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Preserving Seed Quality in Chilli (*Capsicum annuum* L.): The Role of Seed Coating and Storage Temperature

P. Anshidha [a*], Flemine Xavier [a], T. Pradeepkumar [a], P. Anitha [b] and C. R. Rashmi [a]

[a] Department Vegetable Science, Kerala Agricultural University, Vellanikkara - 680 656, India.
[b] Department Plantation Spices Medicinal and Aromatic Crops, Kerala Agricultural University, Vellanikkara - 680 656, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Seed coating is one of the effective seed invigoration techniques used to enhance different quality parameters of seeds under ambient and stress conditions. In the present investigation we studied the effect of seed coating of different chemicals in freshly harvested chilli seeds over a storage period of nine months in two different storage temperature i.e., room temperature and cold storage (≤ 5°C). Freshly harvested chilli seeds subjected to coating with $ZnSO_4$(1%), KNO_3(3%), Na_2HPO_4 (1%), *Pseudomonas fluorescence* (2%) and carbendazim (0.2%) along with control. After the seed treatments they were dried under shade to regain the original weight, packed in 300-gauge air tight polythene bag and stored separately in two storage temperatures. Observations were recorded on

**Corresponding author: E-mail: anshidhapathari@gmail.com;*

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germination (%), speed of germination, root length, shoot length, seedling length, seedling dry weight, seedling vigour index I and II. The experiment was conducted in CRD with three replications. Results revealed that all the treated seeds retained satisfactory seed quality parameters when stored in cold storage compared to room temperature. Under room temperature storage, only seeds coated with KNO_3 and Carbendazim achieved germination rates above 60%. Among these, KNO_3-coated seeds recorded the highest germination (68.50%), speed of germination (11.89), vigour index-I (760.11), and vigour index-II (1231.80). In cold storage conditions, KNO_3-coated seeds again exhibited maximum germination (87.50%), vigour index-I (1087.58), and vigour index-II (1485.50), while seeds coated with Carbendazim showed the highest speed of germination (27.61). Thus, integrating appropriate seed coatings, especially with nutrients and fungicides, along with cold storage, is essential for improving germination and vigor and maintaining the viability, during storage.

Keywords: Seed coating; storage; seed quality; chilli.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.), a member of solanaceae family is a significant vegetable and universal spice crop of India, used often in the preparation and preservation of food and medicines. The excellent nutritive value such as rich in vitamin C and Vitamin A, antibacterial qualities, presence of bioflavonoids and anti-oxidants makes the crop an irreplaceable vegetable in Indian cuisine (Raju & Luckose, 1991; Pawar *et al.,* 2011). However, maintaining seed quality during storage and enhancing seed performance are persistent challenges for growers and seed producers. Rapid deterioration of stored vegetable seed is a serious problem which occurs at an increasing rate in uncontrolled storage. The rate of seed deterioration can be reduced by seed treatment, coating, or pelleting with suitable chemicals, botanicals, micronutrients and biocontrol agents which reduce quantitative and qualitative loss and maintain seed quality for longer storage (Kavitha *et al*., 2009). Seed coating technologies, which involve applying materials such as polymers, nutrients, fungicides, insecticides and biocontrol agents to seeds, have emerged as effective tools to improve seed vigour, germination, and resistance to environmental stresses. Similarly, storage temperature is a critical factor influencing seed longevity and quality. Proper management of these variables can mitigate issues like seed aging, reduced germination rates, and lower field emergence.

This research aims to explore the combined effects of seed coating treatments and storage temperature on the quality attributes of chilli seeds. By understanding these interactions, the study seeks to provide insights into optimizing seed management practices for enhanced crop productivity and sustainability.

2. MATERIALS AND METHODS

Freshly harvested chilli (*Var.* Ujwala) seeds were coated with $ZnSO_4$ (1%), KNO_3 (3%), Na_2HPO_4 (1%), *Pseudomonas fluorescence* (2%) and carbendazim (0.2%). Following coating, the seeds were shade-dried to restore their original moisture content and subsequently stored under two conditions—ambient room temperature and cold storage—for a duration of nine months. Storage and experimental procedures were carried out at the Department of Vegetable Science, College of Agriculture, Kerala Agricultural University, Vellanikkara.

After the storage period, seeds from each treatment, along with untreated control samples, were evaluated for germination using the between-rolled-paper-towel method. Ten seedlings were randomly selected from each treatment for assessing seed quality parameters, including germination (%), speed of germination, shoot length, root length, total seedling length (cm), seedling dry weight (mg), and seedling vigor indices I and II. The experiment was laid out in a factorial Completely Randomized Design (CRD) with three replications.

2.1 Germination (%)

The germination per cent was calculated based on the number of normal seeds germinated

Germination % = (Number of germinated seeds)/ (total number of seeds kept for germination) × 100

2.2 Speed of Germination

Speed of germination = $X_1/ Y_1 + (X_2 – X_1) / Y_2 +$ …… … …. $+ (X_n – X_{n-1}) / Y_n$ (Maguire, 1962)

Where,
X_n = Per cent germination on n^{th} day
Y_n = number of days from sowing to n^{th} count.

2.3 Seedling Vigour Index I & II

Seedling vigour index I (SV-I) = Germination (%) × Mean seedling length in cm. (Abdul Baki & Anderson, 1973)

Seedling Vigour Index II (SV-II) = Germination (%) × seedling dry weight (mg). (Bewley & Black, 1982)

3. RESULTS AND DISCUSSION

3.1 Effect of Seed Coating Treatments on Quality Parameters of Chilli Seed

Effect of seed coating treatments and storage temperature on quality parameters of chilli seeds is presented in Table 1. Seed coating treatments had significant effects on all quality parameters of chilli seeds except speed of germination. The final germination percentages of seeds stored at room temperature were 3.50%, 46.00%, 68.50%, 58.00%, 52.50%, and 64.00% for the treatments of control, seed coating with 1% $ZnSO_4$, 3% KNO_3, 1% Na_2HPO_4, 2% *Pseudomonas fluorescens*, and 0.2% Carbendazim, respectively. In cold storage, the corresponding final germination counts were higher, recorded at 67.50%, 74.50%, 87.50%, 76.50%, 75.00%, and 79.00% for the same treatments. Seed coating with 3% KNO_3 recorded the highest germination count among all treatments. In cold storage, all treatments achieved germination rates above the Indian seed certification standard (>60%), while at room temperature, only seeds coated with 3% KNO_3 and 0.2% Carbendazim maintained this benchmark. Regarding the speed of germination, seeds coated with 0.2% Carbendazim under cold storage recorded the highest value (27.61), followed by seeds coated with 1% Na_2HPO_4 (26.32) and 3% KNO_3 (26.02), both under cold storage and statistically at par. Overall, across both storage conditions, all coated seeds performed significantly better than uncoated seeds, highlighting the positive impact of seed coating on maintaining seed quality during storage.

All the seeds stored under cold conditions recorded higher root length compared to the seeds in cold storage. Seed coating effect 1% $ZnSO_4$ also influenced the root growth of seedlings with highest root length in seeds stored in cold storage (7.98 cm) and room temperature (6.58 cm). All treatments, except the control stored at room temperature, showed increased shoot growth, with the highest shoot length observed in seeds coated with 3% KNO_3, measuring 4.88 cm at room temperature and 4.64 cm under cold storage. The maximum seedling length observed in seeds coated with 1% $ZnSO_4$ (12.53 cm), 3% KNO_3 (12.43 cm) and 1% Na_2HPO_4 (12.40 cm) under cold storage. The highest seedling dry weight (0.19 mg) was recorded in seeds coated with 0.2% carbendazim and stored under cold conditions, and this was statistically at par with all other treatments, except the control and seeds coated with 1% Na_2HPO_4 in cold storage. Seed coating had a significant influence on seedling vigour index–I (SV-I), with seeds coated with 3% KNO_3 and stored in cold storage recording the highest SV-I value (1087.58), followed by all other treatments except the control under room temperature. Similarly, both seed coating and storage temperature had a significant effect on seedling vigour index–II (SV-II). The maximum SV-II value (1485.5) was observed in seeds coated with 3% KNO_3 and stored in cold storage, followed by seeds coated with 0.2% carbendazim (1420.0) under the same storage conditions. Across all treatments, seed coating consistently resulted in higher SV-II values compared to the control, with control seeds showing only 36.5 under room temperature and 1079.2 under cold storage. These findings clearly demonstrate that seed coating enhances the seed quality of chilli compared to uncoated seeds, particularly when stored under cold conditions.

Seed coating is a mechanism of providing plant growth promoting substances with seeds to improve seed quality (Rocha et al., 2019a, b). This method improves seed handling, protects against pathogens, and enhances germination and seedling vigour (Taylor et al., 1998). Additionally, nutrient-enriched seed coatings ensure better nutrient availability during the initial stages of seedling growth, leading to enhanced root and shoot development.

The application of micronutrients and macronutrients as seed priming agents at optimized concentrations has been shown to improve key physiological and agronomic parameters including germination rate, crop

Table 1. Effect of seed coating and storage temperature on chilli seeds after nine months of storage

Treatment		Germination (%)	Speed of germination	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling dry wt. (mg)	SV-I	SV-II
Seed coating	**Storage**								
T_1: Control	Room temp.	3.50	0.54	3.9	1.56	5.46	0.10	19.88	36.5
	Cold storage	67.50	18.54	7.53	4.07	11.26	0.16	762.42	1079.2
T_2: $ZnSO_4$(1%)	Room temp.	46.00	9.00	6.58	4.48	11.06	0.17	510.45	781.8
	Cold storage	74.50	25.24	7.98	4.55	12.53	0.18	933.58	1339.5
T_3: KNO_3(3%)	Room temp.	68.50	11.89	6.22	4.88	11.10	0.18	760.11	1231.8
	Cold storage	87.50	26.04	7.79	4.64	12.43	0.17	1087.58	1485.5
T_4: Na_2HPO_4 (1%)	Room temp.	58.00	9.71	6.70	4.58	11.28	0.17	654.24	983.7
	Cold storage	76.50	26.32	7.91	4.49	12.40	0.14	948.36	1071.0
T_5: *Pseudomonas*	Room temp.	52.50	10.50	6.46	4.27	10.73	0.17	565.02	889.5
fluorescence (2%)	Cold storage	75.00	24.88	7.88	4.27	12.15	0.17	909.77	1273.2
T_6: Carbendazim	Room temp.	64.00	10.12	7.06	4.25	11.31	0.18	722.07	1216.0
(0.2%)	Cold storage	79.00	27.61	7.73	4.29	12.02	0.19	947.78	1420.0
CD (0.01)		3.861	1.65	0.795	0.909	1.478	0.01	0.01	96.994
CV %		3.654	5.863	11.133	7.728	7.842	7.626	7.626	5.393

emergence, stand establishment, seedling growth, mineral nutrient uptake, dry matter accumulation, water use efficiency, vigour indices, seedling biomass, and shoot/root development. Seed pre-treatment initiates crucial metabolic processes that promote efficient mobilization of stored food reserves, converting them into sugars essential for protein synthesis during germination, thereby supporting rapid and uniform seedling emergence (Rouhi *et al.,* 2011). Notably, nitrates play a dual role during germination and early seedling development, acting both as essential nutrients and as signalling molecules (Duermeyer *et al.,* 2018). Among various nutrient treatments, potassium nitrate is particularly effective, as it supplies both potassium and nitrate ions, potentially contributing to improved germination quality and early seedling growth. These findings align with Vijayalakshmi *et al.* (2013), who reported that tomato, brinjal, and chilli seeds fortified with 2% KNO_3, followed by seed coating, exhibited superior performance in terms of seedling quality parameters, including germination, seedling length, dry matter production, and vigour index. Amjad *et al.* (2007) also observed that seeds treated with KNO_3 outperformed all other treatments by reducing the time required for 50% germination and enhancing root length, shoot length, seedling fresh weight, and overall vigour compared to other priming agents. Similarly, Argerich & Bradford (1989) noted increased seed vigour in tomato with KNO_3 and KH_2PO_4. Seed coating with micro- and macronutrients ensures nutrient availability during the early stages of germination, leading to enhanced seed germination and improved seedling growth (Klarod *et al.,* 2021).

Seed aging is the primary cause of reduced germination and vigour, as it depletes food reserves, lowers embryo activity, and increases susceptibility to fungal infections, insect attacks, and unsuitable storage conditions. Protective coatings, along with cold storage, thus play a vital role in preserving seed vigour and ensuring rapid germination. The decline in the speed of germination (SoG) observed in untreated seeds underscores the detrimental effects of seed aging and pathogen activity under suboptimal storage conditions. Most storage fungi are saprophytic, eventually invading the seed embryo, causing deterioration through direct invasion and the production of toxic metabolites that destroy cells and create dead tissue on which they thrive (Copeland & McDonald, 2012). Siddartha et al. (2017) reported that seeds of tomato coated with polymer at 7 ml/kg and thiram at 2 g/kg demonstrated significantly higher germination percentage, seedling length, and vigour indices I and II compared to other treatments after six months of storage. Thiram functioned as a protective agent by inhibiting fungal infection and slowing physiological ageing. Similarly, Geetharani et al. (2006) observed minimal fungal contamination in chilli seeds treated with a combination of polymer and fungicide. Similar findings were reported by Singh *et al.,* (2021), who observed that seeds coated with insecticide and fungicides outperformed untreated controls in all seed quality parameters, including germination, field emergence, seedling length, seedling dry weight, speed of germination, seedling vigour index, and also recorded the lowest electrical conductivity and seed infection at the end of the storage period.

3.2 Effect of Storage Temperature on Quality Parameters of Chilli Seed

Significant results were obtained due to seeds stored in different storage temperature for the seed quality parameters. Among the treatments, all the seeds stored in cold temperature recorded significantly higher germination and quality characteristics at the end of nine months of storage period (Table 1).

Across the treatment combinations, all seeds stored under cold conditions, including untreated seeds, maintained a significant level of germination and vigour. In contrast, among seeds stored at room temperature, only those coated with 3% KNO_3 and 0.2% carbendazim exhibited higher germination percentages (68.5% and 64%, respectively) compared to the other treatments after nine months of storage. In cold storage, all coated seeds recorded higher germination percentages and vigour indices, with seeds coated with 3% KNO_3 achieving the highest germination (87.50%) along with the highest seedling vigour index I of 1087.58 and seedling vigour index II of 1485.5. Additionally, seeds coated with carbendazim and stored under cold conditions recorded the highest speed of germination (SoG) value (27.61) among all treatment combinations.

Proper seed storage management, including temperature control, can significantly impact agricultural productivity by preventing seed deterioration and enhancing plant performance in the field. The longevity of primed seed is

affected by many factors such as oxygen, relative air humidity, seed moisture content, and temperature (Rajjou & Debeaujon 2008). Optimal storage conditions for primed seeds include low temperature, low relative humidity, and vacuum storage. (Wang et al., 2018). Hussain *et al.,* (2015) found the lowest seed germination and growth of seedling in primed rice seeds stored at 25 °C, while no significant reduction in seeds stored at −4 °C. Tu *et al.* (2022) found that the treatment effect on pepper seeds lasts for about six months in three varieties of chilli. Storing primed seeds in sealed plastic bags at a low temperature (-4°C) helps maintain their viability and priming benefits. Barton (1939), from a three-year study on aster seeds, reported that seeds stored under controlled conditions with low temperature and low to moderate moisture content consistently maintained high germination rates, whereas seeds stored at ambient temperature with similar moisture levels more rapidly deteriorated. These findings align with the reports of Copeland & McDonald (2012), who emphasized that storing seeds at lower temperatures reduces their metabolic activity and moisture uptake, thereby slowing deterioration. The results indicate that maintaining low seed moisture content under cool storage conditions is crucial for preserving seed quality over extended periods.

4. CONCLUSION

Chilli seeds treated with different macro or micro nutrients, biocontrol agents or fungicides coatings performed better than untreated seeds in terms of Germination, vigour and seed viability. Furthermore, storage under cold conditions was markedly superior to room temperature in maintaining seed viability and vigour over an extended period. Therefore, the application of seed coatings, combined with cold storage, is recommended as an effective strategy for prolonging the storage life and quality of chilli seeds.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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