International Journal of Plant & Soil Science

Volume 35, Issue 20, Page 474-489, 2023; Article no.IJPSS.106463
ISSN: 2320-7035

Studies on the Storability of Hand-hauled and Machine-hauled Sunnhemp Seeds (*Crotolaria juncea* Linn.)

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Authors' contributions

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

Article Information

DOI: 10.9734/IJPSS/2023/v35i203829

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106463

Original Research Article

Received: 18/07/2023
Accepted: 21/09/2023
Published: 25/09/2023

ABSTRACT

Aim: The present investigation is an attempt to study the effect of different harvesting and threshing methods on storability of sunnhemp seed.
Study Design: Factorial Completely Randomized Design (FCRD).
Place and Duration of Study: Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tiruchirappalli, Tamil Nadu.

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Methodology: The sunnhemp seed crop was harvested and threshed using four different methods *viz.*, manual harvesting and manual threshing, manual harvesting and mechanical threshing, manual harvesting and threshing by tractor treading and harvesting and threshing by combine harvester. The resultant seeds were stored under ambient conditions in both cloth bag and super grain bag containers with 12.0 per cent and 8 per cent moisture content respectively. The experiment was designed adopting FCRD with eight replications. The seed quality parameters recorded at monthly intervals upto 12 months to assess the storability. The seed moisture content, seed health, germination percentage, root and shoot length, dry matter production and vigour index were calculated.

Results: The result revealed seeds stored in cloth bag recorded 12% moisture content for initial month and increased up to 13.76% in 12th month whereas seeds stored in super bag recorded 8% initial month and increased up to 8.78% in 12th month. Seeds obtained by manual harvesting and manual threshing method registered maximum germination percentage (93% & 94%)followed by combine harvesting (91% & 92%).The minimum germination percentage was recorded in manual harvesting and mechanical threshing (89% & 90%). Between the containers, super grain bag maintained the highest germination percentage (92%) while the lowest germination percentage was observed in cloth bag (91%). Seed health test revealed that no incidence was noticed up to four months of storage.

Conclusion: From this study it could be concluded that sunnhemp seed crop harvested and threshed by different methods and reduced to the seed moisture content of 8 per cent and packed in super grain bag maintained seed quality above minimum seed certification standards up to twelve months of storage.

Keywords: Crotolaria juncea; containers; germination; harvesting and threshing methods; seed borne pathogen; seed storage.

1. INTRODUCTION

Farm mechanization is one of the realistic approaches to improving agriculture production, with obvious benefits such as reduced human drudgery, lower cultivation costs, increased working efficiency, and timeliness of work [1,2]. Agriculture encompasses a wide range of farm operations, from soil preparation through seed storage. When performed by manual laborers, all of these activities are labor intensive and time consuming. Failure to finish agricultural activities within the time frame specified may result in a significant reduction in crop production. Seed quality is the most influential component in crop growth, development, and yield processes, and it has the potential to boost yield by 5-20% [3]. Harvesting sunnhemp seed crop using combine has been recognized and used to alleviate peak demand for farm laborers and to reduce field losses caused by hand harvesting. Sunn hemp is a tropical legume that has been utilized as a green manure and nitrogen fixer [4,5]. It has the potential to be a tropical cover crop that decreases erosion while also improving soil fertility and tilth [6]. It has a biomass production of 15-20t/ha [7]. Sunnhemp fibers used as a substitute for synthetic fibers [8,9]. It is resistant to nematodes and may thrive in dry zone soil with poor fertility [10]. It inhibits weeds by burying them [11] and conserves soil moisture by minimizing evaporation from the soil. It encourages biological transformation in soil, which results in enhanced soil structure, fertility, and agricultural yields [12,13]. It is mostly raised for biomass and in normally incorporated in to the soil during pre-flowering phase. The crop is traditionally used for making ropes, strings, twines, floor mat, fishing nets, hand-made paper, *etc*. in cottage industry [14]. Hence there should be enough buffer stock of seed to meet the season-season seed requirement [15]. Efficient seed technological interventions encompassing seed production, processing and storage are essential. Seed deterioration during storage is a gradual and inevitable process causing considerable losses. Seeds tend to lose viability and vigour during storage and information on storability of seed lots from harvest until the next planting season and also for carry over purposes is of immense importance in any seed production programme [16]. Many physicochemical parameters influence seed viability and vigour during storage, including seed moisture content, ambient humidity, temperature and initial seed quality, physical and chemical composition of the seed, gaseous exchange, storage structure, and packing materials. So yet, no research has been conducted to determine the storability of machine harvested sunnhemp seeds. In response to the

impasse, a research was launched to evaluate the storability of hand and mechanically picked and threshed sunnhemp seeds.

2. MATERIALS AND METHODS

An experiment was conducted at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Tiruchirappalli, Tamil Nadu during 2019-2020 to find out the influence of harvesting and threshing methods on seed storability of sunnhemp seeds. The treatments are manual harvesting and manual threshing (T1), manual harvesting and mechanical threshing (axial flow thresher) (T2), manual harvesting and tractor treading (T3) and combine harvesting (with pneumatic wheel) (T4) (Fig. 1). The seeds collected from different harvesting and threshing methods were cleaned and graded. The graded seeds were stored in both cloth bag (C1) and super grain (C2) containers with 12 per cent and 8 per cent moisture content respectively and stored under ambient conditions. The experiment was designed adopting FCRD with eight replications. The following quality parameters were recorded initially and at monthly intervals for a period of 12 months to assess the storability of seeds.

Fig. 1. Different methods of harvesting and threshing of Sunnhemp

2.1 Seed moisture content (%)

Treatment wise the seed samples were taken and the seed moisture content was estimated by low constant temperature oven method at 103 ± 1 °C for 16 ± 1 h with known weight of seed samples. After drying, the seed samples were placed in desiccators containing calcium chloride for 30 min and weighed. The per cent of moisture content was calculated using the following formula [17].

$$Moisture\ content\ (\%) = \frac{M2 - M3}{M2 - M1} \times 100$$

Where,
M_1= Weight of empty moisture bottle along with lid (g)
M_2= Weight of moisture bottle along with sample before drying (g)
M_3= Weight of moisture bottle along with sample after drying (g)

2.2 Germination Test

Treatment wise, the seeds were placed for germination in roll towel method. Under each treatment, 400 seeds were sown with eight replications of 50 seeds each. Seed germination was expressed as the percentage of seeds producing normal seedlings [18]. Ten days after sowing ten seedlings from each replication were randomly selected and the root and shoot lengths were measured and the mean valuewas recorded. Ten random seedlings were dried in a hot air oven at 85^0 C for 24 h. and the dry weight was recorded and expressed as g.seedling^{-10}. The vigour index I and II was calculated using the following formula [19] by following the below given formula.

Vigour index - I = Germination (%) x Total seedling length (cm)
Vigour index - II = Germination (%) x Dry matter production (g/10 seedlings)

2.3 Seed Health Test

At the end of the each every month from one to 12th month, samples were collected from cloth and super grain bag and the seeds were subjected to health test. Seed health tests were done by Blotter Incubation method following ISTA [20] procedure. Blotter incubation test was done on Whatman No. 1 blotter paper contained in petridish. Three layer of water soaked blotter papers were placed on each petridish and 25 seeds/plate were placed. The seeds were incubated in the incubation chamber. After five days, number of seeds with mycelia colonies was counted.

2.4 Statistical Analysis

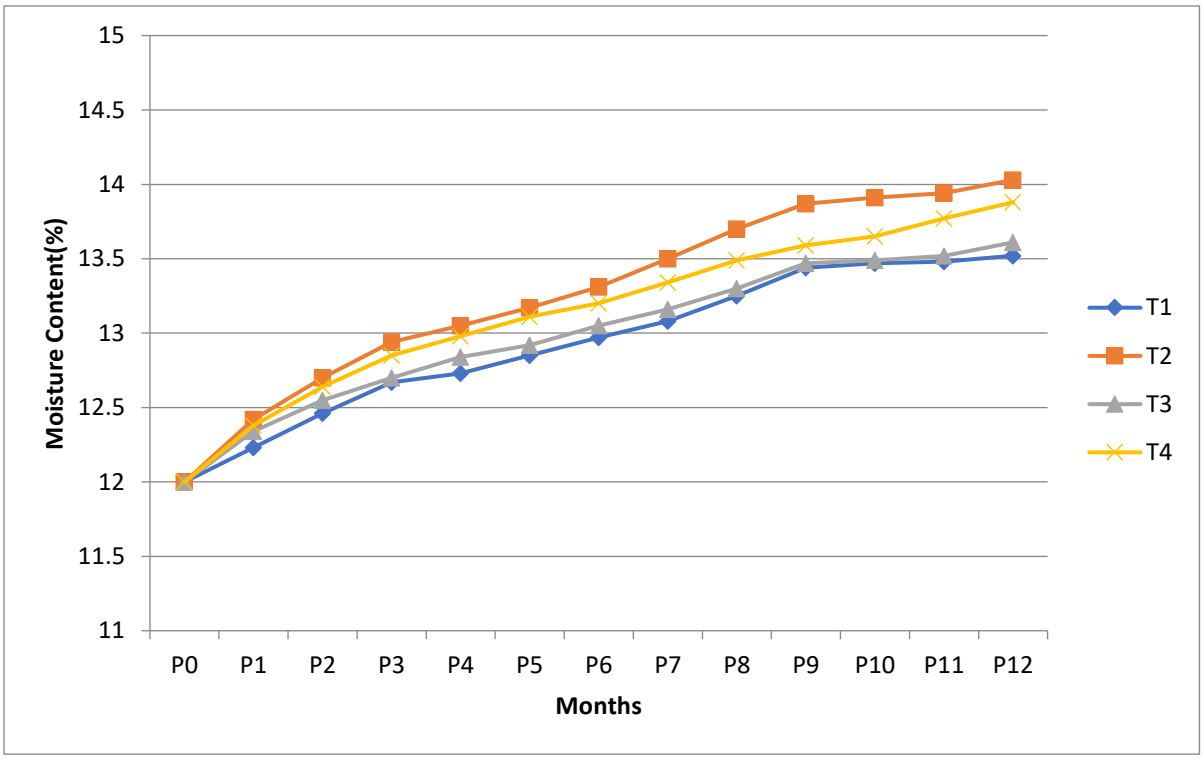
The data obtained from the experiment were analyzed by the 'F' test of significance following the methods described by Panse and Sukhatme [21]. Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance.

3. RESULTS AND DISCUSSION

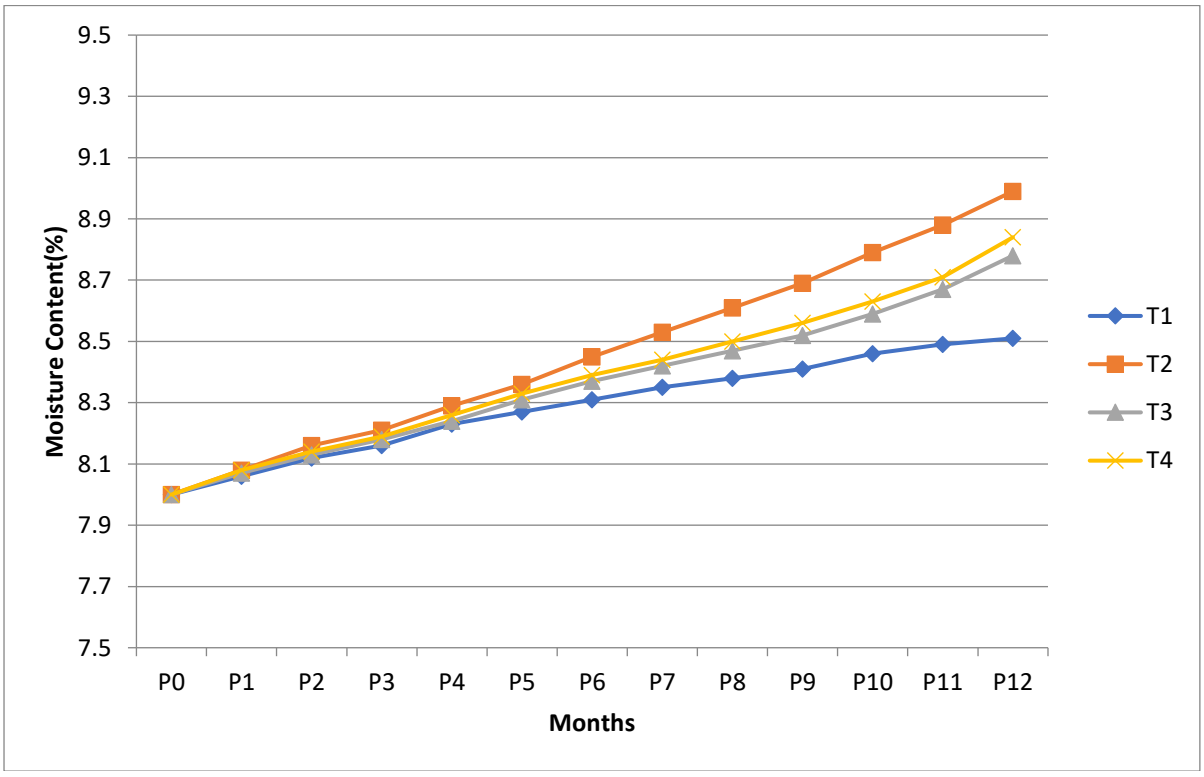
3.1 Moisture Content

The effects of different harvesting and threshing techniques on sunnhemp seed storability indicated that the moisture content was considerably impacted by harvesting and threshing methods, storage container, and storage term in sunnhemp seed examined (Fig.2). In this study, regardless of container, harvesting, and threshing procedures, there was a modest rise in seed moisture content during the storage time. Regardless of harvesting and threshing procedures, seeds stored in cloth bags recorded 12% moisture content for the first month and climbed to 13.76% in the 12th month, whereas seeds stored in super bags reported 8% moisture content for the first month and increased to 8.78% in the 12th month. A rise in moisture content is linked to a drop in seed quality. These findings are consistent. These results are in agreement with the results obtained by Govindaraj *et al.,* [22] in rice. Higher the moisture content and temperature, lesser the shelf life of paddy seed reported by Kaliyan et al., [23]. Ramanadane and Ponnusamy [24] reported that the moisture content is associated with decline of seed quality. Harringtons thumb rule says that storability increases as the moisture content decreases. For every one percent reduction in moisture content, the shelf life is doubled within a range of 5 to 15%. It was reported that, there was a negative logarithmic relation between moisture content and longevity [25].

The super grain bag played significant role in preventing vapour entry from the surrounding air. This becomes effective strategy in regulating



Cloth bag (C_1)



Super grain bag (C_2)

Fig. 2. Influence of harvesting and threshing methods on moisture content of Sunn hemp seed storage

Table 1. Effect of harvesting and threshing methods on germination of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)	98 (82.80)
P_1	97 (80.63)	96 (79.46)	97 (80.63)	97 (80.63)	97 (80.63)	97 (80.63)	97 (80.63)	97 (80.63)	97 (80.63)	97 (80.63)
P_2	96 (79.46)	95 (77.24)	95 (77.24)	96 (79.46)	96 (79.46)	97 (80.63)	96 (79.46)	95 (77.24)	96 (79.46)	96 (79.46)
P_3	95 (77.24)	93 (76.06)	93 (76.06)	94 (76.94)	94 (76.94)	96 (79.46)	95 (77.24)	93 (76.06)	94 (76.94)	95 (77.24)
P_4	94 (76.94)	91 (72.88)	92 (75.44)	93 (76.06)	93 (76.06)	95 (77.24)	93 (76.06)	92 (75.44)	93 (76.06)	93 (76.06)
P_5	94 (76.94)	90 (72.05)	91 (72.88)	92 (75.44)	92 (75.44)	95 (77.24)	92 (75.44)	91 (72.88)	92 (75.44)	93 (76.06)
P_6	93 (76.06)	89 (70.69)	90 (72.05)	91 (72.88)	91 (72.88)	94 (76.94)	89 (70.69)	91 (72.88)	92 (75.44)	92 (75.44)
P_7	93 (76.06)	87 (69.25)	88 (70.47)	90 (72.05)	90 (72.05)	93 (76.06)	88 (70.47)	91 (72.88)	91 (72.88)	91 (72.88)
P_8	92 (75.44)	86 (68.56)	87 (69.25)	89 (70.69)	89 (70.69)	93 (76.06)	85 (67.81)	89 (70.69)	90 (72.05)	89 (70.69)
P_9	91 (72.88)	85 (67.81)	86 (68.56)	88 (70.47)	88 (70.47)	92 (75.44)	84 (66.77)	89 (70.69)	89 (70.69)	89 (70.69)
P_{10}	89 (70.69)	84 (66.77)	84 (66.77)	87 (69.25)	86 (68.56)	91 (72.88)	83 (65.76)	88 (70.47)	89 (70.69)	88 (70.47)
P_{11}	88(70.47)	82 (65.27)	83 (65.76)	86 (68.56)	85 (67.81)	90 (72.05)	83 (65.76)	88 (70.47)	89 (70.69)	88 (70.47)
P_{12}	86 (68.56)	80 (63.63)	82 (65.27)	85 (67.81)	83 (65.76)	89 (70.69)	82 (65.27)	86 (68.56)	88 (70.47)	86 (68.56)
Mean	**93 (76.06)**	**89 (70.69)**	**90 (72.05)**	**91 (72.88)**	**91 (72.88)**	**94 (76.94)**	**90 (72.05)**	**91 (72.88)**	**92 (75.44)**	**92 (75.44)**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**0.317**	**0.807**	**0.448**	**1.142**	**1.614**		**0.633**		**2.283**	
CD (P=0.05)	**0.624**	**1.591**	**0.883**	**NS**	**NS**		**NS**		**NS**	

(Figures in parentheses are arc sine transformed values) P- Storage period in months, T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, T_3- Manual harvesting and Tractor TreadingT_4- Combine harvester

Table 2. Effect of harvesting and threshing methods on root length (cm) of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	18.0	16.9	17.5	17.1	17.4	20.1	19.6	20.0	20.0	19.9
P_1	17.7	16.6	17.3	17.0	17.2	19.8	19.0	19.7	19.5	19.5
P_2	17.5	16.2	17.1	16.7	16.9	19.4	18.5	19.1	19.0	19.0
P_3	17.4	15.9	16.9	16.4	16.7	19.1	18.1	18.5	18.3	18.5
P_4	17.2	15.7	16.6	16.1	16.4	18.7	17.6	18.1	17.8	18.1
P_5	17.0	15.4	16.3	15.9	16.2	18.3	17.1	17.6	17.4	17.6
P_6	16.7	15.1	16.1	15.6	15.9	17.9	16.7	17.0	16.9	17.1
P_7	16.4	14.9	15.9	15.4	15.7	17.6	16.2	16.7	16.5	16.8
P_8	16.1	14.7	15.6	15.1	15.4	17.2	15.9	16.4	16.1	16.4
P_9	15.9	14.5	15.2	14.8	15.1	16.9	15.2	16.1	15.8	16.0
P_{10}	15.7	14.2	15.0	14.6	14.9	16.6	14.7	15.8	15.3	15.6
P_{11}	15.4	14.0	14.8	14.3	14.6	16.1	14.4	15.3	14.9	15.2
P_{12}	15.1	13.8	14.6	14.1	14.4	15.8	14.2	14.8	14.4	14.8
Mean	**16.6**	**15.2**	**16.1**	**15.6**	**15.9**	18.0	16.7	17.3	17.1	**17.3**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**0.049**	**0.127**	**0.070**	**0.179**	**0.253**		**0.099**		**0.358**	
CD (P=0.05)	**0.098**	**0.250**	**0.139**	**0.353**	**NS**		**NS**		**NS**	

T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, T_3- Manual harvesting and Tractor Treading, T_4- Combine harvester

Table 3. Effect of harvesting and threshing methods on shoot length (cm) of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	18.9	17.1	17.9	17.7	17.9	22.4	20.5	21.4	21.1	21.4
P_1	18.9	16.5	17.0	16.9	17.3	22.1	20.0	21.0	20.7	21.0
P_2	17.8	16.3	16.9	16.5	16.9	21.8	19.6	20.6	20.2	20.6
P_3	17.1	16.3	16.7	16.5	16.7	21.5	19.1	20.0	19.6	20.1
P_4	16.0	15.4	15.8	15.6	15.7	20.9	18.7	19.7	19.0	19.6
P_5	15.6	14.9	15.5	15.4	15.4	20.6	18.2	19.3	18.5	19.2
P_6	15.3	14.5	14.8	14.7	14.8	20.1	17.6	18.8	18.2	18.7
P_7	15.1	14.4	14.8	14.7	14.8	19.7	17.0	18.5	17.8	18.3
P_8	14.9	14.3	14.8	14.6	14.7	19.3	16.6	18.0	17.3	17.8
P_9	14.9	13.8	14.8	14.2	14.4	19.0	16.3	17.6	16.9	17.5
P_{10}	14.1	13.9	14.1	14.0	14.0	18.7	15.7	17.1	16.4	17.0
P_{11}	14.0	13.2	13.9	13.7	13.7	18.2	14.9	16.8	16.0	16.5
P_{12}	13.9	12.3	13.7	13.6	13.4	17.8	14.5	16.4	15.6	16.1
Mean	**15.9**	**14.8**	**15.4**	**15.2**	**15.4**	**20.2**	**17.6**	**18.9**	**18.3**	**18.7**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**0.0495**	**0.1262**	**0.0699**	**0.1784**	**0.2523**		**0.0989**		**0.3568**	
CD (P=0.05)	**0.0976**	**0.2487**	**0.1379**	**0.3517**	**NS**		**0.1951**		**NS**	

T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, P- Storage period in months, T_3- Manual harvesting and Tractor Treading,T_4- Combine harvester

Table 4. Effect of harvesting and threshing methods on dry matter production (g) of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	0.238	0.211	0.216	0.214	0.220	0.264	0.242	0.251	0.247	0.251
P_1	0.220	0.190	0.201	0.195	0.202	0.260	0.235	0.247	0.242	0.246
P_2	0.214	0.183	0.190	0.185	0.193	0.253	0.229	0.241	0.237	0.240
P_3	0.207	0.175	0.184	0.182	0.187	0.248	0.222	0.236	0.231	0.234
P_4	0.197	0.170	0.179	0.178	0.181	0.242	0.216	0.229	0.225	0.228
P_5	0.193	0.167	0.177	0.172	0.177	0.237	0.206	0.220	0.217	0.220
P_6	0.187	0.157	0.175	0.168	0.172	0.233	0.193	0.212	0.208	0.212
P_7	0.184	0.156	0.170	0.163	0.168	0.229	0.188	0.205	0.200	0.206
P_8	0.180	0.155	0.165	0.158	0.165	0.222	0.180	0.196	0.192	0.198
P_9	0.177	0.150	0.158	0.154	0.160	0.216	0.172	0.189	0.183	0.190
P_{10}	0.173	0.145	0.155	0.149	0.156	0.208	0.164	0.181	0.176	0.182
P_{11}	0.168	0.144	0.150	0.145	0.152	0.201	0.157	0.174	0.168	0.175
P_{12}	0.159	0.134	0.146	0.138	0.144	0.194	0.151	0.168	0.160	0.168
Mean	**0.192**	**0.164**	**0.174**	**0.169**	**0.175**	**0.231**	**0.197**	**0.211**	**0.207**	**0.211**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**0.0006**	**0.0015**	**0.0008**	**0.0021**	**0.0029**		**0.0012**		**0.0042**	
CD (P=0.05)	**0.0012**	**0.0029**	**0.0016**	**0.0042**	**NS**		**0.0023**		**NS**	

T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, P- Storage period in months, T_3- Manual harvesting and Tractor Treading, T_4- Combine harvester

Table 5. Effect of harvesting and threshing methods on seedling vigour index I of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	3616	3332	3469	3410	3457	4165	3930	4057	4028	4045
P_1	3550	3178	3327	3288	3336	4064	3783	3948	3899	3924
P_2	3389	3088	3230	3187	3223	3996	3658	3772	3763	3797
P_3	3278	2995	3125	3093	3122	3898	3534	3581	3563	3644
P_4	3121	2830	2981	2948	2970	3762	3376	3478	3422	3509
P_5	3064	2727	2894	2880	2891	3696	3248	3358	3303	3401
P_6	2976	2634	2781	2757	2787	3572	3053	3258	3229	3278
P_7	2930	2549	2702	2709	2722	3469	2922	3203	3121	3179
P_8	2852	2494	2645	2643	2659	3395	2763	3062	3006	3056
P_9	2803	2406	2580	2552	2585	3303	2646	2999	2910	2965
P_{10}	2652	2360	2444	2488	2486	3212	2523	2895	2821	2863
P_{11}	2587	2230	2382	2408	2402	3087	2432	2825	2750	2773
P_{12}	2494	2088	2321	2355	2314	2990	2353	2683	2640	2667
Mean	**3024**	**2685**	**2837**	**2825**	**2843**	**3585**	**3094**	**3317**	**3266**	**3315**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**8.997**	**22.938**	**12.724**	**32.439**	**45.876**		**17.994**		**64.879**	
CD (P=0.05)	**17.737**	**45.221**	**25.084**	**63.952**	**90.442**		**35.474**		**NS**	

T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, P- Storage period in months
T_3- Manual harvesting and Tractor Treading, T_4- Combine harvester

Table 6. Effect of harvesting and threshing methods on Seedling vigour index II of Sunn hemp

Treatments(T) / Periods (P)	Cloth bag (C_1)					Super grain bag (C_2)				
	T_1	T_2	T_3	T_4	**Mean**	T_1	T_2	T_3	T_4	**Mean**
P_0	23	21	21	21	22	26	24	25	24	25
P_1	21	18	19	19	19	25	23	24	23	24
P_2	21	17	18	18	18	25	22	23	23	23
P_3	20	16	17	17	18	24	21	22	22	22
P_4	19	15	16	17	17	23	20	21	21	21
P_5	18	15	16	16	16	23	19	20	20	20
P_6	17	14	16	15	16	22	17	19	19	19
P_7	17	14	15	15	15	21	17	19	18	19
P_8	17	13	14	14	15	21	15	17	17	18
P_9	16	13	14	14	14	20	14	17	16	17
P_{10}	15	12	13	13	13	19	14	16	16	16
P_{11}	15	12	12	12	13	18	13	15	15	15
P_{12}	14	11	12	12	12	17	12	14	14	15
Mean	**18**	**15**	**16**	**16**	**16**	**22**	**18**	**19**	**19**	**20**
	C	**P**	**T**	**CP**	**PT**		**CT**		**CPT**	
SEd	**0.065**	**0.165**	**0.092**	**0.233**	**0.330**		**0.129**		**0.466**	
CD (P=0.05)	**0.128**	**0.325**	**0.181**	**0.460**	**0.651**		**0.255**		**0.920**	

T_1- Manual harvesting and Threshing, T_2- Manual harvesting and Mechanical threshing, P- Storage period in months, T_3- Manual harvesting and Tractor Treading, T_4- Combine harvester

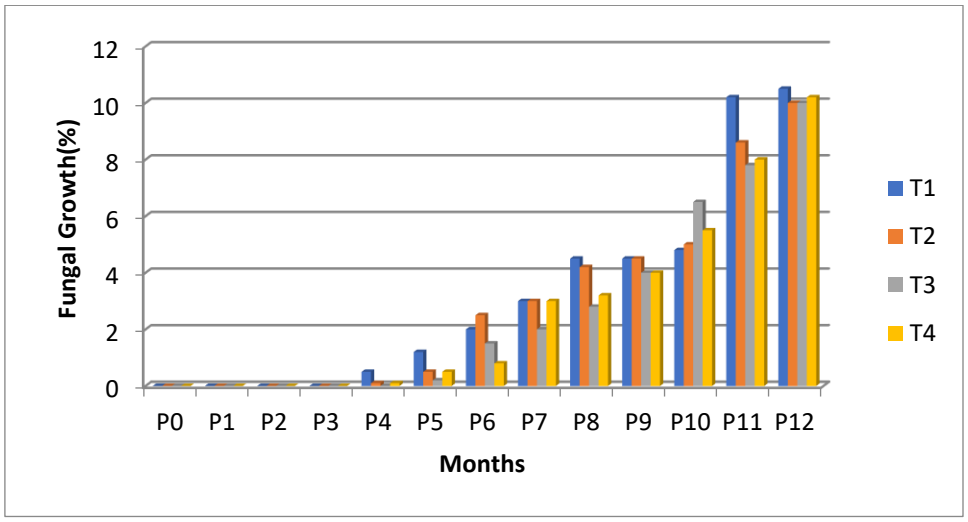
lower moisture content in the seeds using vapour impervious containers. Lower respiration rate and metabolic activity are governed by lower moisture content and temperature during the storage period [26] Doijode [27] reported that the seeds packed in polythene bags exhibited higher germination; seedling length and seedling dry weight. Similar observations have been reported by Padma and Reddy [28] in maize and green gram. Seeds packed in polythene bag and acted as vapour proof barrier in regulating lower moisture content in the seeds.. This is in accordance with the findings of Azad *et al.,* [29] who have observed higher vigour when wheat seeds dried to 12 per cent moisture content and preserved in polythene bags stored for nine months. Similar findings have been reported by Saxena *et al.,* [30] in cereals.

3.2 Germination Test

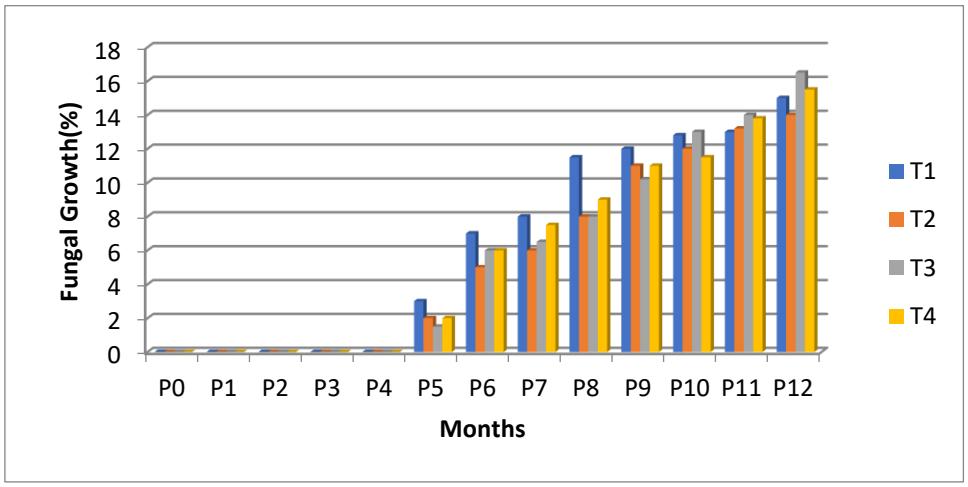
Physiological parameters were significantly influenced by harvesting and threshing methods, container used for storage and period of storage in sunnhemp seed tested. In this study, seeds obtained by manual harvesting and manual threshing method registered maximum germination percentage (93% & 94%), followed by seeds obtained by combine harvesting (91% & 92%) (Table1). The minimum germination percentage was recorded in the seeds obtained by manual harvesting and mechanical threshing (89% &90%).The maximum germination percentage was observed during the initial period of storage and reached the minimum at 12 months of storage. Between the containers, super grain bag maintained the highest germination percentage (92%) while the lowest germination percentage was observed in the seeds stored in cloth bag (91%). The root length and shoot length of the seedling reflected the same trend as on germination percentage. Regarding dry matter production, the seeds obtained by manual harvesting and manual threshing method registered maximum dry matter production (0.192g& 0.231g), seedling vigour I (3024 & 3585) and seedling vigour II (18 & 22) followed by seeds obtained by manual harvesting and tractor treading (2837 & 3317) (16 &19) (Tables 2,3,4,5, 6).

The minimum dry matter production, seedling vigour I and seedling vigour II was recorded in the seeds obtained by manual harvesting and mechanical threshing (0.164g & 0.197g). The maximum dry matter production and seedling vigour I and vigour index II were observed during the initial period of storage and reached the minimum at 12 months of storage. Between the containers, super grain bag maintained the highest dry matter production, seedling vigour I and seedling vigour II while the lowest dry matter production, seedling vigour I and II was observed in the seeds stored in cloth bag. Between the harvesting method, manual harvesting and threshing maintained the highest dry matter production, seedling vigour I and II was observed and the lowest dry matter production, seedling vigour I and II was observed in manual harvesting and mechanical threshing. These results are in agreement with the results obtained by Akter *et al.* [31] in soybean, Sharon *et al.,* [32] in black gram.

The decline in germination percentage may be attributed to ageing effect. Ageing has damaging effect on enzymes that are necessary to convert reserve food in the embryo to usable form and ultimately production of normal seedling [33]. Alternatively, the decrease in germination, dry matter synthesis, and seedling vigour might be caused by mitochondrial membrane breakdown, resulting in a decrease in energy supply required for germination [34] Ajay et al., [35]. showed loss of germination and seedling vigour after storage in soybean and Htweb et al. [36], in green gram and chickpea. The decrease in seedling dry matter production may be related to DNA degradation with ageing, which results in decreased transcription, resulting in inadequate or defective enzyme synthesis required for early phases of germination [37]. All seeds undergo ageing process during long-term storage which leads to deterioration in seed quality, however, the rate of seed deterioration can vary among various plant species [38] Rajasekaran et al. [39] observed that niger seeds packed in polylined cloth bags maintained higher germination and vigour index even after six months of storage. Van Chin and Kieu [40] reported in rice seeds that germination percentage under super bag and vietnamese bag are similar at three and six months after storage. However, at 9 and 12 months storage, IRRI Super bag was superior to Vietnamese bag statistically. Singh and Dadlani [41] stated that soybean seeds packed in700 gauge poly ethylene bag could be stored for fourteen months whereas, the seeds packed in cloth bag could be stored only up to eight months.



Aspergillus flavus



***Fusarium* sp.**

Fig. 3. Influence of harvesting and threshing methods on fungal growth of Sunn hemp seed storage in cloth bag

3.3 Seed Health Test

The seed health studies revealed that the genera of fungi were identified under the compound microscope at 40x. Fungal species identified were *Aspergillus flavus* and *Fusarium* sp. In all the treatments, fungal incidence was noticed in seeds collected from cloth bag whereas no incidence was found in seeds samples collected from super grain bag. Seed borne pathogens were identified after four months of storage period and no incidence was noticed up to four months of storage. Incidence of *Fusarium* sp. ranged from 1.5 to 3% at fifth month and from 14 to 16.5% at 12 months of storage. Incidence of *Aspergillus flavus*, ranged from 0 to 0.5% at four months of storage and from 10 to 10.5% at 12 months of storage (Fig.3). Similar type of seed mycoflora association was also reported by Sadhu [42] and Devamani et el., [43] in green gram and Biswal et al., [44] in black gram.

As seed deterioration is unavoidable and irreversible process it cannot be stopped completely but the extent of determination can be slowed downed to certain extent. Similarly in our study, irrespective of the harvesting and threshing methods, the seed quality parameters declined progressively with an increase in storage period. However, seed harvested and threshed by manual method- manual harvesting and manual threshing, manual harvesting and mechanical threshing, manual harvesting and tractor treading and combine harvesting and stored in both cloth bag and super grain

containers all are found to be maintaining the longevity of sunnhemp seed under ambient conditions. However, fungal incidence were noticed in seeds collected from cloth bag whereas no incidence was found in seeds samples collected from super grain bag.

4. CONCLUSION

From this study it could be concluded that sunnhemp seed crop harvested and threshed by different methods and reduced to the moisture content of 8percent and packed in super grain bag maintained seed quality above minimum seed certification standards up twelve months of storage without any pathogen incidence. Hence it is recommended that combine harvester can used to harvest the sunnhemp seed crop to minimise the cost of labour as well as saving time and found to be maintaining the longevity of sunnhemp seed under ambient storage.

ACKNOWLEDGEMENT

The authors are thankful to Tamil Nadu Agricultural University, Coimbatore for providing facilities and funding for the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/106463