

Effect of Storage Conditions on Seed Viability and Vigour of Quinoa (*Chenopodium quinoa* Willd.) Variety Himshakti

AXAY BHUKER^{1*}, VS MOR¹, MS PUNEETH RAJ¹, JHABARMAL SUTALIYA² AND MS HARISH¹

¹Department of Seed Science and Technology, ²MAP Section (G&PB),
CCS Haryana Agricultural University, Hisar, Haryana-125 004, India
*bhuker.axay@gmail.com

(Received January 2025; Revised February 2025; Accepted March 2025)

ABSTRACT: Quinoa (*Chenopodium quinoa*), a nutrient-rich pseudocereal, is increasingly valued worldwide; however, limited data exist on its seed storability under typical handling conditions. This study assessed the viability and vigor of freshly harvested seeds of the variety 'Himshakti' stored in polythene bags under controlled (4°C and 6°C, 30±5% RH) and ambient conditions over eight months. Initial germination was below 50%, and a sharp decline was observed under ambient storage—from 41% to 6%. In contrast, seeds stored at 4°C retained 37% germination. Superior seedling traits and vigor indices were recorded under cooler conditions, with seeds at 4°C showing maximum seedling length (11.90 cm), dry weight (1.09 mg), vigor index-I (443.1), and vigor index-II (40.42). Seeds stored under ambient conditions showed the poorest performance across all parameters. The study concludes that storing quinoa seeds at 4°C temperature and 30±5% RH in polythene bags significantly preserves seed quality over time.

Keywords: quinoa, seed storability, seed quality, ambient storage, controlled conditions

Quinoa (*Chenopodium quinoa*), a pseudocereal belonging to the Chenopodiaceae subfamily of the Amaranthaceae family, is native to the Andean regions of Chile, Peru, Ecuador, and Bolivia. Its cultivation dates back thousands of years [1,2]. Quinoa is often referred to as a "super grain" due to its abundant content of fibers, vitamins E and C, vitamin B complex, and minerals such as calcium, magnesium, iron, potassium, phosphorus, manganese, zinc, copper, and sodium. In comparison to cereals like wheat, corn, rice, barley, oats, rye, and sorghum, quinoa plays a significant role in the global human diet, offering enhanced nutrition [3,4]. One notable attribute of quinoa is its suitability for producing gluten-free food products, as it lacks gliadins (proteins found in wheat responsible for gluten formation) and gliadin-related protein fractions (found in oats, barley, rye, and malt). This characteristic enables the provision of a greater variety of nutritious foods suitable for individuals with celiac disease [5]. Quinoa seeds are considered a complete food due to their high nutritional value, primarily attributed to their elevated content of high-quality protein [6]. Quinoa's protein content surpasses that of cereals, ranging from 14% to 18% of the seed, while maize has 10%, rice has 8% and wheat has 14%. Notably, quinoa seeds contain higher concentrations of metabolically active proteins, specifically albumins and globulins,

accounting for 44% to 77% of the total protein content. Carbohydrates present in quinoa seeds consist of 58% to 68% starch, with a relatively low amylose content of 11% to 12%. In comparison, rice has 17% amylose content, while maize and wheat have 28% amylose content. Additionally, quinoa contains 2% to 9.5% oil content, rich in essential fatty acids such as linoleic and α -linolenic acids. Furthermore, quinoa exhibits elevated concentrations of natural antioxidants, including α - and γ -tocopherol [7]. Quinoa seeds are round and flat, with diameters ranging from 1.5 mm to 4.0 mm, and come in various colors including white, gray, yellow, red, and purple. With these exceptional qualities, quinoa shows potential as the "super grain" of the future and could potentially replace other cereals in various applications. The quinoa species comprises a total of 1800 varieties, and the seed physiological quality of each variety can vary due to factors such as genetic structure, seed size, and moisture content [8]. A controlled storage environment plays a crucial role in maintaining seed quality during storage. Seeds are living entities that contain embryos, and their quality can deteriorate over time if not stored under proper conditions. Temperature is one of the most critical factors in seed storage. Controlling the storage temperature helps slow down the seed's metabolic processes, reducing respiration rates

and maintaining seed viability [9; 10]. Storing seeds within suitable temperature range helps preserve their viability and germination potential. Humidity levels in the storage environment can greatly impact seed quality. High humidity can lead to moisture uptake by the seeds, potentially causing germination or fungal issues. Conversely, low humidity can cause seeds stored in moisture pervious containers to dry out and seeds subsequently lose their viability. Hence, the present study was planned to assess the effect of storage environment on seed storability of quinoa seeds.

MATERIALS AND METHODS

Seeds of the quinoa variety Himshakti was produced during *Rabi* 2021-22 at breeder seed farm. The freshly harvested seed was packed in polythene bags and stored in two environments *i.e.* Controlled and ambient conditions. Under controlled conditions seed was stored in the seed bank at 4 and 6°C temperature and 30±5% R.H. and under ambient conditions, in the laboratory of Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar. The experiment was conducted using CRD design in four replications and observations were recorded on seed moisture content (%), standard germination (%), seedling length (cm),

seedling dry weight (mg), 1000 seed weight (g) Vigour Index-I & II and seed viability (%). Germination test was conducted by using three replicates of hundred seeds on top of the paper (TP) method at 25°C temperatures [11,12]. After seven days, the final count of normal seedlings was conducted, and the percentage of germination was calculated according to the guidelines set by the International Seed Testing Association [13]. From four replications of the standard germination test, ten normal seedlings were randomly selected. The length of these seedlings was measured, and the average length of the ten seedlings was recorded in centimeters for further calculations. Ten seedlings from each treatment, replicated four times were dried in a hot air oven at a temperature of 80±1°C for 24 hours. Once dried, the seedlings from each replication were weighed, and the average dry weight of seedlings for each genotype was calculated. Seedling vigour indices were calculated according to the method mentioned below [14]:

Vigour index-I = Standard Germination (%) x Average seedling length (cm)

Vigour index-II = Standard Germination (%) x Average seedling dry weight (mg)

Due to poor emergence, the viability was tested through Tetrazolium test. For estimation of viability (%) fifty seeds

Table 1. Effect of storage environment on seed quality parameters of quinoa (*Chenopodium quinoa* Willd.)

Storage Environments (E)	Storage period in months (P)	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Vigour index-I	Vigour index-II	Moisture content (%)	1000 seed weight (g)
Ambient Storage	Initial	41.00 (39.79)	15.33	1.23	628.7	50.34	7.385	2.415
	2	35.00 (36.25)	14.95	1.21	523.1	42.20	7.380	2.396
	4	24.75 (29.81)	13.15	1.05	325.7	26.02	7.395	2.381
	6	15.00 (22.74)	11.73	0.96	176.0	14.37	7.383	2.388
	8	6.25 (14.42)	10.13	0.85	63.2	5.35	7.405	2.395
At 4°C temperature	Initial	41.00 (39.79)	15.33	1.23	628.7	50.34	7.385	2.415
	2	41.00 (39.79)	15.25	1.23	625.2	50.34	7.390	2.418
	4	41.00 (39.79)	14.83	1.19	607.9	48.78	7.388	2.428
	6	38.25 (38.19)	12.46	1.16	476.6	44.35	7.383	2.415
	8	37.25 (37.59)	11.90	1.09	443.1	40.42	7.390	2.413
At 6°C temperature	Initial	41.00 (39.79)	15.33	1.23	628.73	50.34	7.385	2.415
	2	37.75 (37.89)	15.16	1.22	572.4	45.95	7.383	2.410
	4	37.00 (37.45)	14.68	1.19	543.0	43.84	7.368	2.408
	6	35.50 (36.55)	12.20	1.16	433.1	41.00	7.395	2.405
	8	35.25 (36.40)	11.57	1.06	407.6	37.45	7.395	2.390
SE ±(m)		E=0.44, P=0.57, ExP=0.99	E=0.03, P=0.04, ExP=0.08	E=0.005, P=0.007, ExP=0.01	E=6.93, P=8.95, ExP=15.49	E=0.56, P=0.72, ExP=1.76	E=0.01, P=0.01, ExP=0.02	E=0.02, P=0.02, ExP=0.04
CD (P=0.05)		E=1.27, P=1.64, ExP=2.84	E=0.10, P=0.13, ExP=0.22	E=0.02, P=0.02, ExP=0.03	E=20.17, P=26.04, ExP=45.10	E=1.59, P=2.06, ExP=3.56	E=NS, P=NS, ExP=NS	E=NS, P=NS, ExP=NS

replicated thrice were soaked into distilled water at 20°C for 18 hours to activate dehydrogenase enzymes. Then seeds were soaked into 1.0% Tetrazolium solution for 20 hours at 30°C. After that solution was poured off and seeds were rinsed briefly in tap water and examined under stereo microscope Discovery.V20. The completely stained seeds were considered as viable and expressed in percentage according to method developed by Moore [15]. The experiment was conducted in factorial completely randomized design for laboratory parameters as per standard method [16] and data observed was analyzed by using the online statistical tool (OPSTAT) [17].

RESULTS AND DISCUSSION

The results revealed that seeds stored under controlled conditions maintained the germination for longer period. Under ambient conditions, germination reduced from 41.00% to 6% after 8 months of storage but at 4°C germination reduction was from 41% to 37% only. Under ambient conditions, the seed packed in cloth bag lost the germination completely after 4 months of storage only. The poor germination was confirmed by testing the viability of seeds through tetrazolium test (Figure 1). In other seed quality parameters also same trend was recorded. Maximum seedling length (11.90cm), seedling dry weight (1.09 mg), vigour index-I (443.1) and vigour index-II (40.42) was recorded in the seeds stored at 4°C followed by seeds stored at 6°C 11.57cm seedling length, 1.06 mg seedling dry weight, 407.6 vigour index-I and

37.45 vigour index-II while minimum seedling length (10.13cm), seedling dry weight (0.85 mg), vigour index-I (63.2) and vigour index-II (5.35) was found in the seeds stored at ambient conditions after 8 months of storage. No significant effect was recorded for moisture content and 1000 seed weight. The variations in temperature and relative humidity under ambient condition of storage is given in Figure 2. Similar findings were also reported by Granado-Rodríguez *et al.*, [18] suggesting that the quality of quinoa seeds can be preserved and potentially enhanced by maintaining a seed moisture content (SMC) lower than 12% and storing them at low temperatures (4°C) and low relative humidity (30±5%). Storing quinoa seeds in Super Bags with an initial seed moisture content of 8% effectively maintained low seed moisture levels and resulted in higher germination rates [19]. For ensuring longer durability in the storage of quinoa seeds, the most effective temperatures are 4°C and 10°C. It was observed that storing quinoa seeds at 25°C led to evident seed deterioration and loss of vigour [20]. When quinoa seeds are stored in impermeable packaging at a low temperature of 4±2°C, they retain their physiological quality for an extended period of 300 days. However, when stored under uncontrolled temperature and moisture conditions using semi-permeable and impermeable packaging, the seeds remain viable for up to 180 days of storage [21]. Polypropylene bags, whether laminated or non-laminated, serve as a cost-effective packaging option for basmati rice under ambient storage conditions [22]. In a similar study on packaging materials, pigeon pea seeds stored in PICS bags exhibited the best performance, which was statistically comparable to those stored in GrainPro and Trial bags, while the poorest performance was observed in seeds stored in gunny bags under ambient storage conditions [23]. *Gazania splendens* L. recorded highest germination when packed in polyethylene bags and stored in cold store (0-4°C) as compared to storage in incubator (20-22°C) and ambient storage [24]. The effect of controlled storage conditions was also evaluated in mustard (*Brassica juncea*), revealing that seed viability declined to 50% after 33 months at 25°C, whereas at 10°C and -10°C, the reduction was minimal, with only a 1–2% decrease [25]. Our study shows that quinoa seeds have poor germination, with initial germination less than 50% in the studied lot. Freshly harvested seeds also had 41% germination. Hence, further research is required to fully understand the reasons behind low germination in quinoa crops. Provenance effect, physiological factors, and



Figure 1. Quinoa seed viability testing through Tetrazolium test

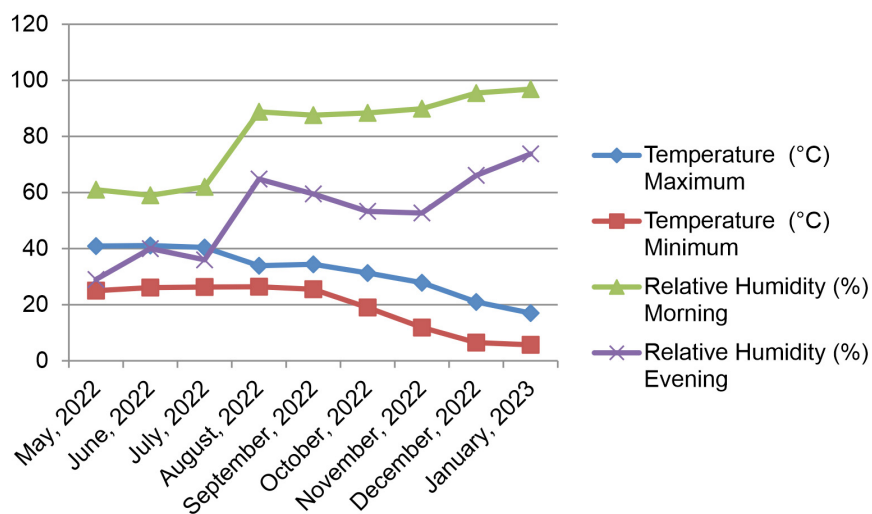


Figure 2. Average weather data during ambient storage period

genetic factors are potential areas that need to be explored. Variations in germination rates among quinoa varieties or accessions from different regions suggest adaptations to specific environmental conditions. Physiological factors such as seed dormancy, water uptake and hormonal imbalances may also play a role. Additionally, genetic factors related to seed coat properties, embryo development, and stress tolerance mechanisms can impact germination. By investigating these factors, researchers can gain valuable insights to improve germination rates in quinoa crops and enhance overall crop productivity. Without proper control over temperature, humidity, light, and pest management, seeds are more susceptible to unfavorable conditions that accelerate their ageing and reduce their quality. To mitigate these risks and ensure long-term seed storage, controlled environments such as seed banks, gene banks, or specialized seed storage facilities should be utilized [26]. Regulation of seed moisture content by drying to safe moisture limits is also very important for prolonging the storage life of such seeds. In the present study, correlation with seed moisture content has not been undertaken and needs further investigation. It is concluded from the study that in order to maintain the seed germination in quinoa, it should be stored at controlled conditions (at 4°C temperature and R.H. of 30±5%).

REFERENCES

1. ABDUL-BAKI AA AND JDANDERSON (1973). Relationship between decarboxylation of glutamic acid and vigour in soybean seed. *Crop Science*, **13**: 222-226.
2. ABUGOCH LE, N ROMERO, CATAPIA, J SILVA AND M RIVERA (2008). Study of some physicochemical and functional properties of quinoa (*Chenopodium quinoa* Willd) protein isolates. *Journal of Agricultural and Food Chemistry*, **56**(12): 4745-4750.
3. ALMEIDA SG AND WAC SAM (2009). Amaranto (*Amaranthus* spp.) e quinoa (*Chenopodium quinoa*) alimentos alternativos para doentes celíacos. *Ensaio e Ciência: Ciências Biológicas, Agrárias e da Saúde*, **12**: 77-92.
4. BAKHTAVAR MA AND I AFZAL (2020). Climate smart Dry Chain Technology for safe storage of quinoa seeds. *Scientific Reports*, **10**(1):12554. doi: 10.1038/s41598-020-69190-w
5. BHUKERA, VS MOR, SS JAKHAR AND MS PUNEETH RAJ (2020). Seed quality testing study in Quinoa (*Chenopodium quinoa* Willd.). *Bhartiya Krishi Anusandhan Patrika*, **35**(1&2): 87-90.
6. DINI A, L RASTRELLI, P SATURNINO AND O SCHETTINO (1992). A compositional study of *Chenopodium quinoa* seeds. *Molecular Research-Food/ Nutrition and Food Nahrung*, **36**: 400-404.
7. GRANADO-RODRÍGUEZ S, I MAESTRO-GAITAN, J MATÍAS, MJ RODRÍGUEZ, P CALVO, LE HERNANDEZ, L BOLAÑOS AND M REGUERA (2022). Changes in nutritional quality-related traits of quinoa seeds under different storage conditions. *Frontiers in Nutrition*, **9**: 995250. doi:10.3389/fnut.2022.995250. PMID: 36324620; PMCID: PMC9620721
8. ISTA (2019). International Seed Testing Association. ISTA International Rules for Seed Testing. Bassersdorf, Switzerland.
9. SELEMANI S, R MADEGE AND Y NZOGELA (2023). Influence of storage conditions on viability and vigour of sunflower (*Helianthus annuus* L.) seeds. *Journal of Current Opinion in Crop Science*, **4**(3): 141-153. <https://doi.org/10.62773/jcocs.v4i3.211>
10. GU DE, SH HAN AND KS KANG (2024). Viability and integrity of *Pinus densiflora* seeds stored for 20 years at three different temperatures. *Conservation Physiology*, **12**(1): coae046. <https://doi.org/10.1093/conphys/coae046>
11. JANCUROVA M, L MINAROVIEVOVA AND A DANDAR (2009). Quinoa: A review. *Czech Journal of Food Sciences*, **27**: 71-79.

12. KIBAR H, S TEMEL AND B YÜCESAN (2021). Kinetic modelling and multivariate analysis on germination parameters of quinoa varieties: Effects of storage temperatures and durations. *Journal of Stored Products Research*, **94**: 101880. <https://doi.org/10.1016/j.jspr.2021.101880>
13. KOZIOL MJ (1992). Chemical composition and nutritional evaluation of Quinoa (*Chenopodium quinoa* Willd.). *The Journal of Food Composition and Analysis*, **5**: 35-68.
14. MARADINI-FILHO AM, MR PIROZI, JTS BORGES, HMP SANTANA AND JBP CHAVES ET AL (2017). Quinoa: Nutritional, functional and anti-nutritional aspects. *Critical Reviews in Food Science and Nutrition*, **57**: 1618-1630.
15. MOORE RP (1985). Handbook of tetrazolium testing. *International Seed Testing Association*, Zurich, Switzerland.
16. PANSE VG AND PV SUKHATME (1985). Statistical methods for agricultural workers. ICAR. Pub. New Delhi.
17. ROBERTS EH AND RH ELLIS (1989). Water and seed survival. *Annals of botany*, **63**(1): 39-39.
18. SHEORAN OP (2010). Online statistical analysis (OPSTAT) software developed by Chaudhary Charan Singh Haryana Agricultural University, Hisar, India.
19. SOUZA FFDJ, IA DEVILLA, RTGD SOUZA, IR TEIXEIRA AND CTR SPEHA (2016). Physiological quality of quinoa seeds submitted to different storage conditions. *African Journal of Agricultural Research*. **11**: 1299-1308. 10.5897/AJAR2016-10870.
20. SPEHAR CR (2007). Quinoa: Alternativa para a diversificação agrícola alimentar. Planaltina, Brasil: Embrapa Cerrados: 21-31.
21. STRENSKE A, ES DE VASCONCELOS, VA EGEWARTH, NFMHERZOG AND MDEMMALAVASI (2017). Responses of quinoa (*Chenopodium quinoa* Willd.) seeds stored under different germination temperatures. *Acta Scientiarum Agronomy*, **39**(1): 83-88. <https://doi.org/10.4025/actasciagron.v39i1.30989>
22. KAUR M, KAUR N, SINGH TP AND R SINGH (2020). Effect of packaging materials on seed quality attributes of basmati rice during seed storage under ambient environmental conditions. *Seed Research*, **48**(1): 42-48.
23. MANJUNATHA UB, BASAVEGOWDA, DODDAGOUDAR SR, SANGEETA IM AND N SUSHILA (2019). Effect of packaging materials on pigeon pea seeds stored under ambient conditions. *Seed Research*, **47**(1): 59-64.
24. DHATT KK AND R KUMAR (2009). Effect of storage conditions, package material and storage period on seed germination and seed viability of *Gazania splendens* L. *Seed Research*, **37** (1&2): 88-98.
25. SINGH N, KHANNA PP AND NK CHAUDHARY (1993). Storability of mustard (*Brassica juncea*) in three different controlled environments. *Seed Research*, Special Volume 1. 319-322.
26. SONDARVA JYOTI, PATEL JB, VAGHASIYA KP AND VORA DV (2023) Effect of seed treatments, packaging materials and storage conditions on seed longevity in onion (*Allium cepa*). *Seed Research*, **51** (1): 26-33.