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

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

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.

Key words: Crotolaria juncea, Containers, Germination, Harvesting and threshing methods, Seed borne pathogen, Seed storage.

UNDER PEER REVIEW

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 (Masilamani and Tajuddin 2012; Masilamani *et al.,* 2021). 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% (Rickman *et al.,* 2006). 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 (Masilamani and Sivasubramaniyam, 2016; Rajendra Prasad *et al.,* 2017). It has the potential to be a tropical cover crop that decreases erosion while also improving soil fertility and tilth (Alwell, 2015). It has a biomass production of 15-20t/ha. (Lates and Mabbayad, 1983). Sunnhemp fibers used as a substitute for synthetic fibers (Rawat, R. and C.S. Saini, 2023: Srikavi,A and M. Mekala. 2023). It is resistant to nematodes and may thrive in dry zone soil with poor fertility (Mc sorely *et al.,* 1994). It inhibits weeds by burying them (Rotar and Joy, 1983) 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 (Pradhan *et al.,* 2001; Ulemale *et al.,* 2002). 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 (Desai *et al*., 2023). Hence there should be enough buffer stock of seed to meet the season-season seed requirement (Masilamani *et al*., 2017). 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 (Johny subakarivin *et al*.,2021). 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.

UNDER PEER REVIEW

2. MATERIALS AND METHOD

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.

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 $^{\circ}$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 (ISTA 1985).

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

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 (Central Seed Certification Board. 2013). 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

UNDER PEER REVIEW

calculated using the following formula (Abdul – Baki and Anderson, 1973) 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 (1999) 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, 1995. 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.

UNDER PEER REVIEW

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

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.,* 2017 in rice. Higher the moisture content and temperature, lesser the shelf life of paddy seed reported by Kaliyan*et al.,* 2006. Ramanadane and Ponnusamy (2004) 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 (Ellis *et al.,* 1990).

The super grain bag played significant role in preventing vapour entry from the surrounding air. This becomes effective strategy in regulating 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 (Muangkaeo *et al.,* 2005). Doijode (1995) 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 (2002) 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.,* (2014) 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.,* (1987) 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

UNDER PEER REVIEW

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)(Table2,3,4,5and 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.* (2014) in soybean, Sharon *et al.*, 2015 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 (Iqbal *et al.*, 2002). 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 (Gidrol et al., 1998). Ajay et al., (2017) showed loss of germination and seedling vigour after storage in soybean and Htweb et al., (2018) 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 (Kapoor et al., 2002). 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 (Merritt *et al.*, 2003). Rajasekaran *et al.* (2005) 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 (2006) 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 (2003) stated that soybean seeds packed in700 gauge poly

UNDER PEER REVIEW

ethylene bag could be stored for fourteen months whereas, the seeds packed in cloth bag could be stored only up to eight months.

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 (2014) and Devamani *et el.*, (2017) in green gram and Biswal et al., 2019 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.

REFERENCES

Abdul Baki AA and JD Anderson (1973). Vigour determination in Soybean seed by multiple criteria. *Crop Science, 13: 630 -633.*

Alwell, A (2015). Sunn hemp gains popularity as stress-tolerant cover crop. *Organic Broadcaster*, 23:1&6

Ajay P.G., K.Vishunavat, C.Mohan, S.Ravi.2017.Effect of seed coating, storage periods and storage containers on soybean (*Glycine max* (L.) Merrill) seed quality under ambient conditions.*Journal of Applied and Natural Science*. Vol. 9(1). DOI https://doi.org/10.31018/jans.v9i1.1237.

UNDER PEER REVIEW

Akter, N., M. M. Haque, M. R. Islam and K. M. Alam. (2014).Seed Quality of Stored Soybean (*Glycine max* L.) as Influenced by Storage Containers and Storage Periods. *The Agriculturists,* 12(1): 85-95

Azad A. W., T. Jaya Joshi, T. Anurag and D. S. Tomar. (2014). Effect of seed treatments and packing materials on seed quality parameters of maize (*Zea mays* L.) during Storage. *Indian J. Appl. Res.,* 4:40-44.

Biswal, K., N. Ranasingh, K. C. Sahu, R. L. Moharana and Behera, S. 2019. Seed Health Status of Farmers' Saved Black Gram (*Vigna mungo* (L.) Heppper) Seeds in Western Undulated Zones of Odisha. *Int.J.Curr.Microbiol.App.Sci.* 8(10): 2738-2742. doi: https://doi.org/10.20546/ijcmas.2019.810.316

Central Seed Certification Board (2013). Indian Minimum Seed Certification Standards. Ministry of Agriculture, GOI, New Delhi. pp. 183-184.

Desai, T.B., Madhu Bala and R.K. Patel (2023). Genetic Divergence in Sunnhemp (*Crotalaria juncea*L.), *Legume Research.* 46(4): 413-416. doi: 10.18805/LR-4397.

Devamani, B.D., Saifulla, M., Jayappa and Sab, J. (2017). Prevalence of Seed mycoflora of Mung bean in Karnatak, India, *Int. J. Microbiol. App. Sci*. 6(6): 844-852

Doijode, S. D. 1995. Effect of silica gel and storage containers on viability and vigour in onion. *Seed Res.,* 18:163-165.

Ellis, R.H., Hong, T.D. and Roberts, E.H. 1990. Moisture content and the longevity of seeds of *Phaseolus valgaris*L. *Ann. Bot.,* 66: 341-348.

Gidrol, X., Noubhani, A., Mocquot, B., Fournier, A. and Pradet, A. 1998. Effect of accelerated aging on protein synthesis in two legume seeds. *Plant Physiol.Biochem.,* 26: 281-288.

Govindaraj**,** M., P. Masilamani and V. Alex Albert. 2017. Influence of Harvesting and Threshing Methods on Storability of Rice Varieties. *Madras Agricultural Journal*. 104: 395-400.

International Seed Testing Association (ISTA). 1985. Determination of moisture content. *Seed Science and Technology* 13: 338-343.

International Seed Testing Association (ISTA). ISTA. 1999. International Rules for Seed Testing. Seed Science and Technology Supplement, **27:** 39.

Lates,J.C. and B.B. Mabbayad.*1983*. The potential and establishment method of *Crotalaria juncea* L. as a green manure for corn (*Zea mays* L.) . *Philippines Journal of Crop Science,*8:145-147

Iqbal, N., Shahzad, A., Basra, M. and Khalil Rehman, U. 2002. Evaluation of vigor and oil quality in cotton seed during accelerated aging. *Int. J. Agric. Biol.,* **4**(3): 318-322.

Johnny subakarivin,J., Anbuselvam, M. Surendhar and J.R. Jerish.2021. Effect of storage containers and seed treatments on germination and vigour of Black gram(*Vigna mungo*(L)Happer). *Plant Archives*. 21(1):2360-2362

Kaliyan, N., Alagusundaram, K. and Gayathri, P. 2006.Effect of temperature and moisture content on shelf life of paddy. The American Society of Agricultural and Biological Engineers. 066-193.

Kapoor, N., Arya, A., Siddiqui., Mohd Asif., Kumar, H. and Amir, A. 2002. Physiological and biochemical changes during seed deterioration in aged seeds of rice (*Oryza sativa* L.). *Am. J. Plant Physiol.,* **6**(1): 28-35.

Masilamani, P and A. Tajuddin 2012. Can we use combine for seed purpose?. *Kisan World*. December2012.39:38-39.

Masilamani, Pand K. Sivasubramaniyam (2016). *Green Manure Seed Production*. Kalyani Publishers, New Delhi. pp.163.

Masilamani., P., V. Alex albert, S. Vallalkannan and M. Govindaraj. 2017. Influence of harvesting and threshing Methods on Seed Quality of Sunn hemp (*Crotalaria juncea* L.). *Seed Research*. 45: 12-15.

Masilamani, P. T. Eevera., T. Ramesh and S.Venkatesan. 2021. Harvesting and Threshing methods on Seed Quality of Dhaincha (*Sesbania aculeate)* Legume Research. DOI: 10.18805, 1-7.

Mc Sorley, R., D.W. Dickson., J.A. De Brito., T.E. Hewlett and J.J. Frederic. 1994. Effects of

UNDER PEER REVIEW

tropical rotation crops on *Meloidogyne arenaria* population densities and vegetable yields in microplots. *Journal of Nematology*, 26: 175-181

Merritt, D.J., Senaratna, T., Touchell, D.H., Dixon, K.W. and Sivasithamparam, K. 2003. Seed ageing of four Western Australian species in relation to storage environment and seed antioxidant activity. *Seed Sci.Res.*, **13**: 155-165.

Muangkaeo, R., S. Srichuwong and S. Vearasilp. 2005. Influence of packaging materials and storage time on seed viability and chemical component of rice seed. Conference on International Agricultural Research for Development, Stuttgart- Hohenheim, October 11-13, 2005

Padma, V. and M. B. Reddy. 2002. Study on seed storage ability in rice genotypes. *Oryzae*, 39(1&2):71-75.

Panse VG and PV Sukhatme (1995). Statistical methods for agricultural workers. Indian Council of Agricultural Research Publications, New Delhi. 175 P.

Pradhan, S.K., S.K. Sarkar and S. Prakash. 2001. Verital response of Sunnhemp, *Crotalaria juncea L. to Rhizobium japanicum*(Cowpea type) with reference to dynamics of nodulation. Legume Research. 24: 164 – 168.

Rajasekaran, R., P. Balamurugan and C. Reshma. 2005. Effect of eco-friendly seed treatments and containers on storability of niger (*Guizotiaabyssinica*L. f. Cass.) cv. Paiyur 1. *The Madras Agric. J.*, 92(1-3):95-100.

Rajendra prasad, R., P. Masilamani, and K. Balakrishnan, 2017. Effect of pre-sowing seed treatments on dormancy of sunn hemp (*Crotalaria juncea* L.). *Seed Research*. 45: 136-140.

Ramanadane, T. and A.S. Ponnuswamy.2004. Ageing and anatomical influence on seed storability in rice (*Oryzasativa* L.) hybrids and parental lines. *Tropical Agric. Res.*, **16**: 37-50.

Rawat, R. and C.S. Saini, 2023. High-Intensity Ultrasound (HIUS) Treatment of Sunnhemp Protein Isolate (*Crotalaria juncea* L.): Modification of Functional, Structural, and Micro structural Properties. *Food Bioprocess Technoogy.* 16, 1464–1477

Rickman, J.F., M. Belland D. Shires, 2006. Seed Quality,Available at http// www.knowledgebank.irri.org.Accessed 21/12/2014.

Rotar PP and RJ Joy (1983). 'Tropic Sun' sunn hemp (*Crotalaria juncea L.).* Research Extension Series. 36. Hawaii Institute of Tropical Agriculture and Human Resources. University of Hawaii,Honolulu.

Sadhu. K.A. 2014. Seed borne fungi and their effect on Seed health of Green gram. *Bioscience Discovery*, 5(2):251-255.

Saxena, O. P., G. Singh, H. Pakeeraiah and N. Pandey. 1987. Seed deterioration studies in some vegetable seeds. *Acta Horticulture*, 215:39-44.

Sharon M.E.M, C. V. K.Abirami, K. Alagusundaram and J. A.Sujeetha.2015. Safe storage guidelines for black gram under different storage conditions. *Journal of Stored Products and Postharvest Research*. Vol. 6(5):38-47

Singh, K.K . and Dadlani.2003. Effect of packaging on vigour and viability of Soybean (*Glycine max* (L) Merrill.) seed during ambient storage. *Seed Research*. 31(1): 27-32

Srikavi ,A and M. Mekala. 2023Characterization of Sunn hemp fibers as a substitute for synthetic fibers in composites and various applications. *Industrial Crops and Products*. 192: 116-132

Ulemale, R.B., D.G. Giri, R.S. Shivankar and V.N. Patil. 2002. Effect of Sowing dates, rowspacing and phosphorus levels on yield and yield attributes of sunnhemp (*Crotalaria juncea.L), Legume Research.* 25: 273-275.

Van Chin, D. and T.T. Kieu. 2006. Study on hermetically sealed storage system for rice seeds. *Omonrice*, 14: 64-70.

Htwe E.M, K.T.One, E.H.Kyaw, K.Ngwe, K.K.Win.2018. Effect of Different Seed Moisture Contents and Storage Containers on Seed Quality of Green Gram(*Vigna radiata* L. Wilczek)and Chickpea(*Cicer arietinum*). *Journal of Agricultural Research*,5(2):67-75

UNDER PEER REVIEW

UNDER PEER REVIEW

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 Treading T_4- Combine harvester

UNDER PEER REVIEW

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

UNDER PEER REVIEW

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

UNDER PEER REVIEW

Table4. 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

UNDER PEER REVIEW

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

UNDER PEER REVIEW

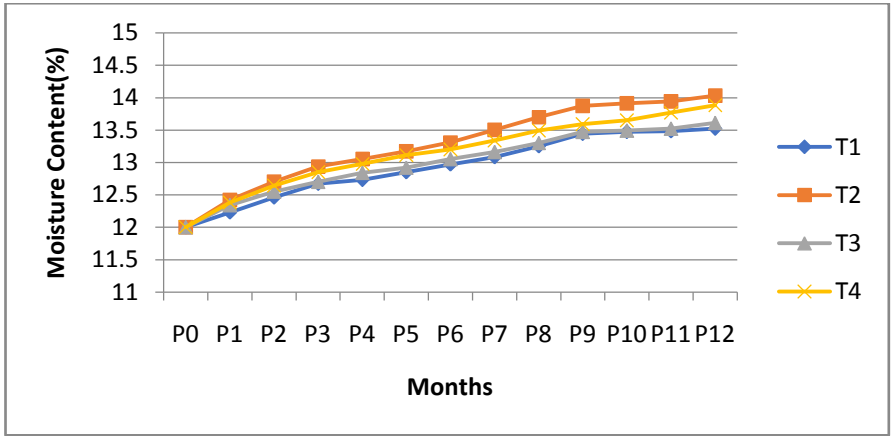
Table 6. Effect of harvesting and threshing methods on Seedling vigour index II of Sunn hemp

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**	

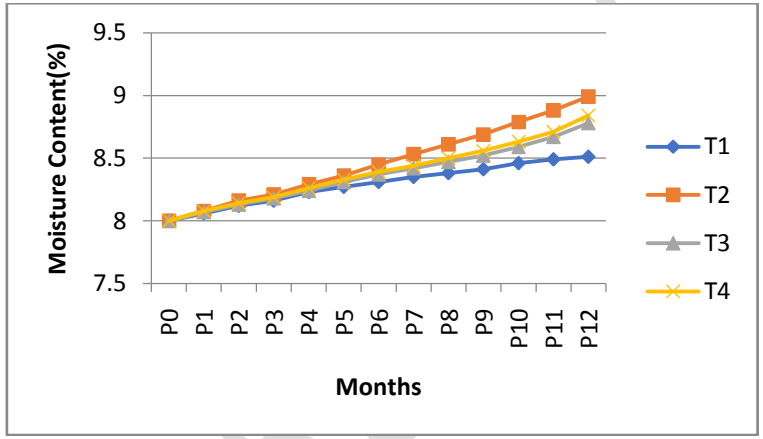
T_1- Manual harvesting and Threshing T_2- Manual harvesting and Mechanical threshing P- Storage period in months

T_3- Manual harvesting and Tractor Treading T_4- Combine harvester

UNDER PEER REVIEW

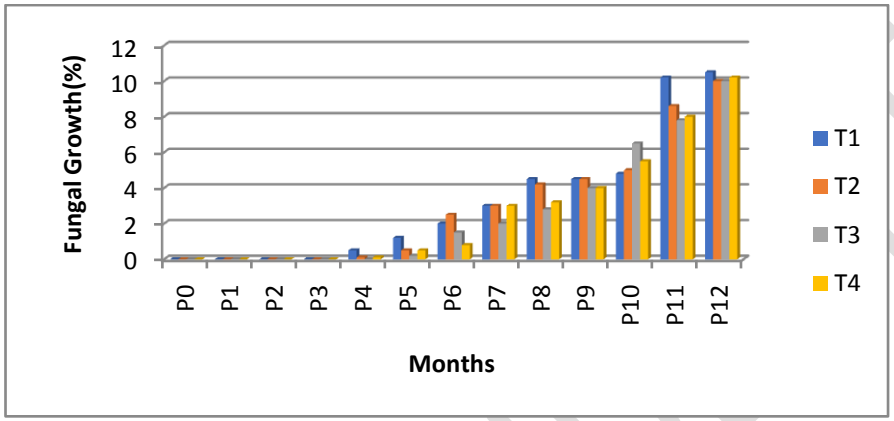


Cloth bag (C_1)

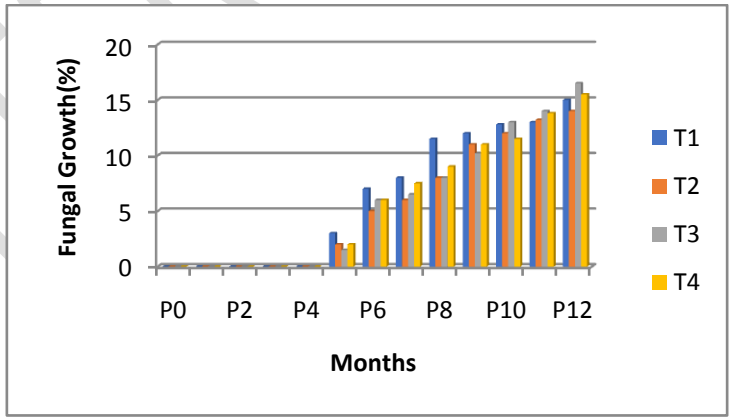


Super grain bag (C_2)

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



Aspergillus flavus



Fusarium sp.

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

T_1- Manual harvesting and Threshing T_2- Manual harvesting and Mechanical threshing P- Storage period in months

T_3- Manual harvesting and Tractor TreadingT_4- Combine harvester