 10 seconds and 15 seconds were found statistically at par with each other. The increased microwave duration had declined the germination percentage. The minimum germination was recorded in microwave seed treatment at 20 seconds as compared to control. The statistical data of seedling length (cm) ranged between10.82 to 17.26 cm. The microwave treatment at 10 seconds resulted with maximum seedling length of 17.26 cm which was statistically at par with 16.97 cm seedling length found at 15 seconds. The inferior seedling length was observed at microwave seed treatment at 20 seconds as compared to different microwave seed treatments and untreated seeds. The untreated seeds were recorded with higher seedling length (13.88 cm) as compared to the microwave seed treatment at 20 seconds. In general the statistical value of seedling dry weight was observed between 8.09 to 15.36 mg. Microwave seed treatment at 10 seconds was recorded with maximum (15.36) seedling dry weight which was statistically at par with microwave seed treatment at 15 seconds. Seeds treated at 20 seconds were recorded with minimum seedling dry weight as compared to untreated seeds. The range of seed vigour index–I (Length), was observed from 717.32 to 1609.83. The highest seed vigour index-I was recorded (1609.83) at 10 seconds and second highest seed vigour-I was recorded at 15 seconds. These treatments were found statistically at par with each other and lowest seed vigour-I was recorded in microwave seed treatment at 20 seconds as compared to control. In general the range of seed vigour index–II (Mass) was recorded from 664.39 to 1432.85. Amongst the different treatments, seed vigour index-II was recorded highest (1432.85) at 10 seconds preceded by 1355.82 seed vigour index-II at 15 seconds. However, the microwave seed treatments for 10 seconds and 15 seconds were statistically at par with each other. The lowest (664.39) seed vigour-II was observed at microwave seed treatment at 20 seconds as compared to control. Polar molecules of water on seeds interact with the microwave radiations resulting in the generation of heat which caused the evaporation of water molecules and therefore, longer duration of microwave declined germination as compared to shorter-duration microwave [11]. Electrical conductivity (S/m) in microwave seed treatment ranged from 0.51 to 0.71 S/m. The lowest electrical conductivity (0.51 S/m) was recorded in control followed by 0.53 S/m in microwave seed treatment at 5 sec. Electrical

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conductivity in microwave seed treatment at 10 seconds and 15 seconds recorded with 0.56 S/m and 0.63 S/m, respectively. However, the values under these treatments were found statistically at par with each other. The highest electrical conductivity was recorded (0.71S/m) at microwave seed treatment 20 seconds. According to Ozden *et al*. Electrical conductivity of seeds increased with ageing of seed at higher temperatures, resulting in lower seed germination [12].

Table 3. Effect of different microwave seed treatments on seed quality parameters in brinjal.

Treatment	Germination (%)*	Speed of germination	Seedling length (cm)	Seedling dry wt. (mg)	SVI–I (Length)	SVI–II (Mass)	Electrical conductivity (S/m)
5 seconds	89.50 (9.51)	24.63	14.90	9.78	1296.01	875.77	0.53
10 seconds	93.25 (9.70)	27.51	17.26	15.36	1609.83	1,432.85	0.56
15 seconds	91.00 (9.59)	26.80	16.97	14.92	1543.02	1,355.82	0.63
20 seconds	79.00 (8.94)	10.15	9.08	8.09	717.32	664.39	0.71
Control	81.00 (9.05)	12.21	10.82	9.40	876.05	827.70	0.51
C.D (0.05)	0.16	1.748	1.92	1.53	171.70	136.62	0.13

Data presented in Table 4. The maximum emergence percentage of 89.66 % was recorded in T_5 treatment (hot water seed treatment at 49˚C for 60 minutes) followed by T_2 treatment and T_6 treatment. However, these treatments were statistically at par with each other. T_4 treatment had the lowest emergence percentage. In nursery condition analysis of variance for speed of germination revealed a significant difference for number of germinated seeds per day. The speed of germination varied from 16.49 to 26.69 in different treatments. Amongst different treatments, the highest speed of germination (26.69) was recorded in T_5 treatment (hot water seed treatment at 49˚C for 60 minutes) followed by 24.25 in T_6 treatment (hot water seed treatment at 50˚C for 30 minutes) and 22.34 in microwave treatment for 15 seconds. These treatments were statistically at par with each other. In T_4 treatment (hot air treatment at 74˚C for 24 hours) lowest speed of germination (16.49) was recorded which followed by 16.91 speed of germination in T_7 treatment (control) and 17.52 in T_3 treatment (hot air treatment at 72˚C for 48 hours). The values under these treatments were statistically at par with each other. Speed of 50 % germination in general, ranged from 11.04 to 19.23. Amongst different treatments, T_5 treatment (hot water seed treatment at 49˚C for 60 minutes) was recorded with highest speed of 50% germination (19.23) whereas the speed of 50% germination (11.04) was recorded lowest in T_4 treatment (hot air seed treatment at 74˚C for 24 hours) which was statistically at par with T_3 treatment (hot air treatment at 72˚C for 48 hours), and also at par with control in which 12.55 and 12.19 speed of 50% germination was recorded , respectively. Baskin reported that hot water seed treatment enhanced the emergence percentage under nursery conditions due to softening the hard seed coat.

Table 4. Effect of thermophysical seed treatments in brinjal on total emergence (%) speed of germination and speed of 50% germination under nursery conditions.

Treatment	Total emergence (%)*	Speed of germination	Speed of 50% germination
T_1: Microwave 10 seconds	84.00 (9.21)	21.52	14.22
T_2: Microwave 15 seconds	88.33 (9.45)	22.34	15.53
T_3: Hot air 72°C/24 hours	76.33 (8.79)	17.52	12.55
T_4: Hot air 74°C/48 hours	73.00 (8.60)	16.49	11.04
T_5: Hot water 49°C/60 minutes	89.66 (9.51)	26.69	19.23

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T_6:Hot water 50°C/30 minutes	85.66 (9.30)	24.25	18.27
T_7: Control	77.66 (8.86)	16.91	12.19
C.D (0.05)	0.29	4.38	1.69

In nursery, analysis of variance is presented in Table 5 revealed significant difference in seedling length. At different time intervals of 28.00, 40.00 and 60.00 days after sowing, seedling height of 7.30, 13.46 and 21.85 cm, respectively were recorded in T_2 treatment (microwave seed treatment at 15 seconds) which was found statistically at par with T_5 treatment (hot water seed treatment at 49˚C for 60 minutes) and was also found at par with T_6 treatment (hot water seed treatment at 50˚C for 30 minutes). The T_5 treatment (hot water seed treatment at 49˚C for 60 minutes) and T_6 treatment (hot water seed treatment at 50˚C for 30 minutes) were observed seedling heights of 6.92, 13.28, and 20.76 cm and 6.41, 12.16, and 20.49 cm at 28.00, 40.00, 60.00 days after sowing, respectively. The T_5 treatment (hot air seed treatment at 74˚C for 24 hours) were recorded with lowest seedling heights of 3.90, 7.59 and 18.92 cm, which was found statistically at par with T_4 treatment (hot air seed treatment at 72˚C for 48 hours) in which the seedling height was observed 4.07, 8.90 and 19.35 cm after 28.00, 40.00, 60.00 days of seed sowing, respectively. The medium-ranged seedling heights were recorded 5.71 cm, 11.09 cm and 19.06 cm after 28.00, 40.00 and 60.00 days of sowing in control, respectively. The results of our current investigation for seedling height in a nursery are in line with those of Wang, who found that short-duration microwave radiation produced convective heat and significantly raised seedling length [13].

Table 5. Effect of thermo physical seed treatments in brinjal on seedling height under nursery conditions.

Seedling height (cm) after days of sowing			
Treatment	**28**	**40**	**60**
T_1: Microwave 10 seconds	5.67	11.33	19.23
T_2: Microwave 15 seconds	7.30	13.46	21.75
T_3: Hot air 72°C/24 hours	4.07	8.90	18.99
T_4: Hot air 74°C/48 hours	3.90	7.59	17.26
T_5: Hot water 49°C/60 minutes	6.92	13.28	20.76
T_6:Hot water 50°C/30 minutes	6.41	12.16	20.49
T_7: Control	5.71	11.09	19.06
C.D(0.05)	1.19	1.70	1.48

Statistical analysis of the data on ungerminated seeds presented in Table 6 revealed that minimum percentage of ungerminated seeds (3.00%) was found in T_2 treatment (Microwave seed treatment 15 seconds) which was followed by control, T_2 and T_5 treatment. However, all these treatments were statistically at par with each other [14]. The percentage of ungerminated seeds was recorded maximum in hot air seed treatment at 72°C for 48 hours. In control, the highest incidence of post-emergence damping-off was observed (7.66%), whereas T_6 treatment was recorded with the lowest incidence of damping-off (1.33%) which was statistically at par with T_5 treatment. In T_4 treatment (hot air seed treatment at 74°C for 24 h) the lowest incidence of viruses was observed to be 2.66 % which was statistically at par with T_6 treatment (hot water seed treatment at 50°C for 30 minutes and T_3 treatment ((hot air seed treatment at 72°C for 48 hours) in which 3.33% and 4.66% viruses incidence was recorded, respectively [15]. The highest incidence of viruses (%) was recorded (11.33 %) in control (T_7) which was found statistically at par with microwave seed treatment at 10 seconds in which 8.66 % viruses incidence was recorded [16].

Table 6. Effect of thermophysical seed treatments on disease incidence in brinjal under nursery conditions.

Treatment	Ungerminated seeds (%)*	Damping-off (Post emergence) (%)*	Virus (%)*
T_1: Microwave 10 seconds	3.67 (1.88)	3.66 (2.15)	8.66 (3.10)

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T_2: Microwave 15 seconds	3.00 (1.69)	2.33 (1.82)	6.33 (2.70)
T_3: Hot air 72°C/24 hours	14.67 (3.81)	4.33 (2.30)	4.66 (2.35)
T_4: Hot air 74°C/48 hours	21.67 (4.65)	2.66 (1.91)	2.66 (1.91)
T_5: Hot water 49°C/60 minutes	6.00 (2.43)	1.66 (1.62)	5.33 (2.50)
T_6:Hot water 50°C/30 minutes	9.67 (2.91)	1.33 (1.52)	3.33 (2.07)
T_7: Control	3.33 (1.79)	7.66 (2.94)	11.33 (3.50)
C.D (0.05)	0.97	0.30	0.44

Our findings for disease incidence in nurseries were in line with those of Nega who found that hot water seed treatment at 50°C for 30 minutes was effective against seed-borne diseases. Seed treatment with chemicals does not destroy the internally seed-borne pathogen but these thermophysical seed treatments destroy the pathogen and viruses RNA particles efficiently both inside and outside the seed tissue [17].

CONCLUSION

The present investigation concluded hot water seed treatment 49°C/60 minutes, 50°C/30 minutes microwave seed treatment at 10 seconds and 15 seconds and hot air seed treatment at 72°C/48 hours and 74°C/36 hours has shown the best effect on seed quality parameters under laboratory conditions but under nursery conditions hot water seed treatment at 49°C/60 min has showed best effect on seed quality attributes and controlling disease incidence.

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