International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Response of sweet pepper (*Capsicum annuum*) to different priming treatments on germination and early growth

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International Journal of Science and Research Archive, 2024, 13(02), 724–732

Publication history: Received on 27 September 2024; revised on 06 November 2024; accepted on 09 November 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.2.2144

Abstract

Production of pepper (*Capsicum annuum*) is reduced by poor stand as a result of poor germination due to physiological dormancy of the seed. Therefore, a laboratory experiment was carried out to evaluate the response of sweet pepper to pre-sowing treatments, with the objective of improving seed germination and growth. The experiment used Completely Randomised Design (CRD) with four treatments replicated four times. The treatments were pre-soaking in water for 24 hours before planting; pre-chilling at 10^{0}C for 7 days before planting; pre-soaking in Potassium nitrate (KNO_3) at 2.4g per 1.2 liters distilled water for 24 hours and; untreated seed (control). The parameters measured were days to 50% germination, final germination % (FG%), speed of germination, mean germination time (MGT), radicle, plumule, seedling length, and seedling vigor index. The results showed that the pre-sowing treatment of seed with KNO_3 and pre-soaking in water significantly ($p < 0.01$) increased germination percent of sweet pepper seeds. Pre-chilling and no treatment of sweet pepper seed resulted in significant reduction of final germination percentage, radicle, plumule and seedling lengths and seedling vigor index. Results also showed an increase in number of abnormal and dead seed were pre-chilling and no treatments were used. Basing on these findings, farmers are recommended to pre-soak sweet pepper seed in KNO_3 and water before sowing to enhance seed germination.

Keywords: Priming; Sweet pepper; Seed; Dormancy; Germination

1. Introduction

Sweet pepper *(Capsicum annum var. grossum L)* is also commonly known as bell peppers or chili pepper belongs to Solanaceae family and originated from South America [1, 2, 3]. Cultivation of pepper in Africa in countries such as Burkina Faso and Benin, started around 1800 century and later distributed to South Africa, Botswana, and Zimbabwe [4]. Pepper is ranked third most popular vegetable after tomato and onion in the world. Pepper is known for its pleasant flavor, crisp texture, delicate aroma, colour, and shape, consumed as immature (green) or ripened (yellow or red) [3]. Furthermore, sweet pepper has quite a number of phytochemicals with exceptional antioxidant properties; this includes neutral phenolic compounds or flavonoids [5, 6]. Nutritionally, sweet pepper contains protein, calcium, thiamine, vitamins, niacin and riboflavin which are all important in human diet [7]. Sweet pepper is used in making salads, added to soups and stews, it can be dried and used as culinary seasoning, or pickled [8]. The flavor and colour extracts of sweet pepper are used in feed, pharmaceutical and food industries [6].

In spite of the economic importance of sweet pepper, its production in Zimbabwe negatively impacted by prolonged germination period or even poor germination due to physical and physiological dormancy [4]. Pepper has a hard seed

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coat and a protective endosperm layer surrounding the embryo and these reduces the movement of water, gas exchange and diffusion of endogenous inhibitors influencing poor germination [8, 10]. In addition, sweet pepper seed also experience physiological dormancy, where the embryos either do not grow or will produce abnormal seedlings [3, 11, 12, 13]. In order to improve germination of sweet pepper, there is need to break this physical or physiological dormancy using priming techniques. Some of the effective methods of seed priming includes pre-soaking, preheating, pre-chilling. Seeds can be presoaked in specific salts such as KNO_3, NaCl, and KCl, as well as in plant growth regulators like Gibberellic acid [14, 13, 10]. These strategies have been widely adopted in many countries; however, in Zimbabwe there is limited information as the crop is not widely grown among the small holder communities [15]. Therefore, this study evaluated the efficacy of different pre-sowing treatments on germination of sweet pepper seed.

2. Material and methods

2.1. Study site

The experiment was carried out at the Department of Research and Specialist Services, Seed Services Institute laboratory, located 30km north of the Central Business District, at longitude of 30°32′E and latitude of 17°41′S, altitude of the area is 1506 m above sea level [16]. The laboratory has an automated system that regulates temperature, humidity and moisture.

2.2. Experimental Design and Treatments

The experiment used Completely Randomised Design (CRD) with four replications. The treatments in this study were pre-soaking, pre-chilling, potassium nitrate (KNO_3) and control (no pre-treatment). Each petri-dish represented a plot and a total of 16 petri-dishes was used for the trial.

2.3. Seed Source and treatment

The variety of sweet pepper used in this experiment was California Wonder, obtained from the Horticultural Research Centre (HRI) in Marondera. Purity test was done on the sweet pepper seed prior to its use in the experiment and the results are shown in Table 1.

Table 1 Purity test of the California wonder capsicum variety

Seed	Initial Sample weight (g)	%
Initial sample	150.7	
Pure seed	15.18	99.9
Inert matter (Sand and chaff)	0.01	0.1
Chaff	0.01	0.1

After purity test, a sample of 20 seeds per experimental unit were selected and disinfected using sodium hypochloride solution (5%) for 20 minutes, then rinsed three times using distilled water. Guided by ISTA [17], 2.4 g of potassium nitrate (KNO_3) was mixed with 1.2 litres of water, the seeds for this treatment were soaked for 24 hours before germination test. The pre-soaking treatment entails sweet pepper seeds to be soaked in distilled water for 24 hours at room temperature before germination test. For the pre-chilling treatment, sweet pepper seeds were placed in glass petri dishes with a layer of cotton wool and filter papers moistened with distilled water and covered. The petri dishes were stored in a refrigerator for seven days at an average temperature of 10^0C before germination test [18]. For the control treatment, no pre-treatment was done. After pre-treatment, seeds were rinsed with distilled water for two minutes. After cleaning, the seeds were surface dried for 48 hours at room temperature. After drying, the seeds were stored in germination cabinets at a relative temperature of 25 °C and relative humidity of 80% before germination test in the growth chamber [18].

2.4. Germination test

The filter papers which anchored the seeds were moistened and 20 seeds per dish were uniformly spread. The petri dishes were covered on top with three filter papers with a diameter of 9 mm were and placed in a water-bath in a growth chamber. The wicks were also inserted below the sample to continuously supply the seed with moisture [17, 19]. Humidity caps were then placed on top of filter papers to reduce water evaporation and also allow diffusion of oxygen.

The growth chamber conditions were set at 16/8 hour of lightness/darkness at maintained at 25-30°C and 70% relative humidity [20].

2.5. Data collection and analysis

One petri- dish represented a plot and the seeds were monitored, and the following data was recorded with the guide of the ISTA rules of 2022:

2.5.1. Number of days to germination of sweet pepper seeds

Number of days to germination was recorded for each treatment. Seeds were considered germinated when they produce radicles that are at least 2mm long.

2.5.2. Germination percentage (%) of sweet pepper seeds

Germination counts were done daily for fortnight as according to ISTA Evaluation handbook (2022). Germination percentage was determined using the following equation [17].

$$Germination\ percentage\ (\%)\ = \frac{Number\ of\ seeds\ germinated\ * 100}{Number\ of\ seeds\ planted.}$$

2.5.3. Speed of germination of sweet pepper seeds

Speed of germination determined using the following formula [21].

Speed of germination= n1/d1+n2/d2+n3/d3+----------

Where,
n = number of germinated seeds,
d= number of days

2.5.4. Mean Germination Time (MGT) of sweet pepper seeds

Mean germination time was calculated using the following equation [21, 22].

Mean germination time= NIG1+N2G2+……NnGn

GI+G2+…….Gn

Where, G1, G2…Gn = number of seeds emerged on the day observed and

N1, N2….Nn= Number of days counted since the day of sowing until the end of trial

2.5.5. Plumule length (cm) of sweet pepper

Plumule length was determined by measuring length from the root crown to the tip of the shoot with a string tape measure on five randomly selected seedlings.

2.5.6. Radicle length (cm), Seedling length and Vigor index 1 (SV1) of sweet pepper

Radicle length was measured from the base (root crown) of the seedling to the tip of the longest root using a string tape measure on five randomly selected seedlings [17]. Seedling length was the addition of radicle and plumule lengths [20]. The seedling vigor index was calculated by multiplying germination percentage and seedling length after 14 days of germination [23, 24].

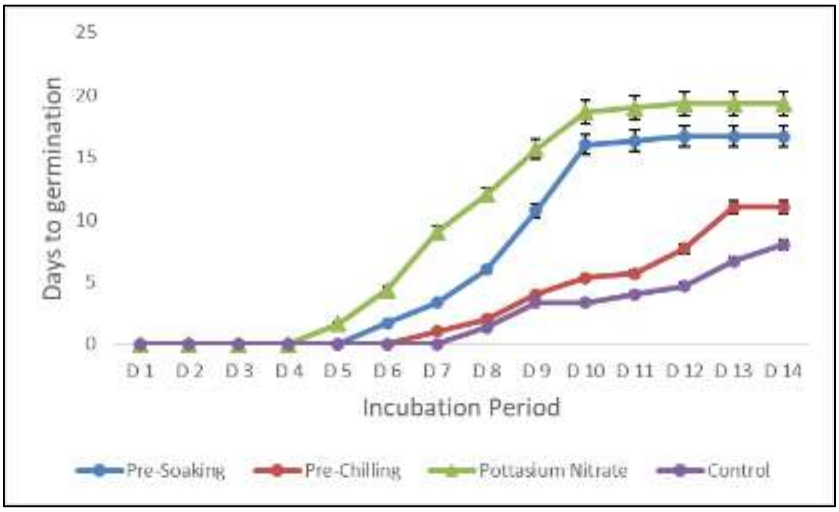
2.5.7. Data analysis

Analysis of variance (ANOVA) was done on the data using GenStat 18th edition statistical software. Separation of treatment means was done using Fisher's protected least significant difference (LSD) test.

3. Results

3.1. Effects of priming treatments on days to germination of sweet pepper

There was a significant difference (P<0.01) in priming treatments on the number of days taken for seeds to germinate. Seeds primed with KNO_3 were the first to germinate on the 5th day of the trial. This was followed by pre-soaking in water which started to germinate on the 6th day. Pre-chilling and no priming (control) took more days to germinate. Pre-soaking in KNO_3 and water reached their maximum cumulative germination on the 10th day while pre-chilling and control were still germinating up to day 14 (Figure 1).

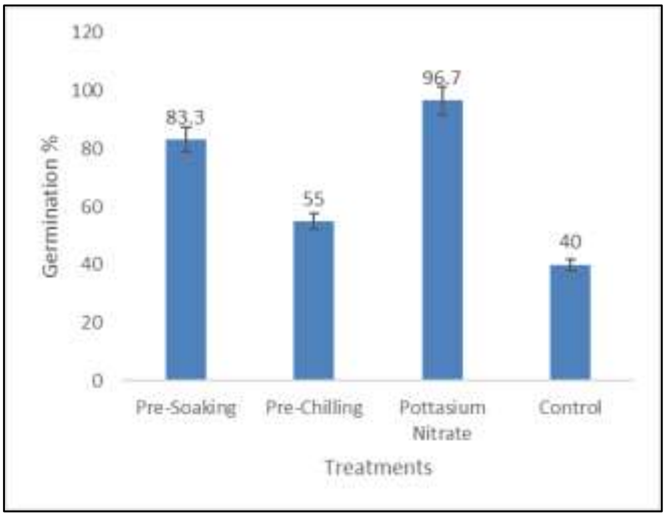


Vertical bars represent standard error bars of means.

Figure 1 Effect of pre-sowing treatments on days to germination of sweet pepper

3.2. Effects of priming treatments on germination percent of sweet pepper

There was a significant difference (P<.001) in priming treatments on germination percent of sweet pepper. Pre-soaking seed in KNO_3 resulted in the highest final germination percent of sweet pepper (96.7), followed by pre-soaking in water which resulted in 83.3 % of final germination. The least final germination (40 %) was observed in treatment where no priming was done (Figure 2).

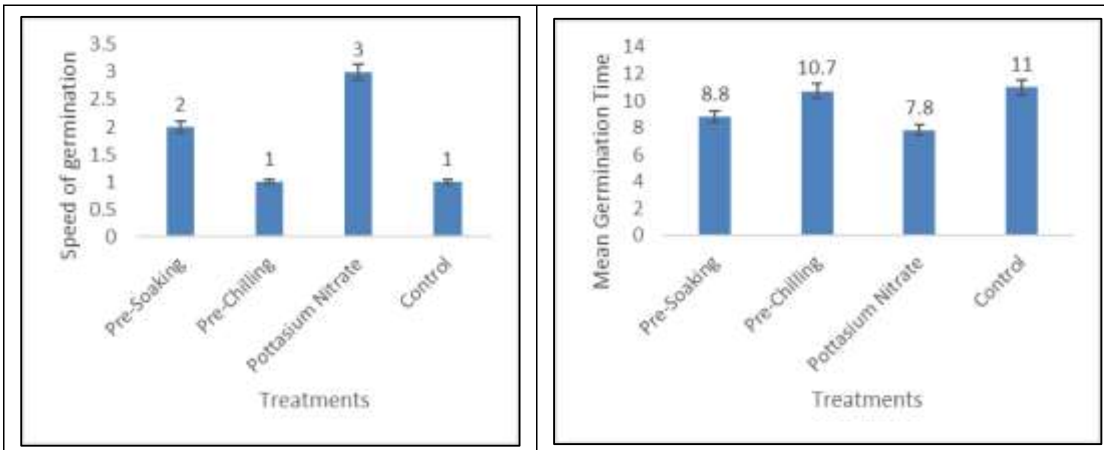


Vertical bars represent standard error bars of means.

Figure 2 Effect of pre-sowing treatments on final germination of sweet pepper

3.3. Effects of priming treatments on Speed of germination and Mean Germination Time (MGT)

Significant differences (P<.001) were observed across priming treatments on speed of germination. Soaking seed in KNO_3 had the highest speed of germination (three seeds germinating per day), followed by pre-soaking in water (two seeds germinating per day). Pre-chilling and no pre-soaking treatment had the lowest speed of germination (one seed would germinate per day) (Fig 3A). Similarly, significant differences in pre-soaking treatments (P<.001) were recorded on mean germination time. The lowest mean germination time was recorded on treatment that was soaked in KNO_3 (7.8) followed by pre-soaking in water (8.8). Pre-chilling and no pre-soaking treatment (control) resulted in the highest mean germination time were not significantly different (Figure 3B).



(A) Speed of germination | (B) Mean germination Time

Vertical bars represent standard error bars of means

Figure 3 Effect of priming treatments on speed of germination of sweet pepper (A) and mean germination time (B).

3.4. Effects of priming treatments on Radicle length, Plumule length, Seedling length and Seedling Vigor Index 1

There were significant differences (P<.001) in pre-sowing treatments on radicle length, plumule length, seedling length and seedling vigor index 1. Presoaking pepper seed in KNO_3 recorded the longest radicle, plumule and seedling lengths and greatest seedling vigor index 1 (Table 2). No priming pepper seed had the shortest radicle, plumule and seedling lengths and reduced seedling vigor index 1 (Table 2).

Table 2 Effects of pre-sowing treatments on Radicle, Plumule and Seedling lengths and seedling vigor index 1

Treatment	**Radicle length (cm)**	**Plumule length (cm)**	**Seedling length (cm)**	**Seedling Vigor Index 1**
Pre-soaking in water	5.233 c	3.133b	8.367c	696.7c
Pre- chilling	2.633 b	1.767a	4.400b	242b
Potassium Nitrate (KNO_3)	6.033d	3.933c	9.967d	963.7d
Control	1.967 a	1.367a	3.333a	135.2a
P-value	<.001	<.001	<.001	<.001
CV %	3.9	8.6	4.7	6.8

Values (in the same column) with the same subscript letters do not differ significantly from each other according to Fisher's protected least significant difference test

4. Discussion

4.1. Effects of priming treatments on days to germination and final germination percentage

Results indicated that seeds treated with KNO_3 were the first to germinate on the 5th day which is faster when compared to the normal time required for the sweet pepper seed to germinate as it is reported to resume germination on the 7th

day [25]. This can be explained by the ability of KNO_3 to produce a hormonal balance that reduces the concentration of chemical inhibitors of germination. In addition, priming using potassium nitrate has been reported to increase balance membrane potential and turgor, activation of enzymes and regulating osmotic pressure in the cells which helps in breaking seed dormancy [26]. These findings corroborate the work of several authors who reported that potassium plays an important role in enhancing seed germination of most Solanaceae crops like pepper [27, 25], tomatoes [28, 26] and other crops like papaya [29] and peas [30].

According to ISTA [18], the minimum percentage germination of *Capsicum* species is normally 75% but in this trial pre-sowing treatments using KNO_3 and pre-soaking improved germination percentage up to 96% and 83% respectively. Pre-sowing treatments trigger reinvigoration, repairs ageing seeds and in turn promote quick germination of crop seeds [26]. These results are supported by [25], who noted that pre-sowing treatments help in breaking seed dormancy through the interaction with the phytochrome signaling pathways, the ethylene biosynthesis, and interplays with reactive oxygen species.

However, on all the pre-sowing treatments, pre-chilling continuously produced the least results across all the germination parameters assessed. Pre-chilling may have lethal effects on some crop species as reported by several authors, so this may have been the case with sweet pepper in this investigation [31]. However, in many other experiments involving pre-chilling of seeds for plant species that grow mostly in summer have revealed that seeds pre-chilled for usually approximately 7 days have the highest germination percentages, but this was not the case with this experiment [11]. On the other hand, those seeds which were not pre-treated had the lowest values on all germination parameters tested and this can used as evidence to concur with several authors who reported that sweet pepper seeds have a low germination percentage due to physiological seed dormancy [32, 20]. According to Evaluations handbook 2019 Potassium Nitrate KNO_3 is effective in that it encourages the germination of the dormant seed of many species when it is incorporated in the germination medium at a concentration of between 0.2% and 0.3% respectively.

4.2. Effects of priming treatments on Speed of germination and Mean germination time (MGT)

The study showed that priming treatments improved the speed of germination but at the same reduced the mean germination time. Across all the treatments, pre-treated seeds had the highest speed of germination and the lowest mean germination time with KNO_3 leading followed by pre-soaking in water. It is reported that pre-treated seeds complete the first two stages of imbibition during the priming process and upon sowing, treated seeds tend to complete the third stage of imbibition and therefore emerge faster [33]. Therefore, it is possible that this could be the reason why pre-treated seeds had to germinate faster in this research. Parera et al [34], also stated that seed priming is commonly used to reduce the time between seed sowing and seedling emergence. This is in agreement with the observations of this study were pre-treated seeds resumed germination on the 5th day, which is much faster than the stipulated time, [17]. Moreover, the reduced mean germination time in pre-treated seeds may be due to improved imbibition of water which decreases resistance of endosperm and causes pre-treated seeds to germinate faster than the control [35]. In support of these findings, [36], also observed a reduction in mean time to germination after pepper seeds were primed in - 1.0MPa PEG. Contrary to these findings of Tariq [37], who observed no significant differences in mean germination time among primed and control seeds when pepper seeds were primed in 1.0 mM NaCl for 48 hours. KNO_3 treated seeds emerge faster and uniformly followed by pre-soaked as a result of changes that take place during priming such as increase water absorption and pre-germinative activities which lead to cell elongation and division [38]. Similar results were observed on several crop species where the mean germination time was reduced while germination rate was improved due to seed priming with KNO_3, tomato [28], soyabean [39], and Brassica napus [26]. The control which was the untreated started to germinate on the 6th day and completed its germination on the 14th day and this was supported by [40], who propounded that untreated seeds germinate slowly and irregularly. The feature of seed coat is soft so that physical disturbance may exert high impact on the embryo. With the given lowest speed germination, initiation of germination day, germination was achieved on the 6th day respectively, this supports the earlier deductions that most Capsicum annuum seed have late germination [35, 25]. In general, the untreated seeds germinate slowly and irregularly [40] this was evidenced by the cumulative germination time where the control took 14 days to germinate, and it was the slowest amongst all the treatments.

4.3. Effects of priming treatments on Radicle, Plumule, Seedling length and Seedling vigor index 1 (SV1)

Pre-treated seeds consistently gave higher values of radicle, plumule and seedling lengths when compared with the control. Higher lengths in $KN0_3$ treated seeds can be attributed to its ability to reactivate metabolic processes in seeds which causes biosynthesis of auxin which then triggers the growth of the embryo, radicle, plumule and seedling (Khan et al 1999). Similar results of improved root, shoot and seedling length due to pre-sowing treatments were reported by several authors working with different crops, corn [41], watermelon and tomato [42, 43]. Moreover, according to several authors pre-sowing treatment is a technique of seed enhancement that improves seed performance by rapid germination, vigorous seedling growth rate and uniformity of different crop species [28, 31, 13].

Pre-treated seeds with KNO_3 had higher seedling vigor when compared to the control. Seedling vigor is not a single measurable entity, but it is a sum of many growth parameters, such as seedling length, seedling fresh weight, and seedling dry weight [20]. Therefore, the combined result of the other growth parameters could have contributed to higher seedling vigor on KNO_3 treated seeds. Furthermore, pre-treating seeds has been reported to influence seedling vigor index in many crop species due the metabolic processes that take place during priming which includes repairing of membrane and channeling of assimilates to the developing embryos [35]. These results are also in line with previous findings in watermelon [33] and chickpea [44].

5. Conclusions

Priming seed in potassium nitrate and water increased days to germination, germination percentage, speed of germination, radicle and plumule lengths, as well as seedling vigor index and reduced the mean germination time of sweet pepper. Pre-chilling is not effective in improving seed germination and early growth of sweet pepper.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the Department of Research and Specialist Services, Institute of Seed Services for providing pepper germplasm and the facilities (lab) for the tests.

Disclosure of conflict of interest

Author (s) declare (s) that there is no conflict of interest

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