QUALITY IMPROVEMENT OF SOME VEGETABLE SEEDLINGS THROUGH SEED PRIMING WITH H_2O_2 AND GA_3

UMMAY MOHSINA

REGISTRATION NO. 13-05454

DEPARTMENT OF HORTICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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BY

UMMAY MOHSINA

REGISTRATION NO. 13-05454

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Approved by:

Prof. Dr. Mohammad Humayun Kabir
Supervisor
Department of Horticulture
Sher-e-Bangla Agricultural University

Asst. Prof. Khairul Kabir
Co-Supervisor
Department of Horticulture
Sher-e-Bangla AgriculturalUniversity

Prof. Dr. Mohammad Humayun Kabir
Chairman
Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

DEPARTMENT OF HORTICULTURE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **“QUALITY IMPROVEMENT OF SOME VEGETABLE SEEDLINGS THROUGH SEED PRIMING WITH H_2O_2 AND GA_3”** submitted to the **DEPARTMENT OF HORTICULTURE**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **UMMAY MOHSINA**, Registration No. **13-05454** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

December, 2019
Dhaka, Bangladesh

(Prof. Dr. Mohammad Humayun Kabir)
Supervisor
Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Dedicated to
My
Beloved Parents

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The Author

QUALITY IMPROVEMENT OF SOME VEGETABLE SEEDLINGS THROUGH SEED PRIMING WITH H_2O_2 AND GA_3

ABSTRACT

This experiment was carried out at The Net House of Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from 1st November to 30th November 2018 to study the quality improvement of three vegetable seedlings *viz*. tomato, brinjal and chilli through seed priming with H_2O_2 and GA_3. Six priming treatments were applied under the present study *viz*. P_0 (no priming), P_1 (Hydro priming), P_2 (Priming with 0.5% aqueous solution of H_2O_2), P_3 (Priming with 1% aqueous solution of H_2O_2), P_4 (Priming with 50 ppm GA_3) and P_5 (Priming with 100 ppm GA_3). The experiment was laid out in Completely Randomized Design (CRD) with three replications. Data were collected on seed germination and growth parameters for each crop and analyzed statistically. Regarding seed priming performance on tomato (Part-1),P_4 showed the highest percentage of seed germination (96.00%), shoot length (19.60 cm), root shoot ratio (0.38), RGR (0.30) and vigor index (3367.68) whereas P_0 showed lowest performance for the respected parameters. The lowest abnormal seedlings of tomato were also found from P_4 treatment. In case of seed priming performance on brinjal (Part-2), P_5 gave the highest percentage of seed germination (97.33%), shoot length (18.92 cm), RGR (0.30) and vigor index (3421.15) whereas P_0 showed lowest results for the aforesaid parameters. The lowest abnormal seedlings of brinjal were also recorded from P_5 treatment. Consideration of seed priming performance on chilli (Part-3), P_5 showed highest percentage of seed germination (88.00%), shoot length (17.88 cm), RGR (0.30) and vigor index (2921.60) whereas P_0 showed lowest performance. The minimum abnormal seedlings were also recorded from P_5 treatment.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Among vegetable crops solanaceous vegetables like tomato, brinjal and chilli have high demand in our country. Tomato (*Solanum lycopersicum* L.) is one of the most important edible and nutritious vegetable crop in the world. It ranks next to potato and sweet potato with respect to world vegetable production. It ranks third in terms of world vegetable production. The demand for the crop is year round, owing to the versatility of its usages both in fresh and processed food preparation. It gains more popularity due to its antioxidant property. It is a very good source of vitamin A and C (Behera, 2016).

Vegetables crops are important in human nutrition and its importance in daily nutrition is getting increases all around the world. Rapid germination and emergence of seedlings are essential for successful crop establishment, importance of good and high crop establishment is recognized by researchers and as well as by farmers they are major challenges in successful crop production (Murungu *et al*., 2004). Main reasons for the successful crop stand are high germination percent and good vigor of seedlings (Noor *et al.*, 2013). Modern strategic approaches are however necessary for sustainable development of crops so as to meet increasing demand in both domestic and export market (Soubhagya Behera, 2016).

Research on techniques for improving the germination, growth and yield of crop species has been done for many years. For successful crop establishment seed priming could play a vital role in crop production. It is a cost effective technique to ensure uniform emergence and high vigourity of seeds which is leading to better crop establishment and yield. Priming can also help to increase enzyme activity and neutralize the effects of seed ageing. According to Lee and Kim (2000), de novo synthesis of α- amylase is also known during priming. Thus, higher vigour of the primed seeds relates to metabolic activities in seeds due to increased α-amylase activity.

It is a simple, effective and low cost technique in which seeds are partially hydrated to a point where pre-germination metabolic activities start without actual germination by treating with different chemicals or growth regulators, and then re-dried until close to the original dry weight. In crop production, stand establishment determines plant density, uniformity, and management options. For expensive hybrid vegetable seeds, it is particularly important that seeds germinate rapidly and uniformly, tolerate adverse germination conditions, and produce normal seedlings. Seed vigor has been proved to be the primary factor governing seed quality, in the context of successful stand establishment. Hence seed invigouration or enhancement of seed vigor has been a major area of interest for researchers, owing to its high industrial and economic implications. Seed invigouration is a post-harvest, pre-sowing technique for improvement of seedling emergence and stand establishment. The most promising invigouration technique for improving the rate and uniformity of plant stand is seed priming (Pandey *et al.*, 2017).

Several chemicals including synthetic plant hormones have been used for seed priming (Afzal *et al*. 2012). The effectiveness of these different priming agents, however, varies under different stresses as well as between crop species. Plant hormones are active members of the signal cascade involved in the induction of plant stress responses (Pedranzani *et al*. 2003). H_2O_2 is one of the main chemicals which are induced to elevate in plants by biotic and abiotic stresses. Environmental stresses are known to induce H_2O_2 and other toxic oxygen species production in cellular compartments and result in acceleration of leaf senescence through lipid peroxidation and other oxidative damage. It also changes the redox status of surrounding cells where it initiates an antioxidative response by acting as a signal of oxidative stress (Sairam and Srivastava, 2002). Some authors suggested that H_2O_2 plays a dual role in plants: at low concentration, it acts as a messenger involved in signaling and in triggering tolerance against various abiotic stresses, but at high concentrations H_2O_2 causes oxidative stress which leads to a loss of protein function, membrane integrity, and to programmed cell death (Asada, 1996). In case of GA_3 priming, Yogananda *et al*. (2004) noticed that bell pepper seeds invigorated with GA_3 (200 ppm) recorded higher germination, root and shoot length seedling dry weight, rate of germination and seedling vigour index over control. Tzortzakis (2009) suggested that priming with Gibberellin (GA_3) treatments in endive and chicory may improve rapid and uniform seedling emergence and plant development in nurseries and/or in greenhouses, which is easily applicable by nursery workers with economic benefits.

Priming enhances seed performance by increasing germination rate and uniformity which will be resulted in faster and better seedling development that was reported in various crop seeds (Powell *et al*, 2000). In Bangladesh little is known about seed priming and information regarding seed priming with H_2O_2 and GA_3 in vegetable crops like tomato, brinjal and chilli in Bangladesh is scarce. Therefore, the present study will be undertaken with the following objectives:

- To achieve uniform and faster germination through seed priming with H_2O_2 and GA_3.
- To enhance the rate of germination, improve seedling stand and crop establishment thereby providing a simple and cheap technology to the farmer for better crop production.
- To find out the safe limit of priming duration and concentration of H_2O_2 and GA_3 for maximum benefit of germination and seedling growth of those three (3) vegetables.

CHAPTER II

REVIEW OF LITERATURE

Tomato, brinjal and chilli are important vegetable crops in our country. Farmers suffer from various natural problems like germination, salinity etc. for vegetable cultivation. Seed priming can reduce the water requirement and increase germination percentage, adaptability to adverse situation which contribute to increase total production of crops. The following review is presented regarding quality improvement of some vegetable seedlings as influenced by seed priming.

2.1 Effect of seed priming

Hejazi *et al*. (2018) tested seed priming effect on guava (*Psidium gujava* L) seeds. The seeds were extracted from the guava fruits and were soaked in 100, 300, 500 ppm GA_3 concentrations, H_2O_2, bleach solution and a control treatment (distilled water) for 24 hrs. Germination was earlier (20 days after sowing) and higher in the GA_3 concentrations than the seeds received any other treatments. After final measurement, the highest percent germination (40%) occurred in 300 ppm GA_3 while the lowest (22%) noticed in the bleach solution. The seedlings of the bleach treatment didn't have primary leaves and died soon after they emerged.

Kamra *et al*. (2017) conducted a study to examine the effect of seed priming with different chemicals on germination and nursery raising of Ridge Gourd (*Luffa acutangula*) and Summer Squash (*Cucurbita pepo*). The seeds of both ridge gourd and summer squash were treated with GA_3 (0.1% and 0.2%) and KNO_3 (0.3% and 0.4%) for 24 hrs at room temperature on 14th Feb, 2017. Untreated seeds of both ridge gourd and summer squash were used as control. After 24 hrs of priming, the seeds were surface washed with distilled water. 10 treated seeds of each treatment were then sown in germination tray filled with growing media (cocopeat) and 10 control seeds of both vegetables were sown in plastic cups containing cocopeat. Both treated and untreated (control) seeds were then allowed to grow in laboratory for 30 days. Priming with 0.2% GA_3 solution enhanced the germination initiation, percentage of germination, mean germination time and vigour index of ridge gourd and summer squash than unprimed seeds. Average seedling length was higher in 0.3% KNO_3 primed seeds than the other seeds.

Debbarma *et al*. (2018) conducted an experiment on seed priming of chilli and coriander seeds. Seeds of chilli cv. Pusa Jwala and coriander cv. Akash Ganga primed with water (hydro priming), GA_3 (50, 100 and 150 ppm), PEG 6000 (-1.1 and -1.5 MPa) for 12, 24 and 36 hours at 25°C and keeping unprimed seeds as control were tested to study the priming effects on germination and seedling growth traits. Significant variation for germination percent, fresh ungerminated seeds, mean germination time, germination index, seed vigour index, root and shoot length, seedling fresh and dry weight, and seedling emergence were observed among the treatments. For both the crops, GA_3 and PEG priming were found the most effective. Twelve hours of hydro-priming and 24 hours of GA_3 and PEG priming were found to be the best duration. GA_3 @ 50 ppm and PEG 6000 @ -1.1 MPa were the best for enhancement of germination and seedling growth traits in both the crops.

Soubhagyabehera, (2016) reported when tomato seeds were primed with GA_3 in Utkal Kumari germination was increased by 30.56%. Venkatasubramanian and Umarani (2010) conducted storage studies to compare four different methods of priming *viz.*, hydropriming, halopriming, sand matrix priming and osmopriming accomplished for two durations. The results revealed that viability of primed seeds were dependent on the method as well as duration of priming. Among the protocols studied, hydropriming (48 hours) for tomato and sand matrix priming (80% water holding capacity, 3 days) for eggplant and chilli were established as best methods of seed priming.

Sikhondze and Ossom (2011) conducted an experiment to determine how long okra seeds should be primed in order to influence seedling growth and development. Four time durations (6, 12, 24, or 36 hours) were taken for hydro priming okra seeds. The results showed that seedlings grown from seeds that are primed for 24 hours had the greatest mean stem length and diameter, as compared to other durations and control. Tajbakhsh *et al.,* (2004) conduct experiment on onion carried different treating methods. The results indicated that hydro-priming in high humidity leads to shortening the average germination time. Kaur *et al.,* (2002) found that priming of pea by water and mannitol (4%) for 12 hours at 25°C increased the number and biomass of plants knots. The positive effect of hydro priming may be due to the maintenance of tissue water content, increase in antioxidant activities and carbohydrate metabolism (Farooq *et al.,* 2005). Hydro-priming of bean seeds in water for 7-14 hours can improve the plant performance (Ghassemi-Golezani *et al.,* 2010).

Sharma *et al.,* (2013) reported that he has taken four different priming methods like hydro-priming, osmopriming, halo-priming and solid matrix along with control. The hydro-priming technique for 12 hour duration and SM priming with calcium aluminum silicate for 24 hour significantly increased the seed germination, seedling vigour, mean germination time and marketable fruit yield. Priming in seed improve seed germination, seedling vigour and fruit yield in okra.

Saleem *et al.* (2013) set an experiment to study the effect of seed soaking on seed germination and growth of bitter gourd cultivars. Three cultivars of bitter gourd Faisalabad Long, Jaunpuri and Palee were soaked in water for various soaking durations (4, 8, 12 and 16 hours) along with control to determine the optimal soaking duration and find out the best growing cultivar. The highest germination percentage (85.18%), number of branches plant^{-1} (8.64), fruits plant^{-1} (20.70) were obtained when the bitter gourd seeds soaked for 12 hours.

Earlier emergence (6.28) and earlier flowering (39.40) were recorded in plants where seeds soaked for 16 hours. Seed soaking in water for 12 hours has the potential to improve germination, seedling growth of bitter gourd cultivars.

Mehta *et al.* (2014) reported that presowing seed priming helps to improve germination and stand establishment. Seeds of bitter gourd cultivar Solan Hara were hydro-primed at 20 C between wet germination papers for different durations keeping unprimed seeds as control. The plateau phase (Phase-II) with little change in water content from 53.3 to 57.3% (after 24 hours to 72 hours of seed priming) found as seed priming regime for bitter gourd. Significantly higher speed of germination, total% germination, seedling length, seedling dry weight, vigour index-I and II were recorded in hydro-priming for 72 hours as compared to other durations and control. Based on seed priming regime i.e. phase-II of seed germination and performance with respect to seed quality parameters it was found that 72 hours of seed priming is optimum in bitter gourd.

Abdoli (2014) set an experiment to evaluate the effects of seed priming on certain important seedling characteristic and seed vigor of fennel *(Foeniculum vulgare L.)* at Department of Agronomy and Plant Breading, Faculty of Agriculture, Maragheh University in Maragheh state, Iran. Treatment included untreated seeds (control) and those primed in water (H_2O), sodium chloride (NaCl, 100 mM) and polyethylene glycol 6000 (PEG-6000, water potential-1.6 MPa), in darkness for 18 hrs. Among them unsoaked seed (control) and hydropriming treatments had the lowest plumule, radicle and seedling length, seedling dry weight and seedling vigor index. PEG and NaCl in all of traits were better than the water priming treatments, respectively. PEG-6000 (1.6 MPa) is the best treatment for breaking of fennel seed dormancy.

Rastin *et al.* (2013) conducted an experiment in 2011 in Arak, Iran, to evaluate the effect of seed priming treatments on the seed quality of red bean. The experiment was conducted in split plot in the form of a randomized complete block design with three replications and two factors. The first factor was primary seed priming, in which seeds were or were not treated with water, for 14 hours. The second factor was complementary seed priming which was conducted after drying the seeds treated in the first stepand water, 100 ppm KCl, 0.5% $CaCl_2.2H_2O$, 50 ppm KH_2PO_4 and 20 ppm GA_3 were used to treat seeds for 14 hours.They found that Primary seed priming had no significant effect on none of the measured traits but complementary seed priming significantly affected plant dry matter, grain yield, 100 grain weight and the number of pods. The highest plant dry matter (53.06 g) and the highest grain yield (5.98 t/ha) were achieved when seeds were first treated with water (as the primary seed priming) and after drying were treated with GA3 (as the complementary seed priming).

Meena *et al.* (2013) conducted an experiment for two consecutive years 2010-11 and 2011-12 to evaluate the influence of hydropriming on the water use efficiency and grain yield of wheat *(Triticum aestivum* L.) under moisture stress. The hydroprimed and pregerminated seeds established earlier than dry seeds leading to better crop establishment under optimum, sub optimum soil moisture as well as dry soil conditions leading to higher tillering and grain yield.

Ajirloo *et al.* (2013) reported that germination and early growth under prevailing environmental conditions improves by seed priming technique. Their result showed that all the priming treatments significantly affect the fresh weight, shoot length, number of roots, root length, vigor index, time to start emergence, time to 50% emergence and energy of emergence of forage maize. The interactive effect of varieties and priming techniques were not significant for mean emergence time and coefficient of uniformity of emergence.

Aymen *et al*. (2014) reported that with increasing salinity, emergence traits (total emergence, mean emergence time), growth parameters (plant height, shoot fresh and dry weight) and mineral contents (K^+ and $Ca^{2+)}$ decreased, but to a less degree in primed seeds. At different salinity levels, primed seeds possessed higher emergence and growth rate than control.

Dastanpoor *et al.* (2013) carried out an experiment to find out the influence of hydro priming treatments on seed parameters of *Salvia officinalis* L. (sage). Seeds of sage were treated by hydro priming at three temperatures 10, 20, 30°C for 0, 12, 24 and 48 h. Hydro priming clearly improved the final germination percentage (FGP), mean germination time (MGT) and synchronized the germination of seeds at each three temperature. All the treatments resulted in germination enhancement except hydro primed seeds for 48 h at temperature 30°C. Hydro priming (12 h at 30°C) was most effective in improving seed germination that FGP was increased by 25.5% as compared to that of non-primed seeds.

Kisetu and Nagwale (2013) conducted a field study to assess the effects of priming okra *(Abelmoschus esculentus* L.) seeds var. clemson spineless in tap-water, di ammonium phosphate (DAP) and Minjingu (M) Mazao fertilizers at varying hours from non-primed (absolute control) to 48 h at an interval of 12 h. The priming materials used contained 0.115 g L^{-1} DAP, 1 g L^{-1} M-Mazao, and 1 L tap-water. Seeds primed with DAP for 36 h gave the highest number of pods (6) as compared with the absolute control (3), tap-water (5) at 36 h and M-Mazao (5) at 12 h. The highest yield (4.52 t/ha) was obtained for DAP at 36 h compared with M-Mazao (3.32 t ha^{-1}) at 12 h, tap-water (3.16 t ha^{-1}) at 36 h and absolute control (1.88 t ha^{-1}).

Ogbuehi *et al.* (2013) carried out a field experiment in 2012 at Teaching and Research Farm of faculty of Agriculture and Veterinary Medicine, Imo State University, Owerri to assess the effect of hydro priming duration on performance of morphological indices of Bambara groundnut *(Vigna subterranean* (L.) Verdc). The treatments were 12 hrs, 24 hrs, 36 hrs, 48 hrs and 0 hrs which served as control (untreated seeds). Among the treatments 24 hours hydro priming duration found to improve the performance of growth indices measured whereas the 36 hours was the least effective.

Ali *et al.* (2013) reported that seed priming improves irrigation water use efficiency, yield, and yield components of late-sown wheat under limited water condition. Seed priming treatments reduced the mean emergence time and promoted germination, early canopy development, and tillering in comparison to the untreated control. The number of fertile tillers, plant height, 1000-grain weight, and grain and biological yield were also increased by different priming techniques. On-farm priming and hydropriming for 12 h gave higher grain and biological yields and higher harvest index than other priming treatments. Seed priming increased the irrigation water use efficiency (IWUE) of all irrigation regimes. Grain yields were linearly increased at 100% ETo while maximum IWUE was achieved at 80% ETo.

Amoghein *et al*. (2013) conducted an experiment on the effect of osmopriming and hydropriming on the different index of germination & early growth of wheat under salty stress. They reported that the simple effect of priming for all the characteristics under study, except of shoot dry weight and simple effect of salinity for all the characteristics under study in the experiment at 1% level was significantly simple effect of seed soaking time (4 hours) only on hypocotyle length was significantly. Interaction of salinity on seed priming for root dry weight, longest root on the 5% level showed a statistical significant difference. Also shoot dry weight had a positive and significant correlation with the first and second leaf length, root number and root longest at the %1 level.

Azadi *et al.* (2013) set an experiment on seed germination, seedling growth and enzyme activity of wheat seed primed under drought and different temperature conditions.They found that the highest germination percentage (GP) (94.33%), normal seedling percentage (NSP) (92%), germination index (GI) (44.85) and seedling length (11.03 cm) were attained from osmo-priming in control conditions. Seed priming with PEG 6000 significantly increased germination characteristics as compared to the unprimed seeds under drought stress. Osmopriming also increased catalase (CAT) and ascorbate peroxidase (APX) as compared to the unprimed.

Abbasdokhta and Edalatpisheh (2013) studied the effect of priming and salinity on physiological and chemical characteristics of wheat *(Triticum aestivum* L.). They showed that primed plants significantly reduced its gas exchanges by accelerating senescence under a series of salt stress, which became more serious along with the increasing of salt concentrations, especially at 21 d after anthesis. Under each level of salt stress, dry matter accumulation of primed plants was always higher than the non-primed plants. Primed plants had higher potassium selectivity against sodium than non-primed plants. Salt stresses caused significant declines in growth period of wheat by accelerating leaf senescence at reproductive stage. Primed plants of wheat successfully preserved normal growth by maintaining *Pn,* K^+/Na^+, leaf area duration (LAD) and dry matter accumulation (DMA), while non-primed plants decreased considerably in those parameters.

Dey *et al.* (2013) carried out an experiment at the Seed Laboratory of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from January to April 2012 to study the effect of hydropriming on field establishment of seedlings obtained from primed seeds of *Boro* rice cv. BRRI dhan29. Seeds were soaked in water for 0, 24, 30, 36, 42, 48, 54 and 60 hours. They found that priming treatments had significant effect on germination and other growth parameters of rice seedlings. The highest germination, vigor index, population m^{-2}, length of shoot and root and their weights were found at 15 and 30 DAS. The lowest mean germination time was observed from hydropriming of seeds with 30 hours soaking. On the contrary, no priming treatment showed the lowest germination, vigor index, population m^{-2}, and the highest mean germination time.

Tilahun *et al.* (2013) carried out a field experiment in 2010 and 2011 at Fogera plains, Ethiopia to study the effect of hydro-priming and pregerminating rice seed on the yield and response of the crop to terminal moisture stress. They found that planting pre-germinated seeds as well as seeds soaked and dried for 24 hrs at the local (farmers') sowing time resulted in significantly earlier seedling emergence, heading, and maturity. Higher numbers of productive tillers, filled spikeletes, leaf area index, crop growth rate, net assimilation rate, grain yield, biomass yield, and harvest index were recorded in response to planting pre germinated seeds followed by seeds soaked and dried for 24 hrs at farmers' sowing time.

Shirinzadeh *et al.* (2013) set an experiment to evaluate the effects of seed priming with Plant Growth Promoting Rhizobacteria (PGPR) on grain yield and agronomic traits of barley cultivars in 2009. Seed priming with Plant Growth Promoting Rhizobacteria affected plant height, spike length, number of spike per area, grains per spike, 1000-grain weight and grain yield, significantly. Maximum of these traits were obtained by the plots in which seeds were inoculated with *Azospirillium* bacteria. The highest grain yield (3063.4kg.ha^{-1}) was obtained in cultivar of Makori. Application of PGPR bacteria (especially Azospirillum) had an appropriate performance and could increase grain yield to an acceptable level and could be considered as a suitable substitute for chemical fertilizer in organic agricultural systems

Hoseini *et al.* (2013) examines the effect of priming on laboratory experiments and field studies. They found that the influence of various treatments on germination percentage and rate were significant. The length of plumule and radicle in magnetic field in comparision with others were the highest. Some treated seeds were stored and reduction of germination percentage were observed. Considering physiological characters, the most Leaf Area Index and Leaf Area Ratio were seen in magnetic field treatment. The effects of priming on plant height, biomass dry weight and essential oil were significant.

Different durations of magnetic field had the most positive effect on essential oil.

Dastanpoor *et al.* (2013) carried out an experiment to find out the influence of hydro priming treatments on seed parameters of *Salvia officinalis* L. (sage). Seeds of sage were treated by hydro priming at three temperatures 10, 20, 30°C for 0, 12, 24 and 48 h. Hydro priming clearly improved the final germination percentage (FGP), mean germination time (MGT) and synchronized the germination of seeds at each three temperature. All the treatments resulted in germination enhancement except hydro primed seeds for 48 h at temperature 30°C. Hydro priming (12 h at 30°C) was most effective in improving seed germination that FGP was increased by 25.5% as compared to that of non-primed seeds.

Sarkar (2012) noted that seed priming improved seedling establishment under flooding. Acceleration of growth occurred due to seed pretreatment, which resulted longer seedling and greater accumulation of biomass. Seed priming greatly hastened the activities of total amylase and alcohol dehydrogenase in variety Swarna-Sub 1 than Swarna. Priming had positive effects on yield and yield attributing parameters both under non-flooding and early flooding conditions.

Moghanibashi *et al.* (2012) conducted a laboratory experiment to evaluate the effect of aerated hydropriming (24h) on two cultivar of sunflower (Urfloar and Blazar) seed germination under a range of drought stress and salt stress. They found that hydropriming for 24 h increased germination percentage, germination rate, germination index, root and shoot length, root and shoot weight of seed sunflower as compared with the control. Primed seeds produced higher germination rate and percentage, D50 and GI under all salinity and drought levels as compared with non-primed seeds. There was interaction between cultivar and priming on the germination rate and D50 as hydropriming was more effective in cultivar Urfloar.

Mirshekari (2012) studied the effects of seed priming with solutions of Fe and B, each at concentrations of 0.5%, 1%, 1.5%, and 2%, and 1.5% Fe + 1% B, on the germination and yield of dill *(Anethum graveolens)* in both field and laboratory condition .He found that in laboratory the effect of the studied treatments on the final germination percentage was significant. The seedling vigor index of dill was restricted when the Fe and B concentrations increased beyond 1.5% and 1%, respectively. The highest seed yield was recorded for the concentration of 1.5% Fe + 1% B in solution, which produced nearly 20% greater yield than the control. The essential oil concentration of the seeds ranged from 2.60% for 0.5% Fe to 2.81% for 1.5% B for the priming solutions. There was a positive response to seed priming with Fe and B regarding the essential oil yield. Priming dill seeds in the 1.5% Fe + 1% B solution resulted in a further increase in dill yield

Elouaer and Hannachi (2012) reported that in a study to the effect of seed priming with 5 g/L NaCl and KCl on germination and seedlings growth of safflower *(Carthamus tinctorius)* exposed to five levels of salinity (0, 5, 10, 15 and 20 g/L). NaCl and KCl priming have improved germination parameters (germination percentage, mean germination time, germination index and coefficient of velocity) and growth parameters (radicle and seedling length, seedling fresh and dry weight and Vigour Index) of safflower under saline condition.

Lemrasky and Hosseini (2012) conducted an experiment on the effect of seed priming on the germination behavior of wheat. They found that Maximum seed germination percentage was observed when seed primed by PEG 10% for 45 h. The most stem and radical length were obtained for seeds with KCl 2% and KCl 4% for 45 h. Rate of germination was improved when the seed soaked water and PEG 10%. There was interaction between seed priming media priming duration showed the beneficial effects on germination percentage and stem length.

Yousaf *et al.* (2011) noted that in an experiment of effects of seed priming with 30 mM NaCl on various growth and biochemical characters of 6 wheat varieties (Tatara-96, Ghaznavi-98, Fakhri Sarhad, Bakhtawar-92, Pirsabaq-2004 and Auqab- 2000) under 4 salinity levels (0, 40, 80 and 120 mM), the effects of varieties and salinity were significant ($P < 0.05$) and of seed priming was non significant ($P > 0.05$) on plant height (cm), root length (cm) and shoot chlorophyll- a contents.

Sharifi *et al.* (2011) set an experiment to evaluate the effects of seed priming with Plant Growth Promoting Rhizobacteria (PGPR) on dry matter accumulation and yield of maize *(Zea mays* L.) hybrids in 2009 at the Research Farm of the Faculty of Agriculture University of Mohaghegh Ardabili. They showed that seed priming with Plant Growth Promoting Rhizobacteria affected grain yield, plant height, number of kernel per ear, number of grains per ear significantly. Maximum of these characteristics were obtained by the plots which seeds were inoculated with *Azotobacter* bacteria. Mean comparison of treatment compound corn hybrids xvarious levels of priming with PGPR showed that maximum grain yield and number of kernel per ear were obtained by the plots which was applied SC-434 hybrid with *Azotobacter* bacteria and minimum of it was obtained in SC-404 hybrid without of seed priming.

Yari *et al.* (2011) set an experiment on the effect of seed priming on grain yield and yield components of bread wheat. They found that osmotic priming with PEG10% had positive significant effects on emergence percentage, straw, grain and biological yield compared to other seed priming treatments (KCl 2%, KH2 PO_4 0.5% and distilled water). It was recognized that the maximum straw, biological yield, kernel weight, number of spikes per m^2 was obtained from Sardari-101 meanwhile the highest number of kernels per spike was achieved from Azar-2.

Arif *et al.* (2010) carried out an experimen to study the effect of seed priming on growth parameters of soybean *(Glycine max* L.) cv. William-82. Three seed priming durations (6, 12 and 18 h) and five Polyethylene glycol (PEG 8000) concentrations (0, 100, 200, 300 and 400 g L^{-1} water) along with dry seed (non primed) as control treatment were included in the experiment. They found that primed seed plots recorded higher AGR and CGR as compared with non-primed seed plots at I_1 during 2004 and RGR showed the same trend at I_1 and I_2 during 2003.

Tzortzakis (2009) noted that halopriming (KNO_3) or growth regulators (gibberelic acid; GA_3) improved the rate of germination of endive and chicory and reduced the mean germination time needed. 30 min pre-sowing treatment with $NaHClO_3$, methyl jasmonate and dictamus essential oil decreased seed germination as well as seed radicle length *in vitro*. 6 benzylaminopurine (BAP) or $NaHClO_3$ treatment reduced plant growth. He suggested that KNO_3 and secondly GA_3 treatments may improve rapid and uniform seedling emergence and plant development in nurseries and/or in greenhouses, which is easily applicable by nursery workers with economic profits.

Farahbakhsha and Saiid (2009) studied the effects of seed priming on agronomic traits in maize using NaCl solutions containing different salt concentrations. Salinity treatments were 0, 4, 8 and 12 dS.m-^{1} and salt solutions for priming were 0.0, 0.5 and 1.0 molar NaCl. Seed characteristics like shoot dry weight, stem length, number of leaves, leaf area, chlorophyll and ion leakage were measured. They found that the effects of salinity and seed priming on shoot dry weight, stem length, number of leaves, leaf area, chlorophyll and ion leakage were significant at the probability level of 1% (P< 0.01). The increase in salinity up to 12 dS.m-1 negatively influenced all traits except ion leakage and the amounts of reduction for the mentioned traits were 75.67, 52.25, 25, 69.97 and 21.17%, respectively, as compared with the control. In the case of ion leakage, the difference was 3.03 times less than that of control. Seed priming compensated the negative effects of salinity on plant traits and all the traits positively responded to the treatment of seed priming.

Amjad *et al.* (2007) set an experiment to evaluate the influence of seed priming using different priming agents (distilled water, NaCl, salicylic acid, acetyl salicylic acid, ascorbic acid, PEG-8000 and KNO_3) on seed vigour of hot pepper cv. They found that all priming treatments significantly improved seed performance over the control. KNO_3 primed seeds excelled over all other treatments; decreased time taken to 50% germination, increased root and shoot length, seedling fresh weight and vigour over all other priming agents. Seeds were primed in water (hydropriming) and NaCl (1% solution) (halopriming) and sown in pots at different salinity levels [1.17 (control), 3, 5 and 7 dS m-1], along with unprimed seeds. Emergence rate (ER), final emergence percentage (FEP), reduction percentage of emergence (RPE), shoots length, number of secondary roots, seedling fresh weight and vigour were significantly improved by both priming treatments over the control; halopriming was more effective than hydropriming. Number of secondary roots was maximum in haloprimed and unprimed seeds. Seed priming treatment did not significantly affect root length, fresh and dry weight of seedlings.

Ghana *et al.* (2003) reported that Insufficient stand establishment of winter wheat *(Triticum aestivum* L.) is a major problem in the low-precipitation (300mm annual) dryland summer fallow region of the inland Pacific Northwest, USA. A 2- yr rstudy involving laboratory, greenhouse, and field components to determine seed priming effects on winter wheat germination, emergence, and grain yield. They suggested that seed priming has limited practical worth for enhancing emergence and yield of winter wheat planted deep into summer fallow.

Giri and Schillinger (2003) conducted an experiment at Washington State University showed that priming media enhanced germination during the first 24 to 48 h, but RGP of checks was generally equal to or greater than all priming treatments at 72 h. Water was equal to or more effective than any other priming media tested. Soaking seed for more than 12 h duration in any priming media tended to reduce rate and extent of germination, suggesting that optimum soaking time for wheat may be less than 12 h.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted to find out the effects of seed priming on quality improvement of tomato, brinjal and chilli seedlings through seed priming with $H_2O_2$and GA_3. This chapter provided a brief description on location, climate, soil, experimental design, seed collection, cultural operations, materials used in the experiment and the methods followed and statistical analyses.

3.1 Experimental site

The research work was conducted at the Net House of Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during 1st to 30thNovember 2018. Experimental field was located at 90°22$^{/}$ E longitude and 23°41$^{/}$ N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low humidity, low temperature and short day period during "Rabi" season (October-March). This climate is also characterized by distinct season, *viz*. the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.* 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Pot preparation

Before planting seeds of tomato, brinjal and chilli, the pots were prepared with silt loam soils. Well, rotten cow dung and soil were mixed using the ratio of 1:3. Earthen pots were filled 10 days before transplanting. Soils were made completely stubbles and weed free.

3.4 Planting materials

Three crops *viz*. tomato, brinjal and chilli were used in the study. The variety of tomato was PushaRubi, brinjal variety was BARI begun-1 and chilli variety was Sunflower (improved). The seeds were fresh, clean, and disease and insect free.

3.5 Experimental details

This experiment was divided into three part*viz*.

Part-1: Improving seedling quality of tomato priming with GA_3 and H_2O_2

Part-2: Improving seedling quality of brinjal priming with GA_3 and H_2O_2

Part-3: Improving seedling quality of chilli priming with GA_3 and H_2O_2

3.6 Part–1: Improving seedling quality of tomato priming with GA_3 and H_2O_2

3.6.1 Experimental treatment

The following treatments for tomato seed were included in the experiment:

Treatments for tomato

1. P_0 = Control (no priming)
2. P_1 = Priming with plain water (H_2O)/Hydro priming
3. P_2 = Priming with 0.5% aqueous solution of H_2O_2
4. P_3 = Priming with 1% aqueous solution of H_2O_2
5. P_4 = Priming with 50 ppm GA_3
6. P_5 = Priming with 100 ppm GA_3

3.6.2 Methods of seed priming techniques

Procedures of pre-sowing seed treatments

a. Five (5) g of seeds for each of the test crop was taken for priming
b. The seeds were soaked in different priming agent for separately at room temperature as per treatments.
c. Twenty four hours seed priming was done for the treatment P_1, P_2, P_3,P_4 and P_5.
d. Primed seeds were sown on each pot for seedling emergence and growth.

3.6.3 Experimental design and layout

The experiment was laid out in Completely Randomized Design (CRD) with three replications. There were 6 treatments in the study for each crop.In total of 54 unit pots for seed sowing.

3.6.4 Sowing of seeds

The seeds of tomato, brinjal and chilli were sown in the field on 1st November 2018.

3.6.5 Intercultural operations

Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were watering, weeding etc.

3.7 Collection of experimental data

Data on the following characters were collected

3.7.1 Germination percentage

The number of sprouted and germinated seeds was counted daily commencing. Germination was recorded at 4 days interval and continued up to 12th. More than 2 mm long plumule and radicle was considered as germinated seed.

The germination rate was calculated using the following formula:

$$\text{Rate of germination (\%)} = \frac{\text{Total number of germinated seeds}}{\text{Total seeds placed for germination}} \times 100$$

3.7.2 Percent (%) abnormal seedlings

The % abnormal seedlings (lacking the functional root/shoot system or abnormal growth) were assessed following the (ISTA, 2010) rules. After 24 days from seed sowing, all the germinated seedlings were kept on a table and then abnormal seedlings were identified.

3.7.3 Shoot length

The shoot length of seedlings from each pot was measured finally at 24 DAS. Measurement was done using the unit millimeter (mm) by a meter scale.

3.7.4 Root length

The Root length of seedlings from each pot was recorded finally at 24 DAS. Measurement was done using a meter scale and unit was expressed in millimeter (mm).

3.7.5 Dry weight plant^{-1}

The dry weight of seedlings from each pot was measured and finally at 24 DAS. Dry weight was recorded by drying the sample in an oven at 70°C till attained a constant weight. Then the weight was converted to gram (g).

3.7.6 Root shoot ratio

Root shoot ration was calculated by the following formula

Root shoot ratio = (Dry weight of root) / (dry weight of shoot)

3.7.7 Relative growth rate (RGR)

Relative growth rate was calculated with the following formula

$$RGR = (\ln W_2 - \ln W_1)/t_2 - t_1$$

Where, W_2 = seedling dry weight at t_2 time

W_1 = seedling dry weight at t_1 time

3.7.8 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = RL + SL \times GP,$$

Where,

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.8 For the Part 2 and 3

Same as the experimentalPart - 1. But the seeds were brinjal and chilli.

3.9 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

Effects of seed priming on quality improvement of tomato, brinjal and chilli vegetable seedlings through seed priming with H_2O_2 and GA_3 was studied in this experiment. This experiment was divided into three parts including three crops viz. tomato, brinjal and chilli. The parameters studied in the experiment were statistically analyzed and the results obtained were presented in Tables and figures with an effective interpretation to arrive at logical conclusions as per objectives of the study. Discussion on the result of the experiment has been made in this chapter under the following headings and sub headings:

4.1 Part 1: Improving seedling quality of tomato priming with GA_3 and H_2O_2

4.1.1 Percent seed germination

Significant variation was remarked on percent seed germination of tomato as influenced by different seed priming treatments (Fig. 1 and Appendix III). It was observed that the highest percent seed germination (88.33, 91.33 and 96.00% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment P_4 (Priming with 50 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2), P_2 (Priming with 0.5% aqueous solution of H_2O_2) and P_5 (Priming with 100 ppm GA_3) whereas the lowest percent seed germination (20.67, 60.33 and 73.33% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment, P_0 (control; No priming).

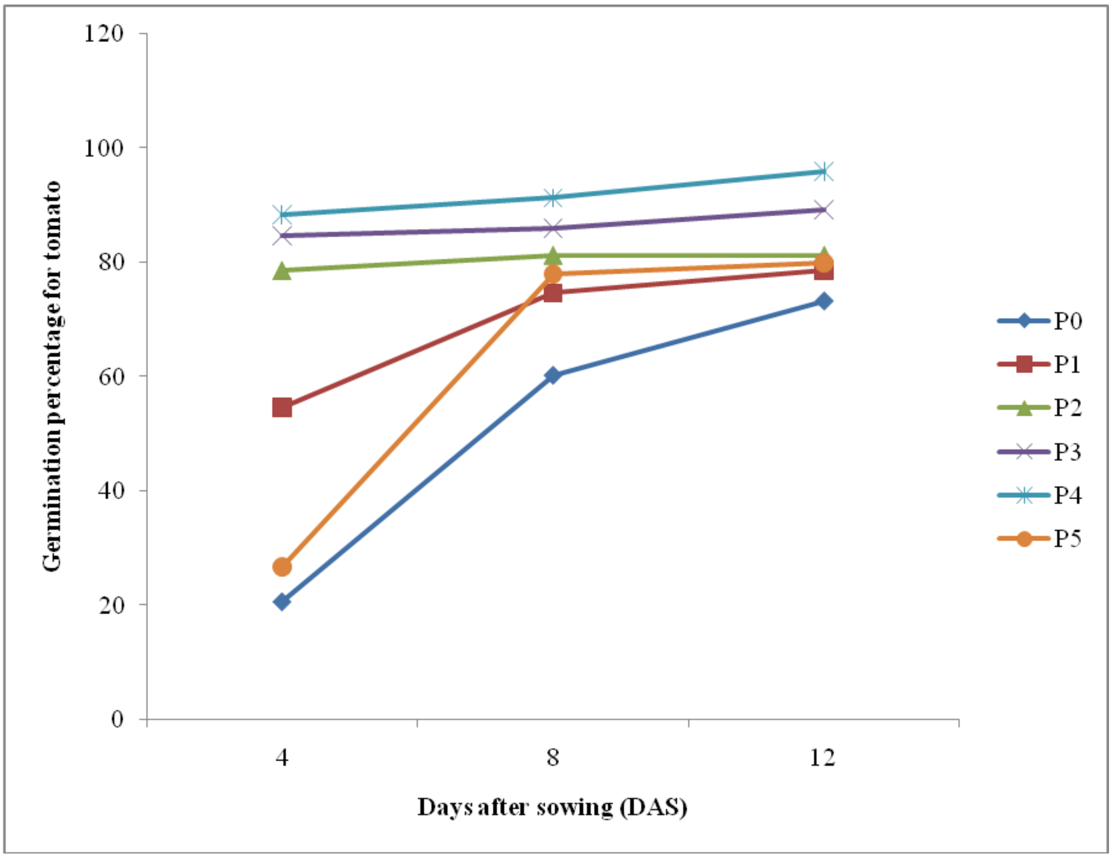

Fig. 1. Germination percentage of tomato seeds as influenced by different priming treatments

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.1.2 Percent abnormal seedlings

No significant variation was found on abnormal seedling of tomato among the treatments influenced by different levels of priming treatments (Fig. 2). However, results showed that the maximum abnormal seedling (2%) was found from control treatment P_0 (no priming) while minimum abnormal seedling (1%) was recorded from P_4 (Priming with 50 ppm GA_3) treatment. this result indicated that lower concentration of GA_3 showed lowest abnormal seedling compared to control or higher GA_3 and/or H_2O_2 primed seed.

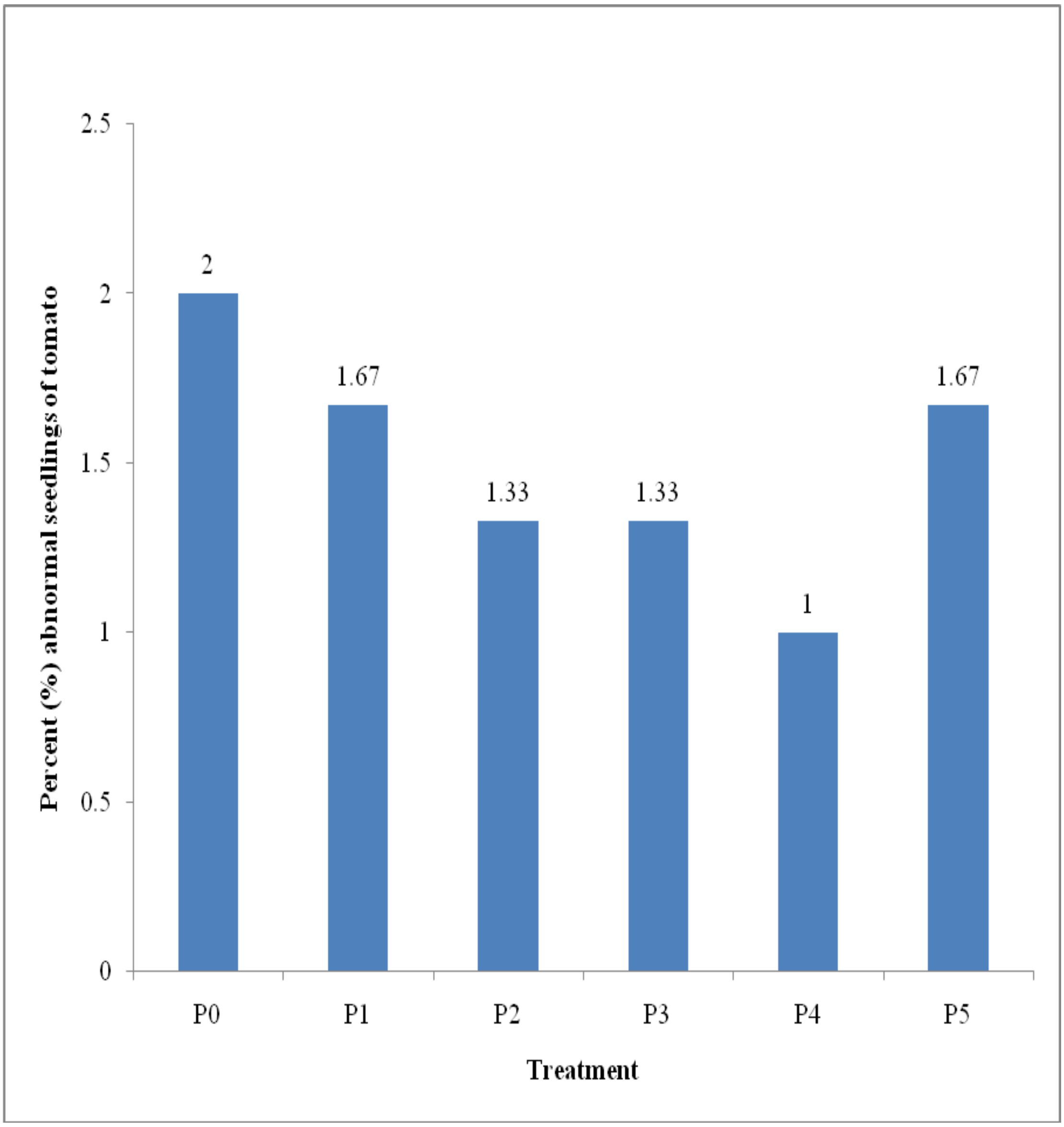

Fig. 2. Effect of priming with GA_3 and H_2O_2 on % abnormal seedling of tomato

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.1.3 Shoot length (cm)

Significant variation was remarked on shoot length of tomato as influenced by different seed priming treatments (Table 1 and Appendix III). Results showed that the highest shoot length (8.72 and 19.60 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS whereas the lowest shoot length (5.88 and 14.21 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

Table 1. Influence of seed priming on seed quality parameters in tomato

Treatment	Effect of priming on seedling quality of tomato										
	Shoot length (cm) at two DAS		Root length (cm) at two DAS		% shoot dry weight at two DAS		% root dry weight at two DAS		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
	12	24	12	24	12	24	12	24			
P_0	5.88 f	14.21 d	5.48 e	9.89 d	3.30	25.40 d	0.51	3.53 d	0.14	0.26	1237.05 f
P_1	6.44 e	16.00 c	5.91 d	12.10 c	3.52	29.48 c	0.54	7.75 c	0.26	0.27	2098.23 e
P_2	7.14 d	16.10 c	6.88 c	13.44 b	3.90	31.64 b	0.61	9.63 b	0.30	0.28	2402.49 d
P_3	8.36 b	19.22 a	8.12 b	15.32 a	4.14	35.72 a	0.72	12.88 a	0.36	0.29	3085.46 b
P_4	8.72 a	19.60 a	8.33 a	15.48 a	4.56	36.64 a	0.79	13.78 a	0.38	0.30	3367.68 a
P_5	7.92 c	17.45 b	6.83 c	13.60 b	3.71	32.86 b	0.65	10.40 b	0.32	0.28	2484.00 c
$LSD_{0.05}$	0.215	1.063	0.191	1.136	NS	1.051	NS	1.314	NS	NS	21.47
CV(%)	3.44	6.422	4.89	7.547	2.17	7.06	2.44	6.14	3.73	2.43	10.15

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.1.4 Root length (cm)

Significant influence was recorded on root length of tomato as influenced by different seed priming treatments (Table 1 and Appendix III). It was observed that the highest root length (8.33 and 15.48 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS whereas the lowest root length (6.44 and 9.89 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.1.5 Shoot dry weight (%)

Non-significant variation was observed on % shoot dry weight of tomato at 12 DAS, but at 24 DAS significant variation was found among the treatments as influenced by different seed priming treatments (Table 1 and Appendix III). However, it was observed that the highest % shoot dry weight (4.50 and 36.64% at 12 and 24 DAS, respectively) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS, whereas the lowest % shoot dry weight (3.30 and 25.40% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.1.6 Root dry weight (%)

Non-significant variation was observed on % root dry weight of tomato at 12 DAS, but at 24 DAS significant variation was found among the treatments as influenced by different seed priming treatments (Table 1 and Appendix III). However, it was observed that the highest % root dry weight (0.79 and 13.78% at 12 and 24 DAS, respectively) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS, whereas the lowest % root dry weight (0.51 and 3.53% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.1.7 Root shoot ration (dry weight basis)

Non-significant variation was observed on root shoot ratio of tomato as influenced by different seed priming treatments (Table 1 and Appendix III). However, it was observed that the highest root shoot ratio (0.38) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) whereas the lowest root shoot ratio (0.14) was found from the priming treatment, P_0 (control; No priming).

4.1.8 Relative growth rate (RGR)

Non-significant variation was observed on RGR at 24 DAS of tomato as influenced by different seed priming treatments (Table 1 and Appendix III). However, it was observed that the highest RGR (0.30) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) whereas the lowest RGR (0.26) was found from the priming treatment, P_0 (control; No priming).

4.1.9 Seedling vigor index

Significant variation was found on vigor index of tomato seeds as influenced by different seed priming treatments (Table 1 and Appendix III). It was observed that at 24 DAS, the highest vigor index (3367.68) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2) where the lowest vigor index (1237.05) was found from the priming treatment, P_0 (control; No priming).

4.2 Part 2: Improving seedling quality of brinjal priming with GA_3 and H_2O_2

4.2.1 Percent seed germination

Percent seed germination of brinjal was significantly influenced due to different seed priming treatments (Fig 3 and Appendix IV). Results revealed that the highest percent seed germination (38.67, 97.33 and 97.33% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest percent seed germination (5.67, 58.71 and 71.33% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment, P_0 (control; No priming).

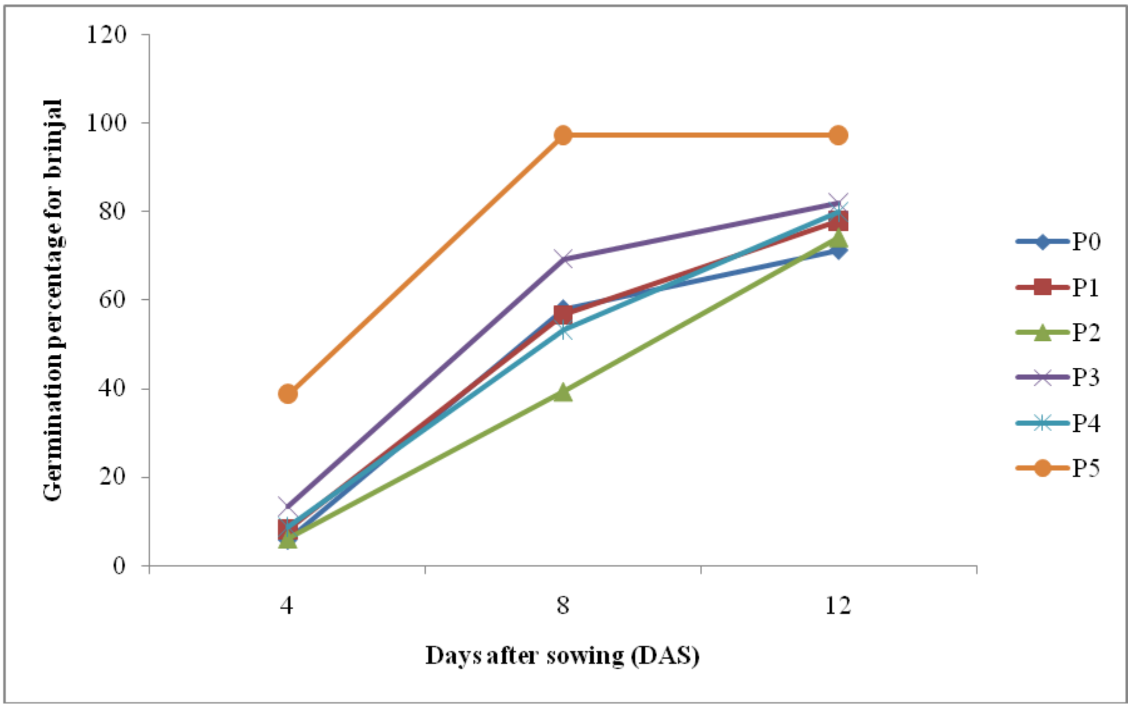

Fig. 3. Germination percentage of brinjal seeds as influenced by different priming treatments

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2, P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.2.2 Percent abnormal seedlings of brinjal

Significant variation was not found on abnormal seedling of brinjal among the treatments influenced by different levels of priming treatments (Fig. 4). However, results indicated that the maximum abnormal seedling (2.67%) was found from control treatment P_0 (no priming) while the minimum abnormal seedling (1.50%) was recorded from P_5 (Priming with 100 ppm GA_3) and P_3 (Priming with 1% aqueous solution of H_2O_2) treatment. This result indicated that higher concentration of GA_3 or H_2O_2 showed minimum abnormal seedling compared to control or lower GA_3 and/or H_2O_2 primed seed of brinjal.

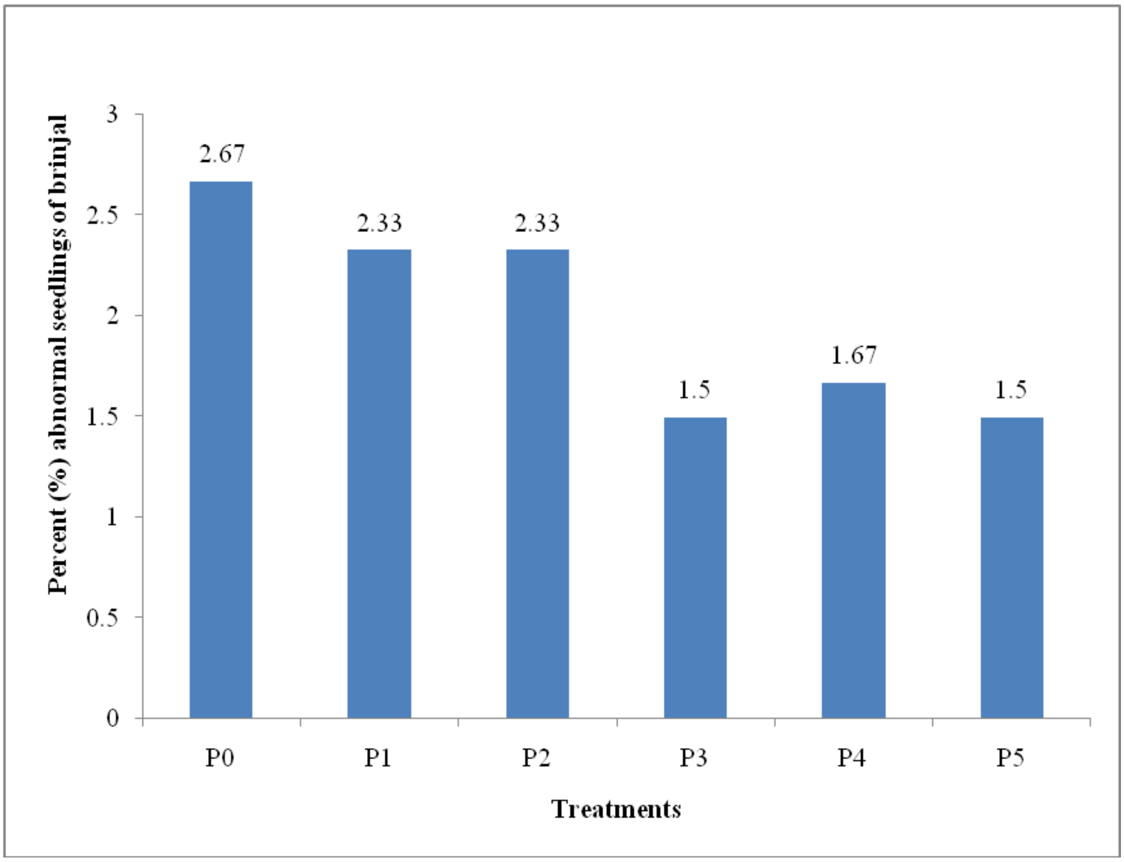

Fig. 4. Effect of priming with GA_3 and H_2O_2 on % abnormal seedling of brinjal

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2, P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.2.3 Shoot length (cm)

Significant variation was remarked on shoot length of brinjal as influenced by different seed priming treatments (Table 2 and Appendix IV). Results showed that the highest shoot length (8.33 and 18.92 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically identical with followed by P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS whereas the lowest shoot length (4.80 and 9.44 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming) which was significantly different from other treatments at all growth stages.

Table 2. Influence of seed priming on seed quality parameters in brinjal

Treatment	Effect of priming on seedling quality of brinjal										
	Shoot length (cm) at two DAS		Root length (cm) at two DAS		% shoot dry weight at two DAS		% root dry weight at two DAS		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
	12	24	12	24	12	24	12	24			
P_0	4.80 f	9.44 d	4.32 f	8.42 e	2.87	27.45 d	0.67	6.53 d	0.24	0.27	666.71 f
P_1	5.72 e	12.72 c	5.14 e	10.06 d	3.63	33.63 c	0.73	11.74 c	0.35	0.28	1412.36 e
P_2	6.12 d	15.48 b	5.78 d	13.11c	3.14	35.78 b	0.88	15.44 b	0.43	0.29	1410.34 d
P_3	7.78 b	18.55 a	7.33 b	15.11 ab	3.82	37.45 b	1.12	21.72 a	0.58	0.29	2760.12 b
P_4	6.67 c	15.60 b	6.24 c	13.32 c	3.70	36.84 b	0.96	16.80 b	0.46	0.29	1966.56 c
P_5	8.33 a	18.92 a	7.83 a	16.23 a	4.18	42.76 a	1.14	22.48 a	0.53	0.30	3421.15 a
$LSD_{0.05}$	0.199	1.507	0.188	1.022	NS	2.063	NS	2.36	NS	NS	17.44
CV(%)	2.81	7.331	2.06	5.871	1.52	8.571	5.281	8.271	2.79	3.87	11.52

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.2.4 Root length (cm)

Significant influence was recorded on root length of brinjal as affected by different seed priming treatments (Table 2 and Appendix IV). It was observed that the highest root length (7.83 and 16.23 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically similar with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS whereas the lowest root length (4.32 and 8.42 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming) which was significantly different from other treatments.

4.2.5 Shoot dry weight (%)

Non-significant variation was observed on % shoot dry weight of brinjal at 12 DAS but at 24 DAS it was found significant as influenced by different seed priming treatments (Table 2 and Appendix IV). However, it was observed that the highest % shoot dry weight (4.10 and 42.76% at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was significantly different from other treatments whereas the lowest % shoot dry weight (2.50 and 27.45% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.2.6 Root dry weight (%)

Non-significant variation was observed on % root dry weight of brinjal at 12 DAS but at 24 DAS it was found significant as influenced by different seed priming treatments (Table 2 and Appendix IV). It was observed that the highest % root dry weight (1.14 and 22.48% at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest % root dry weight (0.67 and 6.53% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.2.7 Root shoot ration (dry weight basis)

Non-significant variation was observed on root shoot ratio of brinjal as influenced by different seed priming treatments (Table 2 and Appendix IV). However, it was observed that the highest root shoot ratio at 24 DAS (0.58) was found from the priming treatment, P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest root shoot ratio (0.24) was found from the priming treatment, P_0 (control; No priming).

4.2.8 Relative growth rate (RGR)

Non-significant variation was observed on RGR of brinjal as influenced by different seed priming treatments (Table 2 and Appendix IV). However, it was observed that the highest RGR (0.30) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) whereas the lowest RGR (0.27) was found from the priming treatment, P_0 (control; No priming).

4.2.9 Seedling vigor index

Significant variation was found on vigor index of brinjal seeds as influenced by different seed priming treatments (Table 2 and Appendix IV). It was observed that the highest vigor index (3421.15) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest vigor index (666.71) was found from the priming treatment, P_0 (control; No priming).

4.3 Part - 3: Improving seedling quality of chilli priming with GA_3 and H_2O_2

4.3.1 Percent seed germination

Chilli seeds used in the present study showed significant variation among the priming treatments in respect of percent seed germination (Fig. 5 and Appendix VI). Results indicated that the highest percent seed germination (14.67, 75.33 and 88.00% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest percent seed germination (5.00, 6.33 and 70.00% at 4, 8 and 12 days after priming, respectively) was found from the priming treatment, P_0 (control; No priming).

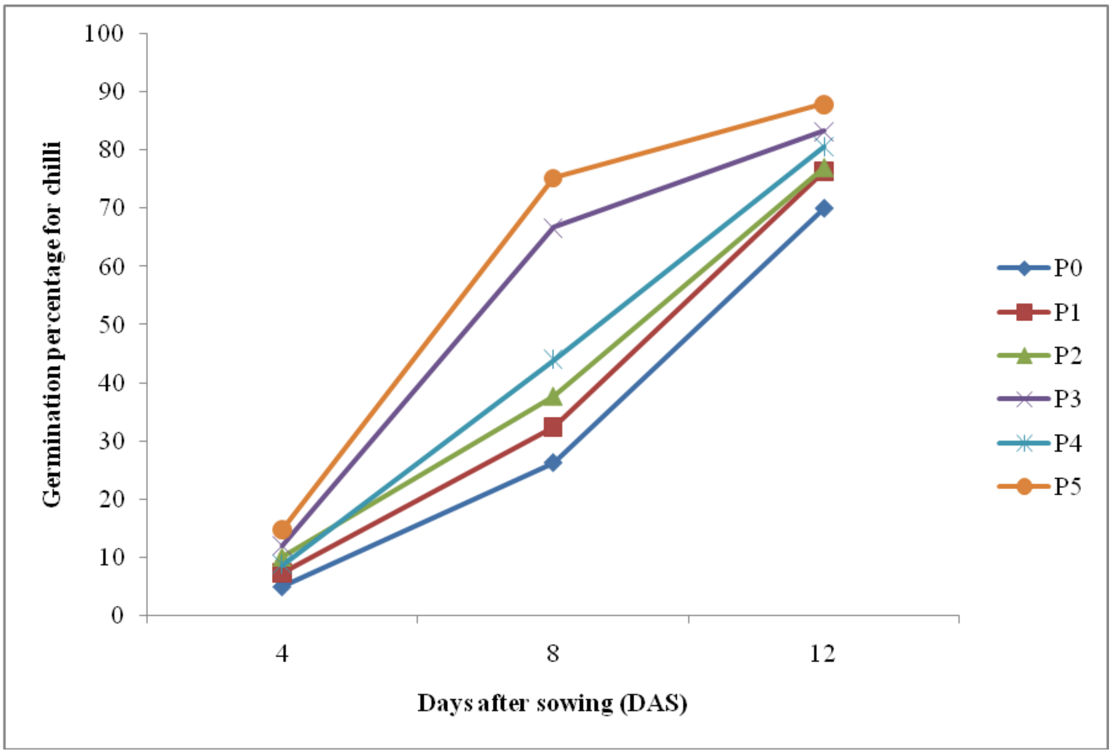

Figure 5. Germination percentage of chilli seeds as influenced by different priming treatments

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.3.2 Percent abnormal seedlings of chilli

No significant variation was found on abnormal seedling of chilli among the treatments influenced by different levels of priming treatments (Fig. 6). However, it was found that the maximum abnormal seedling (3.33%) was found from control treatment P_0 (no priming) while minimum abnormal seedling (2.33%) was recorded from P_5 (Priming with 100 ppm GA_3) treatment. This result indicated that higher concentration of GA_3 and H_2O_2 showed lowest abnormal seedling in chilli compared to control or lower GA_3 or H_2O_2 primed seed.

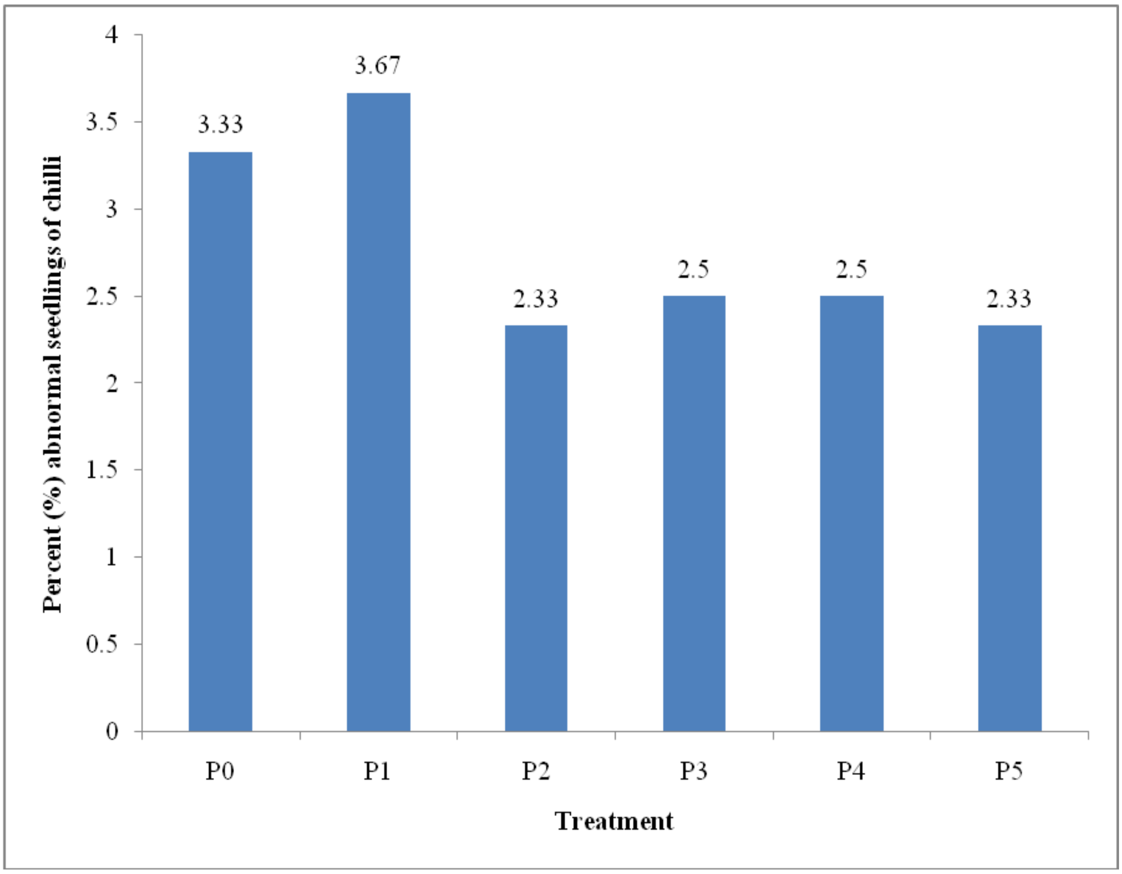

Figure 6. Effect of priming with GA_3 and H_2O_2 on % abnormal seedling of chilli

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.3.3 Shoot length (cm)

Significant variation was remarked on shoot length of chilli as influenced by different seed priming treatments (Table 3 and Appendix VI). Results revealed that the highest shoot length (7.85 and 17.88 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) at 24 DAS whereas the lowest shoot length (5.14 and 8.36 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

Table 3. Influence of seed priming on seed quality parameters in chilli

Treatment	Effect of priming on seedling quality of chilli										
	Shoot length (cm)		Root length (cm)		% shoot dry weight		% root dry weight		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
	12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS			
P_0	5.14 f	8.36 d	4.86 f	7.36 e	2.60	26.32 d	0.58	3.53 d	0.13	0.26	723.12 f
P_1	5.72 e	11.67 c	5.41 e	9.12 d	2.80	33.50 c	0.67	8.74 c	0.26	0.28	1178.17 e
P_2	6.37 d	14.36 b	6.13 d	12.15 c	3.13	34.60 b	0.85	12.44 b	0.36	0.29	1643.62 d
P_3	7.44 b	17.48 a	7.10 b	14.10 ab	3.52	36.40 b	0.92	18.72 a	0.51	0.29	2505.24 b
P_4	6.95 c	14.56b	6.52 c	12.18 c	3.46	35.72 b	0.86	13.8 b	0.39	0.29	1889.72 c
P_5	7.85 a	17.88 a	7.36 a	15.32 a	3.80	40.5 a	0.98	19.48 a	0.48	0.30	2921.60 a
$LSD_{0.05}$	0.207	1.418	0.186	1.103	NS	1.736	NS	1.56	NS	NS	16.54
CV(%)	3.85	6.52	4.12	4.062	2.44	8.571	4.266	8.271	4.25	3.64	10.26

P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3 and P_5 = Priming with 100 ppm GA_3

4.3.4 Root length (cm)

Significant influence was recorded on root length of chilli as influenced by different seed priming treatments (Table 3 and Appendix VI). It was observed that the highest root length (7.36 and 15.32 cmat 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically similar with P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest root length (4.86 and 7.36 cm at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.3.5 Shoot dry weight (%)

Significant variation was observed on % shoot dry weight of chilli at different growth stages except 12 DAS as influenced by different seed priming treatments (Table 3 and Appendix VI). However, it was observed that the highest % shoot dry weight (3.80 and 40.50% at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was significantly different from other treatments whereas the lowest % shoot dry weight (2.60 and 26.32% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.3.6 Root dry weight (%)

Significant variation was observed on % root dry weight of chilli at different growth stages except 12 DAS as influenced by different seed priming treatments (Table 3 and Appendix VI). However, it was observed that the highest % root dry weight (0.98 and 19.48% at 12 and 24 DAS, respectively) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) which was statistically identical with P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest % root dry weight (0.58 and 3.53% at 12 and 24 DAS, respectively) was found from the priming treatment, P_0 (control; No priming).

4.3.7 Root shoot ration (dry weight basis)

Non-significant variation was observed on root shoot ratio of chilli at 24 DAS as influenced by different seed priming treatments (Table 3 and Appendix VI). However, it was observed that the highest root shoot ratio (0.51) was found from the priming treatment, P_3 (Priming with 1% aqueous solution of H_2O_2) whereas the lowest root shoot ratio (0.13) was found from the priming treatment, P_0 (control; No priming).

4.3.8 Relative growth rate (RGR)

Non-significant variation was observed on RGR of chilli as influenced by different seed priming treatments (Table 3 and Appendix VI). However, it was observed that the highest RGR (0.30) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) whereas the lowest RGR (0.26) was found from the priming treatment, P_0 (control; No priming).

4.3.9 Seedling vigor index

Significant variation was found on vigor index of chilli seeds at 24 DAS as influenced by different seed priming treatments (Table 3 and Appendix VI). It was observed that the highest vigor index (2921.60) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) followed by P_3 (Priming with 1% aqueous solution of H_2O_2) where the lowest vigor index (723.12) was found from the priming treatment, P_0 (control; No priming).

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted at Net House of Horticulture Farm ofSher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from 1st November to 30 thNovember 2018 to study the quality improvement of some vegetable seedlings through seed priming with H_2O_2 and GA_3. The seed priming treatment were applied in tomato, brinjal and chilli seeds.Six priming treatments were applied under the present study *viz*. P_0 = Control (no priming), P_1 = Priming with plain water (H_2O)/Hydro priming, P_2 = Priming with 0.5% aqueous solution of H_2O_2 P_3 = Priming with 1% aqueous solution of H_2O_2, P_4 = Priming with 50 ppm GA_3, P_5 = Priming with 100 ppm GA_3. Data were collected on seed germination and growth parameters for each crop. The experiment was laid out in Completely Randomized Design (CRD) with three replications. Collected data were analyzed using a computer software MSTAT-C. The significance of difference among the treatments means was estimated by the least significant difference (LSD) at 5% level of probability.

In terms of Part-1 (seed priming performance on tomato), results showed that the highest percent seed germination (96.00%) was found from the priming treatment, P_4 (Priming with 50 ppm GA_3) whereas the lowest percent seed germination (73.33% a) was found from control treatment, P_0 (no priming). In case of abnormal seedling, the maximum abnormal seedling (2%) was found from control treatment P_0 (no priming) while minimum abnormal seedling (1%) was recorded from P_4 (Priming with 50 ppm GA_3). Again, the highest shoot length (8.72 and 19.60 cm at 12 and 24 DAS, respectively), root length (8.33 and 15.48 cm at 12 and 24 DAS, respectively), % shoot dry weight (4.50 and 36.64% at 12 and 24 DAS, respectively), % root dry weight (0.79 and 13.78% at 12 and 24 DAS, respectively), root shoot ratio (0.38), RGR (0.30) and vigor index (3367.68) were found from the priming treatment, P_4 (Priming with 50 ppm GA_3) whereas the lowest shoot length (5.88 and 14.21 cm at 12 and 24 DAS, respectively), root length (6.44 and 9.89 cm at 12 and 24 DAS, respectively), % shoot dry weight (3.30 and 25.40% at 12 and 24 DAS, respectively), % root dry weight (0.51 and 3.53% at 12 and 24 DAS, respectively), root shoot ratio (0.14), RGR (0.26) and vigor index (1237.05) were found from control treatment, P_0 (no priming).

Regarding Part-2 (seed priming performance on brinjal), results revealed that the highest percent seed germination (97.33%) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) but control treatment P_0 (no priming) showed lowest percent seed germination (71.33%). In case of abnormal seedlings, the maximum (2.67%) was found from control treatment P_0 (no priming) while the minimum abnormal seedling (1.50%) was recorded from P_5 (Priming with 100 ppm GA_3) and P_3 (Priming with 1% aqueous solution of H_2O_2) treatment. Similarly, the highest shoot length (8.33 and 18.92 at 12 and 24 DAS, respectively cm), root length (7.83 and 16.23 cm at 12 and 24 DAS, respectively), % shoot dry weight (4.10 and 42.76% at 12 and 24 DAS, respectively), % root dry weight (1.14 and 22.48% at 12 and 24 DAS, respectively), RGR (0.30) and vigor index (3421.15) were found from the priming treatment, P_5 (Priming with 100 ppm GA_3) but highest root shoot ratio at 24 DAS (0.58) was found from the priming treatment, P_3 (Priming with 1% aqueous solution of H_2O_2). Likewise, the lowest shoot length (4.80 and 9.44 cm at 12 and 24 DAS, respectively), root length (4.32 and 8.42 cm at 12 and 24 DAS, respectively), % shoot dry weight (2.50 and 27.45% at 12 and 24 DAS, respectively), % root dry weight (0.67 and 6.53% at 12 and 24 DAS, respectively), root shoot ratio (0.24), RGR (0.27) and vigor index (666.71) were found from the control treatment, P_0 (no priming).

Considering Part-3 (seed priming performance on chilli), the highest percent seed germination (88.00%) was found from the priming treatment, P_5 (Priming with 100 ppm GA_3) whereas the lowest percent seed germination (70.00%) was found from the control treatment, P_0 (no priming). Regarding abnormal seedlings, the maximum abnormal seedling (3.33%) was found from control treatment P_0 (no priming) while minimum abnormal seedling (2.33%) was recorded from P_5 (Priming with 100 ppm GA_3) treatment. Again, the highest shoot length (7.85and 17.88 cm at 12 and 24 DAS, respectively), root length (7.36 and 15.32 cmat 12 and 24 DAS, respectively), % shoot dry weight 3.80 and 40.50% at 12 and 24 DAS, respectively), % root dry weight (0.98 and 19.48% at 12 and 24 DAS, respectively), RGR (0.30) and vigor index (2921.60) were found from the priming treatment, P_5 (Priming with 100 ppm GA_3) but the the highest root shoot ratio (0.51) was found from the priming treatment, P_3 (Priming with 1% aqueous solution of H_2O_2). Similarly, the shoot length (5.14 and 8.36 cm at 12 and 24 DAS, respectively), root length (4.86 and 7.36 cm at 12 and 24 DAS, respectively), % shoot dry weight (2.60 and 26.32% at 12 and 24 DAS, respectively), % root dry weight (0.58 and 3.53% at 12 and 24 DAS, respectively), root shoot ratio (0.13), RGR (0.26) and vigor index (723.12) were found from the controltreatment, P_0 (no priming).

From the above findings it can be concluded that seed priming is an important term for proper seedling establishment. It was found that the priming treatment P_3 (Priming with 1% aqueous solution of H_2O_2), P_4 (Priming with 50 ppm GA_3) and P_5 (Priming with 100 ppm GA_3) showed better performance for seed germination and on other growth parameters but among the parameters, P_4 (Priming with 50 ppm GA_3) showed best performance in tomato and P_5 (Priming with 100 ppm GA_3) showed best performance in brinjal and chilli. So, P_4 (Priming with 50 ppm GA_3) and P_5 (Priming with 100 ppm GA_3) can be considered as the best priming treatment under the present study.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

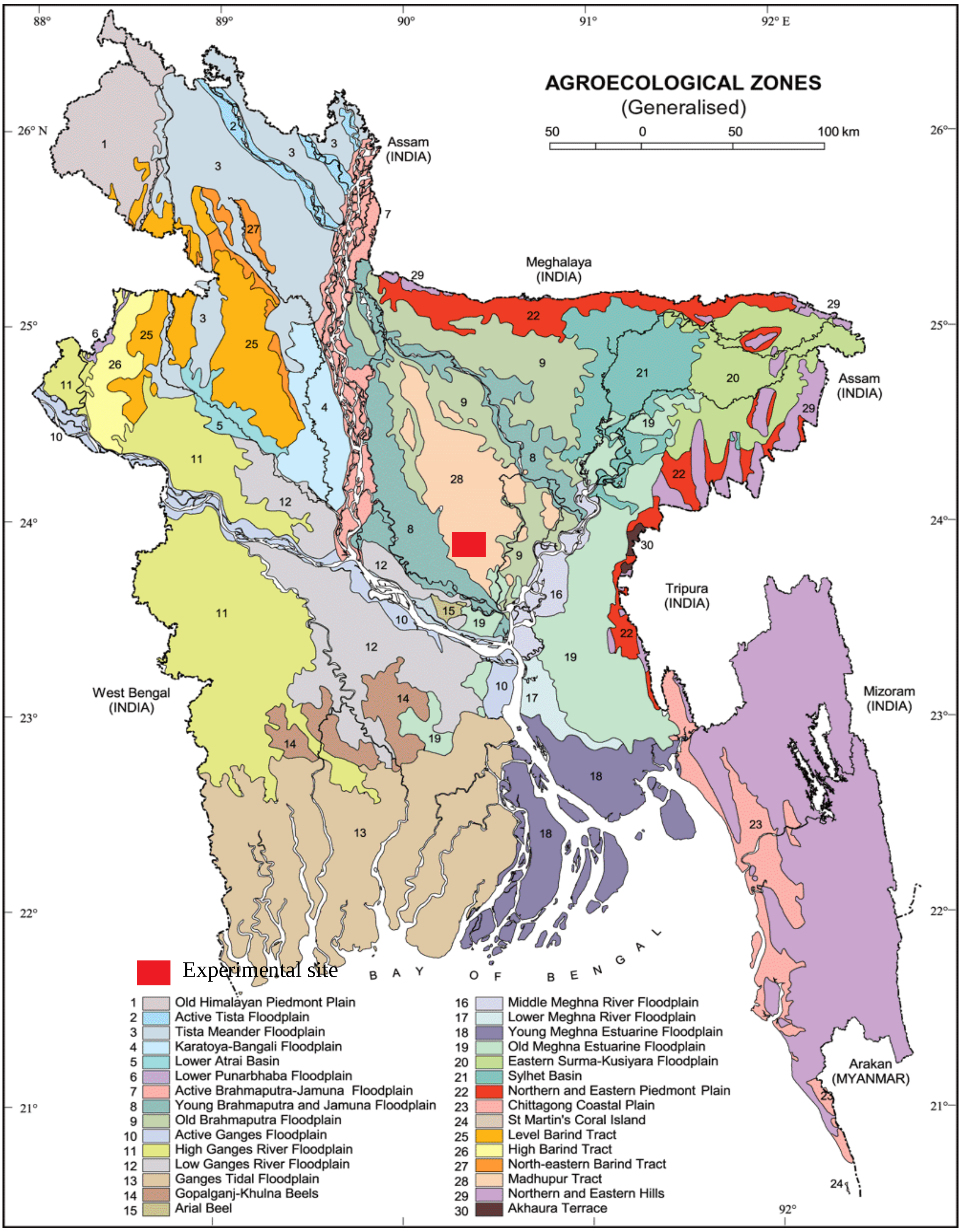

Fig. 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to December 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Germination percentage of tomato seeds as influenced by different priming treatments

Sources	DF	Germination percentage for tomato			
		4 DAS	8 DAS	12 DAS	Abnormal seedlings observed at 12 days after seed priming
Replication	2	2.143	2.014	4.288	0.000
Factor A	5	64.228*	83.62*	89.62*	NS
Error	10	3.58	4.293	3.144	0.001

Appendix V. Influence of seed priming on seedling quality parameters in tomato

Sources	DF	Priming effect on seed quality of tomato										
		Shoot length (cm)		Root length (cm)		% shoot dry weight		% root dry weight		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
		12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS			
Replication	2	1.244	1.36	0.422	1.052	0.022	0.588	0.042	0.117	0.001	0.001	124.66
Factor A	5	26.52*	112.3*	44.76*	63.24	NS	32.46 *	NS	26.28*	NS	NS	21425.2*
Error	10	1.312	1.56	1.036	0.563	0.012	1.241	0.003	0.342	0.001	0.003	26.533

Appendix VI. Germination percentage of brinjal seeds as influenced by different priming treatments

Sources	DF	Germination percentage for tomato			
		4 DAS	8 DAS	12 DAS	Abnormal seedlings observed at 12 days after seed priming
Replication	2	1.852	2.322	3.338	0.000
Factor A	5	53.24**	92.62*	98.61*	NS
Error	10	3.144	4.863	3.571	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Influence of seed priming on seedling quality parameters in brinjal

Sources	DF	Priming effect on seed quality of brinjal										
		Shoot length (cm)		Root length (cm)		% shoot dry weight		% root dry weight		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
		12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS			
Replication	2	1.036	1.214	0.366	1.100	0.014	0.211	0.012	0.104	0.001	0.001	108.22
Factor A	5	25.47**	98.13*	58.71*	72.48	NS	18.5 *	NS	236.25*	NS	NS	2248.7*
Error	10	1.072	1.316	1.104	0.466	0.023	1.033	0.004	0.144	0.003	0.006	24.377

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Germination percentage of chilli seeds as influenced by different priming treatments

Sources	DF	Germination percentage for tomato			
		4 DAS	8 DAS	12 DAS	Abnormal seedlings observed at 12 days after seed priming
Replication	2	1.087	2.568	4.884	0.000
Factor A	5	68.47*	102.55**	110.42*	NS
Error	10	2.914	2.293	3.529	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Influence of seed priming on seedling quality parameters in chilli

Sources	DF	Priming effect on seed quality of chilli										
		Shoot length (cm)		Root length (cm)		% shoot dry weight		% root dry weight		Root shoot ratio at 24 DAS	Relative growth rate (RGR) at 12-24 DAS	Vigor index at 24 DAS
		12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS	12 DAS	24 DAS			
Replication	2	1.133	1.511	0.362	1.402	0.035	0.326	0.036	0.106	0.001	0.001	124.66
Factor A	5	29.64*	122.5*	58.76*	74.24*	NS	43.4 *	NS	26.27*	NS	NS	21425.2*
Error	10	1.214	1.314	1.147	0.463	0.013	1.158	0.002	0.383	0.002	0.002	28.72

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level