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ESTIMATION OF BIOCHEMICAL CHANGES IN GREEN GRAM (*Vigna radiata* L.) DURING STORAGE

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ABSTRACT

This study sought to determine the optimal storage conditions for green gram seeds by evaluating biochemical changes under various conditions. Eight green gram genotypes were stored in different containers, subjected to both ambient and refrigerated conditions, and monitored over a twelve-month period. Initially, the seeds were cleaned and sun-dried to achieve a safe moisture content of 8%. Throughout the storage period, assessments were made bi-monthly to measure protein and carbohydrate content, as well as electrical conductivity of the seeds. The results revealed a significant decline in protein and carbohydrate content, accompanied by an increase in electrical conductivity over time. Notably, genotypes G_6 (IPM-512-1), G_5 (Samrat), and G_1 (Pusa Vishal) consistently demonstrated the highest levels of protein and carbohydrates throughout the storage period. Among all storage conditions, seeds kept under refrigerated conditions (T_6) maintained the highest levels of both protein and carbohydrates. Furthermore, G_1 (Pusa Vishal) exhibited the lowest electrical conductivity during storage, with refrigerated conditions (T_6) proving to be the most effective in preserving the lowest electrical conductivity over the twelve-month period.

Keywords: Carbohydrate, Electrical conductivity, Green gram, Protein

With 22% of the global population and 33% of the world's land area devoted to pulse cultivation, India stands as the largest producer and consumer of pulses worldwide. In the agricultural year 2023-24, India cultivated green gram across approximately 15.93 lakh hectares (39.38 lakh acres), representing a slight increase from the 15.57 lakh hectares (38.47 lakh acres) in 2022-23. The principal green gram-producing states are Rajasthan, with 13.99 lakh hectares (34.57 lakh acres); Karnataka, with 1.14 lakh hectares (2.83 lakh acres); Madhya Pradesh, with 0.25 lakh hectares (0.61 lakh acres); Haryana, with 0.16 lakh hectares (0.41 lakh acres); and Gujarat, with 0.13 lakh hectares (0.32 lakh acres) (Source: Greengram Outlook, July 2023).

The genus *Vigna* encompasses several grain legume crops of substantial economic significance worldwide. Notable members of this genus include green gram (*Vigna radiata* (L.) Wilczek), urd bean (*Vigna mungo* L. Hepper), cowpea (*Vigna unguiculata* L. Walp), rice bean (*Vigna umbellata* Thunb), moth bean (*Vigna aconitifolia*), bambara groundnut (*Vigna subterranea*), adzuki bean (*Vigna angularis*), Sarawak bean (*Vigna hosei*), and beach bean (*Vigna marina*), among others. According to Chakraborty et al. (2022), green gram (*Vigna radiata* L.), characterized by a chromosome number of 2n=24, is extensively cultivated in India across three distinct seasons: pre-*kharif*, *kharif*, and *rabi*. In North India, it is grown during both the *kharif* and summer seasons, while in South India, it is cultivated as well.

According to Ray and Bordolui (2022a), seed storage is a critical post-harvest process that significantly influences the viability of seeds in subsequent generations. High-quality seeds, characterized by increased viability and vigour, are essential prerequisites for enhanced productivity, as highlighted by Yaklich *et al.* (1979) and Chakraborty and Bordolui (2021). Pulses, as noted by Ewart (1908), display mesobiotic storage behavior. Furthermore, Agrawal and Dadlani (1995) observed that their elevated lipoprotein content leads to rapid lipid peroxidation during storage, ultimately resulting in seed deterioration and degradation of quality characteristics. Consequently, the objective of this study is to evaluate how different storage conditions and containers impact the response of various genotypes.

MATERIALS AND METHODS

Seeds from control plots of eight genotypes—Pusa Vishal (G_1), PM-11-9 (G_2), IPM-2-3 (G_3), Meha (IPM

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Table 1. Average protein content (mg g^{-1}) of seeds over the storage period

Genotype/ Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1	224.212	216.558	209.929	204.414	199.292	193.758
G_2	220.219	212.688	206.057	200.643	195.731	190.295
G_3	224.191	216.525	209.925	204.427	199.262	193.729
G_4	222.138	214.144	207.603	202.148	197.071	191.598
G_5	224.207	216.539	209.912	204.409	199.275	193.745
G_6	224.226	216.543	209.943	204.396	199.279	193.74
G_7	223.79	216.532	209.918	204.403	199.268	193.735
G_8	220.076	212.549	206.191	200.774	195.603	190.171
SEm (±)	0.023	0.024	0.023	0.023	0.021	0.024
CD (p≤0.05%)	0.066	0.067	0.065	0.063	0.059	0.066

Genotypes: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822

99-125) (G_4), Samrat (G_5), IPM-512-1 (G_6), TMB-37 (G_7), and SML-1822 (G_8)—were utilized to assess their storage potential. After harvesting, the seeds were thoroughly cleaned and sun-dried to a safe moisture content of approximately 8% (Mbeyagala *et al.*, 2017). The seeds were then stored for twelve months. During the storage period, the protein and carbohydrate contents of the seeds were analyzed using the methods described by Lowry *et al.* (1951) and Hedge and Hofreiter (1962), respectively. Electrical conductivity measurements were taken every two months, resulting in six assessment intervals over the storage period. Each genotype's seeds were sealed in six different types of containers: aluminum foil packets (T_1), brown paper packets (T_2), polythene packets (700 gauge thickness) (T_3), cloth bags (T_4), and earthen pots (T_5) for storage under ambient conditions. Additionally, approximately 20 grams of seeds from each genotype were sealed in six 700 gauge polythene packets and stored in a refrigerator (T_6) at 4-5°C for comparative analysis. The laboratory experiment was conducted at the Seed Testing Laboratory, Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, using a two-factor Complete Randomized Design. Each set of storage conditions and containers was tested six times to evaluate various quality parameters at two-month intervals, culminating in a total of six testing sessions over the twelve-month storage period.

RESULTS AND DISCUSSION

Protein content (mg g^{-1}) of seeds at different stages of storage

The protein content of green gram seeds exhibited a slight decline from just after harvesting to two months into storage, with a consistent decrease observed up to twelve months. When averaging across genotypes and treatments, G_6 (IPM-512-1), G_5 (Samrat), and G_1 (Pusa Vishal) maintained the highest protein levels, recorded as 224.226 mg g^{-1}, 224.207 mg g^{-1}, and 224.212 mg g^{-1}, respectively. These genotypes remained statistically comparable throughout all storage durations (Table 1).

Table 2. Average protein content (mg g^{-1}) of seeds over the storage period

Treatment Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
T_1	223.018	215.290	208.811	203.325	198.126	192.623
T_2	222.700	215.083	208.447	203.035	197.935	192.439
T_3	222.914	215.390	208.714	203.230	198.218	192.713
T_4	222.628	215.014	208.514	203.134	197.872	192.532
T_5	222.808	215.188	208.615	202.970	198.032	192.377
T_6	223.227	215.592	209.007	203.516	198.404	192.894
SEm (±)	0.020	0.021	0.020	0.020	0.018	0.020
CD (p≤0.05%)	0.057	0.058	0.056	0.055	0.051	0.057

Treatments: T_1=Aluminium foil, T_2=Brown paper, T_3=Polythene, T_4=Cloth bag, T_5=Earthen pot, T_6=Freeze condition

Table 3. Average protein content (mg g-1) of seeds over the storage period

Genotype x Treatment	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1T_1	224.349	216.599	210.058	204.539	199.331	193.795
G_1T_2	224.037	216.385	209.696	204.254	199.133	193.602
G_1T_3	224.243	216.685	209.959	204.443	199.410	193.872
G_1T_4	223.962	216.334	209.765	204.341	199.086	193.704
G_1T_5	224.132	216.498	209.855	204.187	199.237	193.557
G_1T_6	224.545	216.845	210.242	204.718	199.557	194.015
G_2T_1	220.343	212.713	206.167	200.750	195.754	190.317
G_2T_2	220.044	212.519	205.829	200.489	195.575	190.144
G_2T_3	220.245	212.808	206.086	200.672	195.841	190.403
G_2T_4	219.970	212.446	205.898	200.575	195.509	190.234
G_2T_5	220.150	212.621	205.987	200.421	195.669	190.080
G_2T_6	220.563	213.020	206.374	200.952	196.037	190.591
G_3T_1	224.315	216.528	210.086	204.548	199.265	193.731
G_3T_2	224.015	216.354	209.646	204.264	199.105	193.576
G_3T_3	224.195	216.644	209.974	204.467	199.371	193.834
G_3T_4	223.962	216.303	209.726	204.370	199.058	193.667
G_3T_5	224.111	216.456	209.855	204.216	199.199	193.530
G_3T_6	224.545	216.866	210.261	204.698	199.576	194.033
G_4T_1	221.856	214.167	207.724	202.266	197.092	191.618
G_4T_2	221.558	213.981	207.365	201.995	196.921	191.453
G_4T_3	221.750	214.269	207.625	202.170	197.186	191.709
G_4T_4	221.474	213.899	207.445	202.082	196.846	191.534
G_4T_5	224.121	214.073	207.534	201.918	197.006	191.379
G_4T_6	222.068	214.473	207.923	202.459	197.374	191.892
G_5T_1	224.379	216.590	210.026	204.566	199.322	193.772
G_5T_2	223.994	216.334	209.696	204.216	199.086	193.594
G_5T_3	224.259	216.705	209.914	204.457	199.428	193.864
G_5T_4	223.909	216.252	209.746	204.341	199.011	193.675
G_5T_5	224.132	216.467	209.845	204.138	199.209	193.530
G_5T_6	224.566	216.886	210.242	204.737	199.595	194.033
G_6T_1	224.359	216.574	210.067	204.508	199.308	193.786
G_6T_2	224.047	216.374	209.726	204.235	199.124	193.557
G_6T_3	224.270	216.677	209.983	204.399	199.402	193.889
G_6T_4	223.994	216.303	209.776	204.332	199.058	193.675
G_6T_5	224.164	216.467	209.885	204.187	199.209	193.483
G_6T_6	224.524	216.866	210.222	204.718	199.576	194.051
G_7T_1	224.345	216.570	210.055	204.535	199.304	193.769
G_7T_2	223.994	216.334	209.657	204.216	199.086	193.557
G_7T_3	224.239	216.673	209.955	204.439	199.398	193.860
G_7T_4	223.920	216.262	209.726	204.322	199.020	193.658
G_7T_5	221.654	216.447	209.835	204.148	199.190	193.493
G_7T_6	224.587	216.907	210.281	204.756	199.613	194.070
G_8T_1	220.193	212.580	206.307	200.887	195.631	190.198
G_8T_2	219.906	212.386	205.957	200.614	195.453	190.025
G_8T_3	220.107	212.663	206.216	200.798	195.708	190.273
G_8T_4	219.832	212.314	206.028	200.711	195.387	190.107
G_8T_5	220.001	212.477	206.127	200.546	195.537	189.961
G_8T_6	220.414	212.876	206.513	201.087	195.904	190.464
SEm (±)	0.057	0.058	0.056	NS	0.052	NS
CD (p≤0.05%)	0.161	0.164	0.158	NS	0.145	NS

Genotypes: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822; Treatments; T_1= Aluminium foil, T_2= Brown paper, T_3= Polythene, T_4= Cloth bag, T_5=Earthen pot, T_6=Freeze condition

Table 4. Average carbohydrate content (mg g^{-1}) of seeds over the storage period

Genotype Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1	634.497	631.986	618.335	606.317	593.827	573.061
G_2	633.163	630.8	616.823	604.912	592.45	571.659
G_3	633.524	630.44	617.174	605.386	592.915	571.985
G_4	633.391	630.667	617.045	605.259	592.791	571.865
G_5	634.715	631.769	618.123	606.525	594.03	572.967
G_6	634.61	631.882	618.233	606.425	593.932	572.864
G_7	634.173	631.447	617.807	606.007	593.523	572.572
G_8	633.027	630.305	616.69	605.041	592.577	571.537
SEm (±)	0.038	0.028	0.035	0.029	0.032	0.031
CD (p≤0.05%)	0.106	0.08	0.097	0.08	0.09	0.087

Genotypes: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822

They continued to exhibit the highest protein content at twelve months, with levels of 193.740 mg g^{-1}, 193.745 mg g^{-1}, and 193.758 mg g^{-1}, respectively (Table 1). In contrast, the lowest protein content was observed in G_8 (SML-1822), with an initial value of 220.076 mg g^{-1}, followed by G_2 (PM-11-9) at two months after storage. These two genotypes consistently exhibited the minimum protein content throughout the twelve-month period, although their relative positions fluctuated at different times. By twelve months, the protein content for G_8 (SML-1822) was 190.171 mg g^{-1}, and for G_2 (PM-11-9), it was 190.295 mg g^{-1} (Table 1).

When considering the effect of storage treatments across genotypes throughout the storage period, seeds stored under refrigerated conditions (T_6) consistently exhibited the highest protein content. Initially, the protein content was 223.227 mg g^{-1} at two months after storage and decreased to 192.894 mg g^{-1} by twelve months. This was followed by seeds stored in aluminum foil packets (T_1) and polythene packets (T_3). In contrast, seeds stored in cloth bags (T_4) had the lowest protein content, starting at 222.628 mg g^{-1} at two months and declining to 192.532 mg g^{-1} by twelve months. Seeds stored in brown paper packets (T_2) also showed relatively low protein levels (Table $_2$). Notably, with the exception of refrigerated conditions (T_6), the protein content of seeds stored in other containers varied over time, with their relative positions fluctuating throughout the storage period.

Carbohydrate content (mg g^{-1}) of seeds at different stages of storage

Similar to protein content, the carbohydrate content of green gram seeds exhibited a slight decline from just after harvesting to two months into storage, continuing to decrease consistently up to twelve months. Averaging across genotypes and treatments, G_5 (Samrat) had the highest carbohydrate content, with an initial measurement of 634.715 mg g^{-1} at two months after storage, followed by G_6 (IPM-512-1) and G_1 (Pusa Vishal) (Table 4). These three genotypes maintained the highest carbohydrate levels among the eight genotypes up to ten months of storage. Although their relative positions fluctuated during various

Table 5. Average carbohydrate content (mg g^{-1}) of seeds over the storage period

Treatment Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
T_1	634.103	631.313	617.738	605.94	593.398	572.508
T_2	633.596	630.872	617.492	605.37	592.983	572.051
T_3	634.04	631.376	617.677	605.879	593.457	572.451
T_4	633.507	630.783	617.245	605.455	592.9	571.97
T_5	633.85	631.124	617.158	605.698	593.221	572.28
T_6	634.23	631.503	617.862	606.061	593.576	572.623
SEm (±)	0.033	0.024	0.03	0.025	0.0328	NS
CD (p≤0.05%)	0.092	0.069	0.084	0.07	0.078	NS

Treatments: T_1=Aluminium foil, T_2=Brown paper, T_3=Polythene, T_4=Cloth bag, T_5=Earthen pot, T_6=Freeze condition

Table 6. Average carbohydrate content (mg g-1) of seeds over the storage period

Genotype x Treatment	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1T_1	634.713	632.137	618.545	606.522	593.968	573.256
G_1T_2	634.206	631.695	618.298	605.952	593.554	572.798
G_1T_3	634.65	632.2	618.483	606.462	594.028	573.198
G_1T_4	634.117	631.606	618.05	606.038	593.47	572.717
G_1T_5	634.46	631.948	617.964	606.281	593.792	573.027
G_1T_6	634.84	632.327	618.669	606.644	594.147	573.371
G_2T_1	633.378	630.951	617.032	605.117	592.593	571.854
G_2T_2	632.872	630.51	616.786	604.549	592.178	571.396
G_2T_3	633.315	631.014	616.971	605.057	592.652	571.796
G_2T_4	632.783	630.421	616.539	604.633	592.095	571.316
G_2T_5	633.125	630.762	616.452	604.875	592.415	571.625
G_2T_6	633.505	631.14	617.156	605.238	592.77	571.969
G_3T_1	633.739	630.591	617.383	605.591	593.057	572.179
G_3T_2	633.233	630.151	617.137	605.023	592.643	571.722
G_3T_3	633.676	630.654	617.322	605.531	593.116	572.122
G_3T_4	633.144	630.062	616.89	605.108	592.56	571.642
G_3T_5	633.486	630.402	616.804	605.35	592.88	571.951
G_3T_6	633.866	630.781	617.507	605.713	593.236	572.294
G_4T_1	633.606	630.818	617.254	605.465	592.933	572.06
G_4T_2	633.1	630.377	617.008	604.896	592.519	571.603
G_4T_3	633.543	630.881	617.193	605.404	592.993	572.003
G_4T_4	633.011	630.289	616.761	604.981	592.435	571.522
G_4T_5	633.353	630.629	616.674	605.223	592.755	571.831
G_4T_6	633.733	631.008	617.378	605.585	593.11	572.173
G_5T_1	634.931	631.921	618.333	606.73	594.172	573.161
G_5T_2	634.423	631.479	618.086	606.16	593.758	572.703
G_5T_3	634.867	631.984	618.271	606.67	594.232	573.104
G_5T_4	634.334	631.39	617.838	606.246	593.673	572.623
G_5T_5	634.677	631.731	617.752	606.488	593.995	572.933
G_5T_6	635.058	632.11	618.456	606.852	594.351	573.275
G_6T_1	634.826	632.033	618.443	606.63	594.075	573.059
G_6T_2	634.319	631.591	618.196	606.061	593.66	572.601
G_6T_3	634.763	632.096	618.381	606.57	594.134	573.001
G_6T_4	634.23	631.502	617.949	606.146	593.576	572.521
G_6T_5	634.573	631.844	617.862	606.389	593.898	572.831
G_6T_6	634.953	632.222	618.566	606.752	594.253	573.174
G_7T_1	634.389	631.598	618.017	606.213	593.665	572.766
G_7T_2	633.882	631.156	617.771	605.643	593.25	572.308
G_7T_3	634.326	631.661	617.955	606.152	593.724	572.709
G_7T_4	633.793	631.067	617.523	605.728	593.167	572.228
G_7T_5	634.136	631.409	617.436	605.971	593.488	572.538
G_7T_6	634.516	631.787	618.141	606.334	593.844	572.881
G_8T_1	633.242	630.456	616.899	605.247	592.719	571.731
G_8T_2	632.736	630.015	616.653	604.678	592.305	571.274
G_8T_3	633.179	630.519	616.838	605.186	592.779	571.674
G_8T_4	632.647	629.927	616.407	604.763	592.222	571.194
G_8T_5	632.989	630.267	616.32	605.005	592.542	571.502
G_8T_6	633.369	630.645	617.023	605.368	592.898	571.845
SEm (±)	0.093	0.069	0.085	0.07	0.079	0.076
CD ($p \leq 0.05\%$)	0.261	0.195	0.238	0.197	0.221	0.214

Genotype: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822; Treatments: T_1=Aluminium foil, T_2= Brown paper, T_3=Polythene, T_4=Cloth bag, T_5=Earthen pot, T_6=Freeze condition

Table 7. Average electrical conductivity (mS m^{-1}) of seeds over the storage period

Genotype Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1	2.117	3.677	4.574	5.937	6.697	8.397
G_2	2.622	4.136	5.005	6.442	7.156	8.828
G_3	2.195	3.709	4.652	6.115	6.729	8.475
G_4	2.295	3.809	4.752	6.015	6.829	8.575
G_5	2.387	3.901	4.844	6.207	6.921	8.73
G_6	2.45	3.964	4.907	6.27	6.984	8.667
G_7	2.163	3.631	4.62	5.983	6.651	8.443
G_8	2.548	4.062	5.079	6.368	7.082	8.902
SEm (±)	0.002	0.003	0.002	0.002	0.002	0.002
CD ($p \leq 0.05\%$)	0.007	0.008	0.006	0.004	0.005	0.006

Genotypes: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822

storage periods, G_1 (Pusa Vishal) exhibited the highest carbohydrate content at twelve months, with a value of 573.061 mg g^{-1} (Table 4). On the other hand, the lowest carbohydrate content was recorded in G_8 (SML-1822), with 633.027 mg g^{-1} at two months after storage, followed by G_2 (PM-11-9) (Table 4). These genotypes continued to show the minimum carbohydrate content throughout the twelve-month storage period. By twelve months, G_8 (SML-1822) had the lowest carbohydrate content at 571.537 mg g^{-1} (Table 4).

When evaluating the effect of storage treatments across genotypes throughout the storage period, seeds stored under refrigerated conditions (T_6) consistently had the highest carbohydrate content. At two months after storage, T_6 exhibited the highest carbohydrate level of 634.230 mg g^{-1}, followed by T_1 (aluminum foil) and T_3 (polythene packet). However, between four and twelve months of storage, the relative positions of T_1 and T_3 fluctuated. Seeds stored in cloth bags (T_4) accumulated the least amount of carbohydrates, with brown paper packets (T_2) showing slightly higher carbohydrate levels (Table 5).

Electrical conductivity (mS m^{-1}) of seeds at different stages of storage

Electrical conductivity serves as a reliable indicator of seed viability due to its advantages of providing rapid, non-destructive results, allowing for the post-test use of seeds in seedling production. Lower electrical conductivity values are preferred as they indicate better seed condition during storage. In this study, electrical conductivity measurements varied significantly among genotypes and over time. Initially, G_2 (PM-11-9) exhibited the highest electrical conductivity, followed by G_8 (SML-1822). However, the rankings of these genotypes shifted at six and twelve months of storage. On the other hand, G_1 (Pusa Vishal) consistently showed the lowest electrical conductivity, with values initially recorded as 2.117 mS m^{-1} at two months after storage, increasing to 8.397 mS m^{-1} by twelve months. Other genotypes with relatively low conductivity values included G_7 (TMB-37), G_3 (IPM-2-3), and G_4 (Meha) at the two-month interval. A clear trend of increasing electrical conductivity over time was observed. For G_2

Table 8. Average electrical conductivity (mS m^{-1}) of seeds over the storage period

Treatment Mean	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
T_1	2.292	3.806	4.78	6.112	6.826	8.603
T_2	2.404	3.884	4.861	6.267	6.938	8.684
T_3	2.323	3.837	4.749	6.143	6.857	8.572
T_4	2.447	3.918	4.904	6.224	6.904	8.727
T_5	2.37	3.961	4.827	6.19	6.981	8.65
T_6	2.246	3.76	4.703	6.066	6.78	8.526
SEm (±)	0.002	0.003	0.002	0.001	0.002	0.002
CD ($p \leq 0.05\%$)	0.006	0.007	0.005	0.004	0.005	0.005

Treatments: T_1=Aluminium foil, T_2=Brown paper, T_3=Polythene, T_4=Cloth bag, T_5=Earthen pot, T_6=Freeze condition

Table 9. Average electrical conductivity (mS m^{-1}) of seeds over the storage period

Genotype x Treatment	2 months after storage	4 months after storage	6 months after storage	8 months after storage	10 months after storage	12 months after storage
G_1T_1	2.062	3.622	4.55	5.882	6.642	8.373
G_1T_2	2.174	3.7	4.631	6.037	6.754	8.454
G_1T_3	2.093	3.653	4.519	5.913	6.673	8.342
G_1T_4	2.217	3.734	4.674	5.994	6.72	8.497
G_1T_5	2.14	3.777	4.597	5.96	6.797	8.42
G_1T_6	2.016	3.576	4.473	5.836	6.596	8.296
G_2T_1	2.567	4.081	4.981	6.387	7.101	8.804
G_2T_2	2.679	4.159	5.062	6.542	7.213	8.885
G_2T_3	2.598	4.112	4.95	6.418	7.132	8.773
G_2T_4	2.722	4.193	5.105	6.499	7.179	8.928
G_2T_5	2.645	4.236	5.028	6.465	7.256	8.851
G_2T_6	2.521	4.035	4.904	6.341	7.055	8.727
G_3T_1	2.14	3.654	4.628	6.06	6.674	8.451
G_3T_2	2.252	3.732	4.709	6.215	6.786	8.532
G_3T_3	2.171	3.685	4.597	6.091	6.705	8.42
G_3T_4	2.295	3.766	4.752	6.172	6.752	8.575
G_3T_5	2.218	3.809	4.675	6.138	6.829	8.498
G_3T_6	2.094	3.608	4.551	6.014	6.628	8.374
G_4T_1	2.24	3.754	4.728	5.96	6.774	8.551
G_4T_2	2.352	3.832	4.809	6.115	6.886	8.632
G_4T_3	2.271	3.785	4.697	5.991	6.805	8.52
G_4T_4	2.395	3.866	4.852	6.072	6.852	8.675
G_4T_5	2.318	3.909	4.775	6.038	6.929	8.598
G_4T_6	2.194	3.708	4.651	5.914	6.728	8.474
G_5T_1	2.332	3.846	4.82	6.152	6.866	8.706
G_5T_2	2.444	3.924	4.901	6.307	6.978	8.787
G_5T_3	2.363	3.877	4.789	6.183	6.897	8.675
G_5T_4	2.487	3.958	4.944	6.264	6.944	8.83
G_5T_5	2.41	4.001	4.867	6.23	7.021	8.753
G_5T_6	2.286	3.8	4.743	6.106	6.82	8.629
G_6T_1	2.395	3.909	4.883	6.215	6.929	8.643
G_6T_2	2.507	3.987	4.964	6.37	7.041	8.724
G_6T_3	2.426	3.94	4.852	6.246	6.96	8.612
G_6T_4	2.55	4.021	5.007	6.327	7.007	8.767
G_6T_5	2.473	4.064	4.93	6.293	7.084	8.69
G_6T_6	2.349	3.863	4.806	6.169	6.883	8.566
G_7T_1	2.108	3.576	4.596	5.928	6.596	8.419
G_7T_2	2.22	3.654	4.677	6.083	6.708	8.5
G_7T_3	2.139	3.607	4.565	5.959	6.627	8.388
G_7T_4	2.263	3.688	4.72	6.04	6.674	8.543
G_7T_5	2.186	3.731	4.643	6.006	6.751	8.466
G_7T_6	2.062	3.53	4.519	5.882	6.55	8.342
G_8T_1	2.493	4.007	5.055	6.313	7.027	8.878
G_8T_2	2.605	4.085	5.136	6.468	7.139	8.959
G_8T_3	2.524	4.038	5.024	6.344	7.058	8.847
G_8T_4	2.648	4.119	5.179	6.425	7.105	9.002
G_8T_5	2.571	4.162	5.102	6.391	7.182	8.925
G_8T_6	2.447	3.961	4.978	6.267	6.981	8.801
SEm (±)	0.006	NS	0.005	0.004	NS	NS
CD ($p \leq 0.05$%)	0.016	NS	0.014	0.011	NS	NS

Genotypes: G_1=Pusa Vishal, G_2=PM-11-9, G_3=IPM-2-3, G_4=Meha (IPM 99-125), G_5=Samrat, G_6=IPM-512-1, G_7=TMB-37, G_8=SML-1822; Treatments: T_1= Aluminium foil, T_2= Brown paper, T_3=Polythene, T_4= Cloth bag, T_5=Earthen pot, T_6=Freeze condition

(PM-11-9), electrical conductivity rose from 2.622 mS m^{-1} at two months to 7.156 mS m^{-1} at ten months. G_8 (SML-1822) recorded its highest conductivity at twelve months with 8.902 mS m^{-1}, while the highest conductivity for G_8 was noted at six months (5.079 mS m^{-1}). In contrast, G_1 (Pusa Vishal) maintained the lowest conductivity across all time points, with values of 4.574 mS m^{-1} at six months, 5.937 mS m^{-1} at eight months, and 8.397 mS m^{-1} at twelve months (Table 7).

Considering the average impact of storage conditions across genotypes, refrigerated conditions (T_6) were identified as the most effective for maintaining the lowest electrical conductivity throughout the twelve-month storage period, compared to other storage conditions. This was followed by aluminum foil packets (T_1) and polythene packets (T_3). Among the genotypes, G_1 (Pusa Vishal) consistently exhibited the lowest electrical conductivity, with values of 2.246 mS m^{-1} at two months, 3.760 mS m^{-1} at four months, 4.703 mS m^{-1} at six months, 6.066 mS m^{-1} at eight months, 6.780 mS m^{-1} at ten months, and 8.526 mS m^{-1} at twelve months after storage. In comparison, G_7 (TMB-37) recorded the lowest electrical conductivity at four months (3.631 mS m^{-1}) and ten months (6.651 mS m^{-1}) (Table 8).

As storage duration extends, a significant decrease in protein content is commonly observed (Shi *et al.*, 2017). This decline is attributed to several factors, including accelerated protein degradation in cotyledons and embryonic axes, damage to protein synthesis pathways, and the activation of proteolytic enzymes during seed deterioration (Ebone *et al.*, 2019; Bewley & Black, 1994). Studies by Agarwal and Kharlukhi (1987) and Sharma *et al.* (2018) have documented elevated protease activity in *Vigna radiata* and *Cicer arietinum* seeds during natural or artificial aging. Likewise, Krishna Chaitanya *et al.* (2000) observed increased protease activity in the embryonic axis and cotyledons of *Shorea robusta* seeds. Sanjay *et al.* (2023) noted a comparable decline in total carbohydrate content with extended storage time in green gram. Garcia *et al.* (2006) reported that freshly harvested seeds of *Caesalpinia echinata* L. contained approximately 10% total soluble carbohydrates by dry weight, which decreased to 8% after 18 months of storage at room temperature. Electrical conductivity of seed leachate, a significant biochemical indicator, typically increases with storage time, regardless of treatment conditions. This rise in electrical conductivity is believed to result from the loss of cell membrane integrity with prolonged storage (Koostra & Harrington, 1969; Chakraborty *et al.*, 2020; Ray & Bordolui, 2022b).

The protein and carbohydrate content of green gram seeds showed a slight decline from immediately after harvesting to two months of storage, with a steady decrease continuing up to twelve months. Averaging across genotypes and treatments, G_6 (IPM-512-1), G_5 (Samrat), and G_1 (Pusa Vishal) consistently maintained the highest levels of both protein and carbohydrate content throughout the storage periods. Among the storage treatments, T_6 (refrigerated condition) consistently preserved the highest levels of protein and carbohydrate content throughout the entire storage duration.

The electrical conductivity of seed leachate, a crucial biochemical indicator of seed quality, progressively increased throughout the storage period, regardless of the treatments applied. Among the genotypes, G_1 (Pusa Vishal) consistently recorded the lowest electrical conductivity, followed by G_7 (TMB-37), G_3 (IPM-2-3), and G_4 (Meha) at the two-month storage mark. When evaluating the average impact of storage conditions across all genotypes, T_6 (refrigerated condition) demonstrated the lowest electrical conductivity throughout the entire twelve-month storage period, with T_1 (aluminum foil) following closely behind.

Regarding seed storability among genotypes, seeds stored under T_6 (refrigerated condition) exhibited consistently lower rates of protein and carbohydrate depletion and maintained lower electrical conductivity compared to those stored under other conditions throughout the various storage periods.

Authors' contribution

Conceptualization and designing of the research work (SKB); Execution of field/lab experiments and data collection (AC, JMD); Analysis of data and interpretation (AC, DN); Preparation of manuscript (JR, SR).

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Conflict of interest

The authors declare that they have no conflict of interest.

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