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Effect of stages of harvesting and threshing methods on seed storability of soybean [*Glycine max* (L.) Merrill] cv. DSb-21]

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Abstract
A research study was conducted to determine the most appropriate stage of harvesting and the best threshing method with minimal impact on seed quality characteristics of soybean seeds during storage. The field experiment was conducted in 'H' Block of seed unit in two factorial randomized complete block design (RCBD) with the different treatments of harvesting soybean pods at 90 days after sowing (DAS), 100 DAS and 110 DAS and the threshing of seed was done by three methods *viz*., Stick beating (T_1), Tractor trampling (T_2) and Mechanical thresher (T_3) and the seed quality during storage was analyzed in the Post Graduate laboratory of the Department of Seed Science and Technology. The study revealed that initially and at the end of 180 days of storage, soybean harvested at 90 DAS and threshed by beating with sticks recorded highest germination, seedling dry weight and vigour and lower EC as compared to other treatments. During storage EC increased and germination percentage, seedling dry weight and vigour were reduced in all the treatments. Results obtained indicated that for good seed quality, soybean pods should be harvested at 90 DAS and threshed by beating with sticks.

Keywords: stages of harvesting, threshing methods, soybean seed storage

1. Introduction
Soybean seed is regarded as a poor storer and it loses its viability and vigour at a faster rate due to loss of membrane permeability of seeds. Presence of high lipid content and high level of polyunsaturated oleic acid, linolenic and linoleic acid is the main reason for short shelf life of soybean seed.
Storability of seed is mainly a genetic character and it is influenced by pre storage history of seeds, seed maturation and environmental factors during pre and post harvest stages and storage conditions (Mahesha *et al*, 2001) [6]. The storage becomes successful depending upon quality of seeds to be stored. Kumar *et al*. (2002) [5] stated that seed yield and quality largely depend upon the stage of maturity of crop. Therefore, harvesting of seeds at the optimum stage of maturity is an important factor as harvesting either at early or late stage results in lower yields with poor quality seeds. It is universal that when plant attains physiological maturity, on that day itself the storage of seeds starts on plant.
Threshing is an important post harvest operation in soybean because the seed is more vulnerable to mechanical damage due to its thin seed coat and low lignin content. These methods directly influence on seed quality during storage. Keeping this in view the present experiment on influence of stage of harvesting and threshing methods on storability of soybean seed [*Glycine max* (L.) Merrill] cv. DSb-21 was carried out.

2. Material and Methods
The field experiment was conducted in 'H' Block of seed unit in two factorial randomized complete block design (RCBD) in three replications with the different treatments of harvesting soybean pods at 90 DAS (H_1), 100 DAS (H_2) and 110 DAS (H_3) and the threshing of seed was done by three methods viz., Stick beating (T_1), Tractor trampling (T_2) and Mechanical thresher (T_3) and the quality analysis during storage was carried out in the Post Graduate laboratory of the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad.

2.1 Germination percentage
The standard germination test was conducted as per the ISTA Rules (*Anon*., 2011) [2] by adopting the rolled paper towel between paper method in four replications of randomly drawn 100 seeds. Rolled paper towel was kept at 25 + 1^0c and 95 + 1 per cent relative humidity (RH) in the seed germinator. On eighth day of germination test (final count), number of normal seedlings were counted and were expressed as germination percentage.

2.2 Seedling dry weight
The seedlings used to measure shoot and root lengths were used for seedling dry weight. Seedlings were packed in a butter paper pocket and dried in an Hot air oven and maintained at 70^0 + 1^0 C for 24 h. After drying, the seedlings were kept in a desiccators for 30 minutes for cooling and later on the seedling dry weight was recorded and expressed in milligram (mg) per 10 seedlings (*Anon*., 2011) [2].

2.3 Seedling vigour index
The seedling vigour index was calculated as per the formula given by Abdul Baki and Anderson (1973) and expressed in pure number.

2.4 Electrical conductivity of seed leachate
Electrical conductivity of seed leachate was calculated by taking five gram of randomly drawn seed material in four replications from each treatment and weighed up to two decimal points. The seeds were surface sterilized with acetone for half a minute and washed thoroughly for several

times with distilled water and then soaked in beaker with 25 ml distilled water in it. The beakers were kept in incubator at constant temperature of 25 + 1^0C for 24 h along with blank. The electrical conductivity of seeds leachate was measured in the digital electrical conductivity meter, the actual EC due to the electrolyte (leachate) was measured and expressed in dS m^{-1}.

2.5 Statistical analysis
The data collected from the experiment was analyzed statistically and subjected to the analysis of variance by adopting the appropriate methods as outlined by Sundar rajan *et al.* (1972) [7]. Critical differences were calculated at one per cent level. In the tables, the critical difference values were given for those observations which were significant at one per cent.

3. Results & Discussion
3.1 Germination Percentage
The results on germination percentage as influenced by stages of harvesting, threshing methods and their interaction effects at different months of storage period are presented in Table 1. The per cent germination decreased with the advancement of storage period in all the treatments. Whereas, initially higher germination was recorded in H_1 (90.71%) and T_1 (92.70%) and H_1T_1 (94.23%) and lower germination was recorded H_3 (87.33%), T_2 (85.65%), H_3T_2 (83.00%). At the end of six months of storage period, highest germination was recorded in H_1 (80.30 %), T_1 (83.48%), H_1T_1 (83.13 %) while significantly lower germination was recorded in H_3 (75.45 %), T_2 (74.16%), H_3T_2 (70.03 %).

3.2 Seedling vigour index
The results of seedling vigour index as influenced by stages of harvesting, threshing methods and their interaction effects at different months of storage period are presented in Table 2. The seedling vigour index decreased with the advancement of storage period in all the treatments. Whereas, initially higher seedling vigour index was recorded in H_1 (2768), T_1 **(**2850), H_1T_1 (3021) and lower was in H_3 **(**2572), T_2 (2508), H_3T_2 (2370). At the end of six months of storage period, highest seedling vigour index was recorded in H_1 (2362), T_1 (2473), H_1T_1 (2569) while, significantly lower seedling vigour index was recorded in H_3 (2164), T_2 (2068), H_3T_2 (1927).

3.3 Seedling dry weight (g)
The results of seedling dry weight as influenced by stages of harvesting and threshing methods and their interaction effects at different months of storage period are presented in Table 3. Initially higher seedling dry weight was recorded in H_1 (1.30g), T_1 (1.35g), H_1T_1 (1.43g) and lower seedling dry weight was recorded in H_3 (1.26g), T_2 (1.21g), H_3T_2 (1.19g). At the end of six months of storage period, highest seedling dry weight was recorded in H_1 (1.27 g), T_1 (1.31g), H_1T_1 (1.35g) while significantly lower seedling dry weight was recorded in H_2 (1.23g), T_2 (1.18g), H_3T_2 (1.14g).

3.4 Electrical conductivity of seed leachate (dS/m)
The data on electrical conductivity of seed leachate as influenced by stages of harvesting, threshing methods and interactions are presented in Table 4. Electrical conductivity of seed leachate was increased gradually as the storage period advanced. Initially, Lowest EC of seed leachates was observed in H_1 (0.34 dSm^{-1}), T_1 (0.32 dSm^{-1}), H_1T_1 (0.31 dSm^{-1}) and highest EC of seed leachates was observed in H_3 (0.36 dSm^{-1}), T_2 (0.38 dSm^{-1}) H_3T_2 (0.39 dSm^{-1}). At the end of storage period significantly lowest EC of seed leachates was observed in H_1 (0.78 dS m^{-1}), T_1 (0.64 dS m^{-1}), H_1T_1(0.54 dS m-1) and highest EC of seed leachates was observed in H_3(1.00 dS m^{-1}), T_2 (1.19 dS m^{-1}) H_3T_2(1.26 dS m^{-1}).

As the harvesting period delayed (H_1 to H_3), germination percentage was reduced, due to the fact that the deterioration processes begin ever since seed development starts. During seed development, anabolic processes predominate and bring about gradual decrease in dry matter including development of embryo and food reserve. Following maturation, biochemical changes continue and eventually catabolic processes predominate and deterioration becomes apparent. Changes associated with the seed deterioration are depletion in food reserve, increased enzyme activity, increased fat acidity and membrane permeability. As the catabolic changes continue with increasing age, the ability of seeds to germinate is reduced (Justice and Bass, 1979) [4].

It was noticed that seedling length, dry matter content and vigour index were decreased as the storage period advanced. The decrease in length of seedlings could be ascribed to the ageing or deterioration of seed, which is progressive process, accompanied by accumulation of metabolites and progressively decrease germination and growth of seedlings with increased age (Floris, 1970) [3] and ultimately reducing the dry matter and vigour of soybean seed during storage. Seedling growth is considered to be an important tool that can be used for assessing the magnitude of deterioration (Toole *et al*., 1957) [4].

Table 1: Effect of stages of harvesting and threshing methods on germination (%) of soybean seed cv. DSb -21 during storage

Treatments	Initial	30 days (After harvest)	60 days (After harvest)	90 days (After harvest)	120 days (After harvest)	150 days (After harvest)	180 days (After harvest)
H_1	90.71	89.44	87.68	85.72	83.77	81.77	80.30
H_2	89.42	88.25	86.52	84.46	82.40	80.63	78.84
H_3	87.33	86.07	83.83	83.05	79.39	77.67	75.45
Mean	89.15	87.92	86.01	84.41	81.85	80.02	78.19
S. Em. ±	0.18	0.22	0.23	0.36	0.54	0.24	0.22
C. D. (P=0.01)	0.73	0.89	0.94	1.48	2.20	0.99	0.90
T_1	92.70	91.32	89.72	88.33	86.56	85.33	83.48
T_2	85.65	84.45	82.25	80.48	77.92	75.68	74.16
T_3	89.11	87.99	86.07	84.43	81.08	79.06	76.95
Mean	89.15	87.92	86.01	84.41	81.85	80.02	78.19
S. Em. ±	0.18	0.22	0.23	0.36	0.54	0.24	0.22
C. D. (P=0.01)	0.73	0.89	0.94	1.48	2.20	0.99	0.90

H_1T_1	94.23	92.50	91.00	89.95	87.00	86.07	83.13
H_1T_2	87.55	86.72	84.50	82.90	81.33	78.11	76.50
H_1T_3	90.34	89.11	87.54	84.32	82.97	81.13	79.83
H_2T_1	92.87	91.23	89.21	87.19	86.54	84.98	82.73
H_2T_2	86.40	85.40	84.00	81.21	79.51	77.40	75.96
H_2T_3	89.00	88.12	86.35	84.98	81.15	79.50	77.83
H_3T_1	91.00	90.24	88.94	87.85	86.13	84.94	81.23
H_3T_2	83.00	81.23	78.24	77.32	72.93	71.54	70.03
H_3T_3	88.00	86.73	84.32	83.99	79.11	76.54	73.19
Mean	89.15	87.92	86.01	84.41	81.85	80.02	77.83
S. Em. ±	0.31	0.38	0.40	0.63	0.94	0.42	0.38
C. D. (P=0.01)	1.26	1.54	1.63	2.56	3.81	1.71	1.55

Table 2: Effect of stages of harvesting and threshing methods on seedling vigour in soybean seed cv. DSb -21 during storage

Treatments	Initial	30 days (After harvest)	60 days (After harvest)	90 days (After harvest)	120 days (After harvest)	150 days (After harvest)	180 days (After harvest)
H_1	2768	2719	2651	2578	2519	2434	2362
H_2	2714	2593	2530	2454	2388	2321	2252
H_3	2572	2601	2520	2484	2352	2275	2164
Mean	2685	2638	2567	2505	2420	2343	2259
S. Em. ±	11.69	13.23	13.8	12.64	12.67	12.8	13.99
C. D. (P=0.01)	47.61	53.87	56.16	51.45	51.58	52.09	56.94
T_1	2850	2795	2730	2677	2629	2567	2473
T_2	2508	2467	2390	2328	2239	2147	2068
T_3	2700	2656	2584	2519	2406	2331	2242
Mean	2686	2639	2568	2508	2425	2348	2261
S. Em. ±	11.69	13.23	13.8	12.64	12.67	12.8	13.99
C. D. (P=0.01)	47.61	53.87	56.16	51.45	51.58	52.09	56.94
H_1T_1	3021	2949	2881	2836	2770	2688	2569
H_1T_2	2593	2562	2483	2392	2327	2208	2125
H_1T_3	2745	2698	2639	2529	2476	2410	2359
H_2T_1	2855	2613	2538	2467	2466	2393	2313
H_2T_2	2529	2492	2444	2357	2294	2212	2157
H_2T_3	2708	2673	2607	2549	2425	2369	2277
H_3T_1	2860	2825	2770	2724	2658	2610	2429
H_3T_2	2370	2387	2287	2249	2100	2016	1927
H_3T_3	2647	2599	2504	2479	2319	2217	2095
Mean	2703	2644	2573	2509	2426	2347	2250
S. Em. ±	20.26	22.92	23.89	21.89	21.95	22.16	24.23
C. D. (P=0.01)	82.46	93.31	97.27	89.12	89.34	90.22	98.62

Table 3: Effect of stages of harvesting and threshing methods on seedling dry weight (g) of soybean seed cv. DSb -21 during storage

Treatments	Initial	30 days (After harvest)	60 days (After harvest)	90 days (After harvest)	120 days (After harvest)	150 days (After harvest)	180 days (After harvest)
H_1	1.30	1.30	1.30	1.29	1.29	1.28	1.27
H_2	1.29	1.29	1.27	1.26	1.25	1.25	1.23
H_3	1.26	1.28	1.26	1.27	1.25	1.24	1.24
Mean	1.28	1.28	1.27	1.27	1.27	1.26	1.25
S. Em. ±	0.03	0.03	0.03	0.03	0.03	0.03	0.03
C. D. (P=0.01)	NS	0.13	0.13	0.12	0.12	0.12	0.12
T_1	1.35	1.37	1.36	1.35	1.35	1.34	1.31
T_2	1.21	1.21	1.20	1.20	1.20	1.19	1.18
T_3	1.29	1.26	1.26	1.25	1.25	1.27	1.26
Mean	1.28	1.28	1.27	1.27	1.27	1.27	1.25
S. Em. ±	0.03	0.03	0.03	0.03	0.03	0.03	0.03
C. D. (P=0.01)	NS	0.13	0.13	0.12	0.12	0.12	0.12
H_1T_1	1.43	1.42	1.40	1.39	1.39	1.36	1.35
H_1T_2	1.28	1.26	1.26	1.25	1.24	1.24	1.23
H_1T_3	1.26	1.25	1.25	1.24	1.24	1.32	1.23
H_2T_1	1.26	1.32	1.32	1.31	1.31	1.31	1.24
H_2T_2	1.26	1.19	1.19	1.18	1.18	1.17	1.15
H_2T_3	1.33	1.26	1.26	1.25	1.25	1.24	1.30
H_3T_1	1.37	1.37	1.37	1.36	1.36	1.34	1.33
H_3T_2	1.19	1.18	1.19	1.19	1.17	1.15	1.14
H_3T_3	1.28	1.28	1.27	1.27	1.27	1.26	1.25
Mean	1.28	1.28	1.28	1.27	1.27	1.27	1.25
S. Em. ±	0.05	0.05	0.05	0.05	0.05	0.05	0.05
C. D. (P=0.01)	NS	0.22	0.22	0.22	0.22	0.21	0.21

Table 4: Effect of stages of harvesting and threshing methods on electrical conductivity (dS/m) of soybean seed cv. DSb -21 during storage

Treatments	Initial	30 days (After harvest)	60 days (After harvest)	90 days (After harvest)	120 days (After harvest)	150 days (After harvest)	180 days (After harvest)
H_1	0.34	0.35	0.39	0.44	0.54	0.74	0.78
H_2	0.35	0.35	0.40	0.42	0.59	0.77	0.91
H_3	0.36	0.37	0.39	0.44	0.67	0.86	1.00
Mean	0.35	0.36	0.39	0.43	0.60	0.79	0.90
S. Em. ±	0.01	0.01	0.00	0.00	0.01	0.02	0.02
C. D. (P=0.01)	0.03	0.03	0.01	0.02	0.06	0.07	0.09
T_1	0.32	0.33	0.35	0.36	0.47	0.61	0.64
T_2	0.38	0.38	0.46	0.55	0.75	0.95	1.19
T_3	0.35	0.36	0.38	0.39	0.58	0.81	0.87
Mean	0.35	0.36	0.40	0.43	0.60	0.79	0.90
S. Em. ±	0.01	0.01	0.00	0.00	0.01	0.02	0.02
C. D. (P=0.01)	NS	NS	0.01	0.02	0.06	0.07	0.09
H_1T_1	0.31	0.31	0.32	0.34	0.41	0.59	0.54
H_1T_2	0.37	0.37	0.48	0.60	0.73	0.95	1.11
H_1T_3	0.35	0.35	0.37	0.39	0.49	0.68	0.71
H_2T_1	0.32	0.32	0.34	0.35	0.47	0.59	0.65
H_2T_2	0.38	0.38	0.49	0.51	0.80	0.95	1.20
H_2T_3	0.35	0.36	0.38	0.40	0.51	0.75	0.90
H_3T_1	0.34	0.35	0.37	0.39	0.52	0.65	0.72
H_3T_2	0.39	0.40	0.42	0.53	0.72	0.95	1.26
H_3T_3	0.36	0.37	0.38	0.39	0.76	0.99	1.02
Mean	0.35	0.36	0.39	0.43	0.60	0.79	0.90
S. Em. ±	0.01	0.01	0.00	0.01	0.02	0.03	0.04
C. D. (P=0.01)	NS	NS	0.02	0.03	0.10	0.13	NS

4. Equations

The seedling vigour index was calculated and expressed in pure number.

Vigour index = Germination (%) × [Shoot length (cm) + Root length (cm)]

5. Conclusion

The investigation on effect of stages of harvesting and threshing methods on seed storability of soybean revealed that for better storage, seeds should be harvested at 90 days after sowing and threshed by beating with sticks to maintain better germination and vigour and seedling dry weight with minimum seed leachate content throughout storage period.

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