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Design and Development of Cold Storage System for Community-based Small-size Seed Banks for Farmers

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ABSTRACT

Background: Seed preservation in the context of changing climatic conditions and retaining quality is a big challenge, especially for marginal farmers who does not have appropriate seed storage facilities. Moisture and temperature variations (both seasonal and diurnal) during storage result in moulds, bacteria, insects, mites and rodents attacks. Tropical regions with higher ambient temperatures and relative humidity variations need to address the storage issue.

Methods: This research work discusses the process of design, fabrication and testing of a low-cost seed storage unit (SSU) for community-based seed banks. The SSU of 200 L storage capacity was cooled using a thermoelectric cooler (TEC) to provide the temperature range of 15°C to 18°C and relative humidity <70% inside the SSU. The SSU was field-tested at fourteen different agro-climatic locations for seeds of paddy (*Oryza sativa*), gram (*Cicer arietinum*), onion (*Allium cepa*), groundnut (*Arachis hypogaea*) and maize (*Zea mays*) during the period 18 months between 2017 to 2019. These seeds were tested for germination count (GC) and moisture content (MC).

Result: Results obtained indicated that the SSU developed can retain essential seed quality parameters *i.e.* more than 80% germination count (GC), except for groundnut seeds over a period of 18 months as against loss of seed viability in 8 months' time in traditional storage at ambient temperature. Based on the field performance testing, we recommend the use of such devices for farmers' and farmers' producer companies for a decentralised seed storage capacity of 100 to 200 kg.

Key words: Community-based, Germination count, Seed quality, Seed storage unit, Thermoelectric cooling.

INTRODUCTION

Preservation of viable seeds from the time of collection/ harvesting until they are required for sowing is important (Hongs, 1996). The quality of the stored seeds is greatly affected by the storage conditions. Poor quality seeds can result in poor germination and lower agricultural production leading to losses. In the present scenario with the rapid change of climatic conditions, there is a need to store the seeds for a minimum period of two seasons *viz*. ~ 20 months (Patil, 2015). This will ensure the availability of quality seeds, even if the first season gets adversely affected by the climatic changes. Storage is a basic practice in the control of the physiological quality of the seed and is a method through which the viability of the seeds can be preserved and their vigour kept at a reasonable level during the time between planting and harvesting (Birhanu Gebeyehu, 2020).

Indian farmers have been conserving indigenous varieties of seeds with traditional methods such as bamboo baskets and earthen pots (Patil, 2015). Conservation of these seeds is important because most of the indigenous seeds are likely to be extinct due to the exploitation of hybrid and high yielding varieties by seed companies, farmers need to purchase seeds from market every season, seed cannot be saved from season to season as they have applied patents on these products. Presently, the aforementioned methods followed by the community-based seed banks and farmers are not appropriate for longer storage periods of more than two years that lead to a drop in the germination percentage of the seeds to less than 10% in a year. Major causes for the reduction of germination count during traditional seed storage are higher mould growth due to the moisture ingress and possible insects and rodent attacks (Befikadu, 2014). The quality of seeds during the storage period is strongly influenced by the quality of the initial seed before storage, seed moisture content, temperature and humidity during the storage period (Rahmawati and Muhammad Aqil, 2020).

Conserving the seeds without compromising the quality requires new interventions that need to satisfy the requirements of the marginal farmer's community. However,

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in the Indian scenario, the studies on the development and trials of small seed storage units are scanty. Hence, the current research work was undertaken with the following objectives i) design and develop an affordable, medium-term seed storage unit, ii) *in-situ* testing for storage of five different seeds for 18 months, iii) quality analysis of seeds at intervals of 3 months till completion of the storage period of 18 months.

MATERIALS AND METHODS

Need assessment

The research started with a request from BAIF Development Research Foundation to develop a seed storage unit for their community-based seed bank, as they were facing difficulties in preserving the seeds for more than one year. Surveys and interactions with small farmers have been conducted to understand the needs and practices related to the seed storage units of marginal farmers in Maharashtra state. The interactions involve semi-structured interviews and focus group discussions. There were limitations in maintaining the seed viability in conventional seed storage methods adopted by farmers. As Singh (2001) has observed in her research on the storage structures among farming communities, the ownership pattern of the storage structures in this case also differed between the medium to large famers and small to marginal farmers. The investment on storage structures was found to depend mainly on the holding size, one of the Strongest indication of economic status of rural families. From the data analysis of the survey, the following necessities were listed for medium term seed storage:

1. A minimum capacity of 200 L (for eventual coming-together if say 10 farmers who would afford and maintain the seed storage unit).
2. Prevention of storage pests and rodent attack.
3. Low electricity consumption and feasible to use at locations where scheduled power outage is longer than 8 hours in a day.
4. Minimum moving parts and lesser maintenance.

Prototype design

Harrington's (1960) thumb rule on seed storage states that, for each 10°F (5.6°C) decrease in temperature, the longevity period doubles. Harrington (1972) also indicated that this rule applies when the seed moisture content is between 5 and 14 per cent. The higher moisture content of seeds increases respiration rates, which in turn raises seed temperature. Mould growth is encouraged by higher moisture, damaging the seeds, reducing their germination count.

Based on observations and recommendations of the field survey, A 200 L capacity seed storage unit has been developed aiming to keep the seeds safe for a period of 2 years. The capacity chosen is sufficient to provide seeds for a group of 10 farmers. The unit provides an inside temperature of 15°C to 18°C. The choice of TEC as a cooling engine was determined to keep the temperature requirement of 15°C to 18°C and the running cost as low as possible (Brown, 2012). Since the cooling technology is based on Thermo- Electric Cooling (TEC) (TEC/Peltier Element Design Guide), the energy consumption of the SSU is very low (approximately 0.7 kW-h per day). The cold SSU unit comprises of 5 major parts. 1. Thermo-electric cooling module, 2. Inlet fan for the circulation of air inside the storage unit, 3. Exhaust fan for expelling the hot air from the TEC, 4. AC to DC switching unit and 5. A feedback system to control the storage temperature. Fig 1 depicts the schematic of the prototype developed. Table 1 shows the technical specifications of the developed seed storage unit.

Fig 2 (a) and 2 (b) shows the images of prototypes used for initial lab testing and refined SSU deployed in field testing at different locations, respectively. To compare the performance of the SSU, temperature and relative humidity sensors were placed inside and outside the seed storage units and the data have been collected for seed storage units.

The TEC has been selected based on the maximum cooling capacity Qmax and Temperature difference ΔT the Peltier element can provide. In the case of this prototype, as we required an average temperature difference of ΔT = 25 K, a single-stage Peltier element is sufficient. The Thermo-electric cooler (TEC) used in the prototype is of model-TEC-12706. The TEC based cooling engine has been received from Godrej and Boyce Mfg. Pvt. Ltd. It is the same cooler unit used in their smaller cooling unit, *Chotukool*. This can provide Qmax of 50 W and a ΔTmax of 66°C (TEC/ Peltier Element Design Guide, 2015). It is possible that the TEC unit can provide more cooling load and this will lead to a temperature less than what is exactly required and specified in the literature. So it has been decided to design a temperature feedback system so that the TEC will run in the sleep mode when it achieves a temperature of 15°C. This will also help the unit to consume lesser energy while it is in sleep mode. Thus, the energy supply to the overall unit will reduce from 75 W to 15 W.

Experimental locations

Fifteen seed storage units were manufactured. one SSU was kept under laboratory conditions and 13 for field testing in different agro-climatic regions. The locations chosen for field-testing of the unit are shown in Fig 3 and detailed addresses of locations (A to N) are given in Table A-1 (Appendix A). Seeds of popularly used varieties of maize, paddy, gram, onion and groundnut were procured from farmer-based NGO (BAIF, Pune) and the details are indicated in Table 2.

Table 1: Technical specifications of seed storage unit.

Parameters	Levels
Capacity	200 L
Cooling load	15 W_T
Thermo-electric cooler model	TEC-12706 (H B Corporation)
Insulation material	Polyurethane (density 30 kg/m^3)
Energy input	AC
Energy consumption	72 W during active mode 15 W during the sleep mode

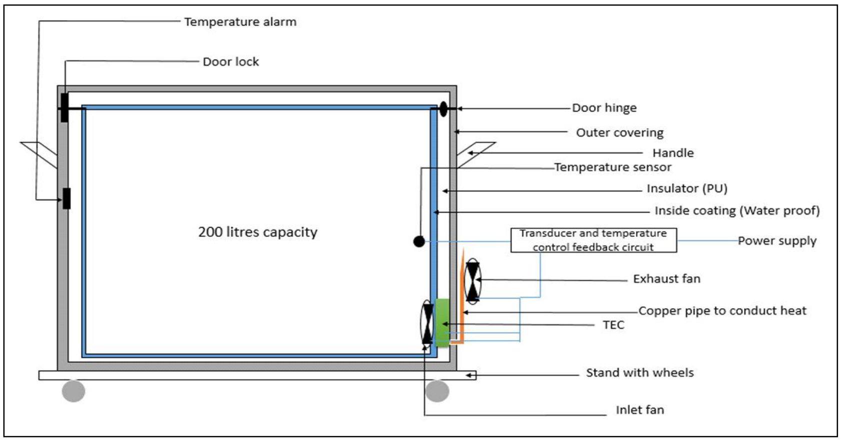
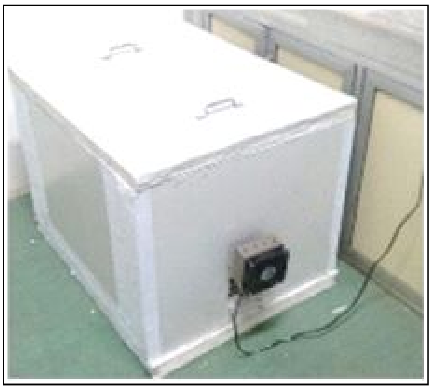


Fig 1: Schematic diagram of the seed storage unit (side view).

Table 2: Seed varieties taken for the field test and their initial germination count (GC) and moisture content (MC).

Crop name	Variety	Class of seed	Germination count (%)	Moisture (%)	Start date of test
Maize	African tall	Trufully Labelled	90.0	10.0	24.5.2017
Onion	Local	Trufully Labelled	89.3	5.0	24.5.2017
Paddy	J. Gundi	Trufully Labelled	88.0	8.0	20.6.2017
Gram	Local	Trufully Labelled	88.0	8.0	5.6.2017
Ground nut	TG-38	Trufully Labelled	NA	NA	NA



a) : SSU Prototype (1) image displaying placement of TEC.

b) : SSU Prototype (2) used in field testing.

Fig 2: Images of developed SSU.

Quality attributes

The parameters used to monitor the “seed-storage” unit performance are: moisture content and germination count of seeds every 3 months. Moisture content was measured by AOAC protocol using a hot air oven (AOAC, 2000). Germination count was estimated using wet-cellulosic germination paper (ISTA Standard Proficiency Test) (25°C temperature and 90 per cent relative humidity).

Laboratory test of SSU

The laboratory test of SSU was carried out in Food Processing Laboratory, Indian Institute of Technology Bombay, Mumbai (India) for the period of 9 months (Nov. 2016 to July 2017). Twenty kg of paddy seeds (*Oryza sativa*) were packed inside airtight zip-lock bags and placed inside the storage unit. Another sample of 5 kg paddy seeds was packed in a gunny bag and kept on a rack near the SSU to simulate conventional storage practice. Quality attributes were measured at an interval of 3 months.

Field testing of SSU

The field testing of SSU was carried out at 14 different geo-climatic regions of Maharashtra State (India) as shown in Fig 3. Five different seed types (Paddy, maize, gram, onion and groundnut) were chosen for the experiment purpose. The selection of the seeds was based on the availability of seeds during the period of the field test. Properties of each seed sample are also given. Seeds stored using the traditional method of seed storage *i.e.*, earthen pots were kept as a control for reference. The seeds were kept in earthen pots and closed with mud as practised by farmers in the traditional method. The pots were opened after 18 months for evaluating the SSU performance towards the retention of seed quality.

Cost attributes

The seed storages for the field testing was manufactured by Godrej and Boyce Mfg. Pvt. Ltd. as per the design provided by the research team. A SSU costed fourteen thousand rupees (INR 14000/-). The higher cost incurred due to the SSU being a custom design and having non-standard dimensions, thus requiring a specially manufactured mould. However, according to the manufacturer, as the production goes for mass manufacturing scale, the cost of seed unit will come down between INR 5000 to 6000. This means, if a group of 10 farmers purchases a seed unit, a single farmer has to contribute a maximum amount of INR 600.

RESULTS AND DISCUSSION

Laboratory test

Performance of the SSU in terms of retaining germination was tested by storing paddy seeds (landrace name *Ananti*) inside the laboratory seed storage unit. Since the procured seed was one year old, the germination count of the seed at the beginning of the test was also recorded. As shown in Table 3, the germination count and moisture content of seed stored in SSU remained unchanged at end of 8 months whereas traditionally stored seeds lost germination capability completely.

Field test

Germination count (GC) and moisture content (MC) of the seeds kept in SSU at different locations have been measured every 3 months for a storage duration of 18 months. The initial germination count and moisture content of the seeds kept at different locations have a small variation (negligible). This is because of the losses in the quality of the seeds

Table 3: Comparison of seed storage in SSU and tradition seed storage system.

Parameter	0th day	6th months	8th months
A) Germination count (%)			
Inside SSU	54	54	53
Traditional storage	54	8	0
B) Moisture content (%)			
Inside SSU	12.3	12.2	12.3
Traditional storage	13	13.8	17

Fig 3: Field test locations of SSU units.

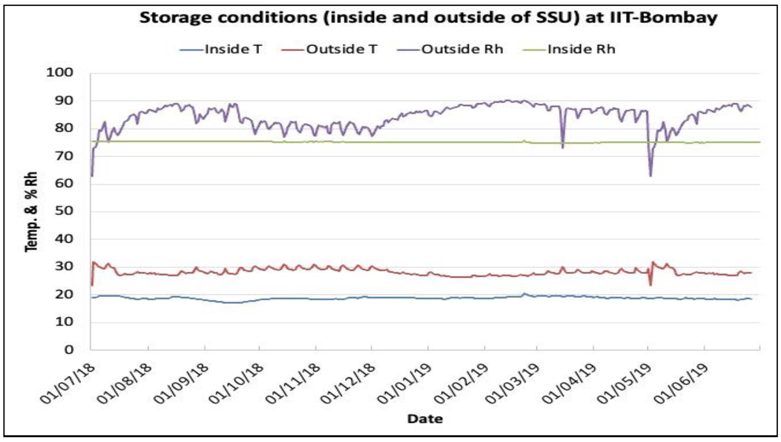


Fig 4: Typical storage conditions maintained in all SSUs (displayed here for one of the SSUs).

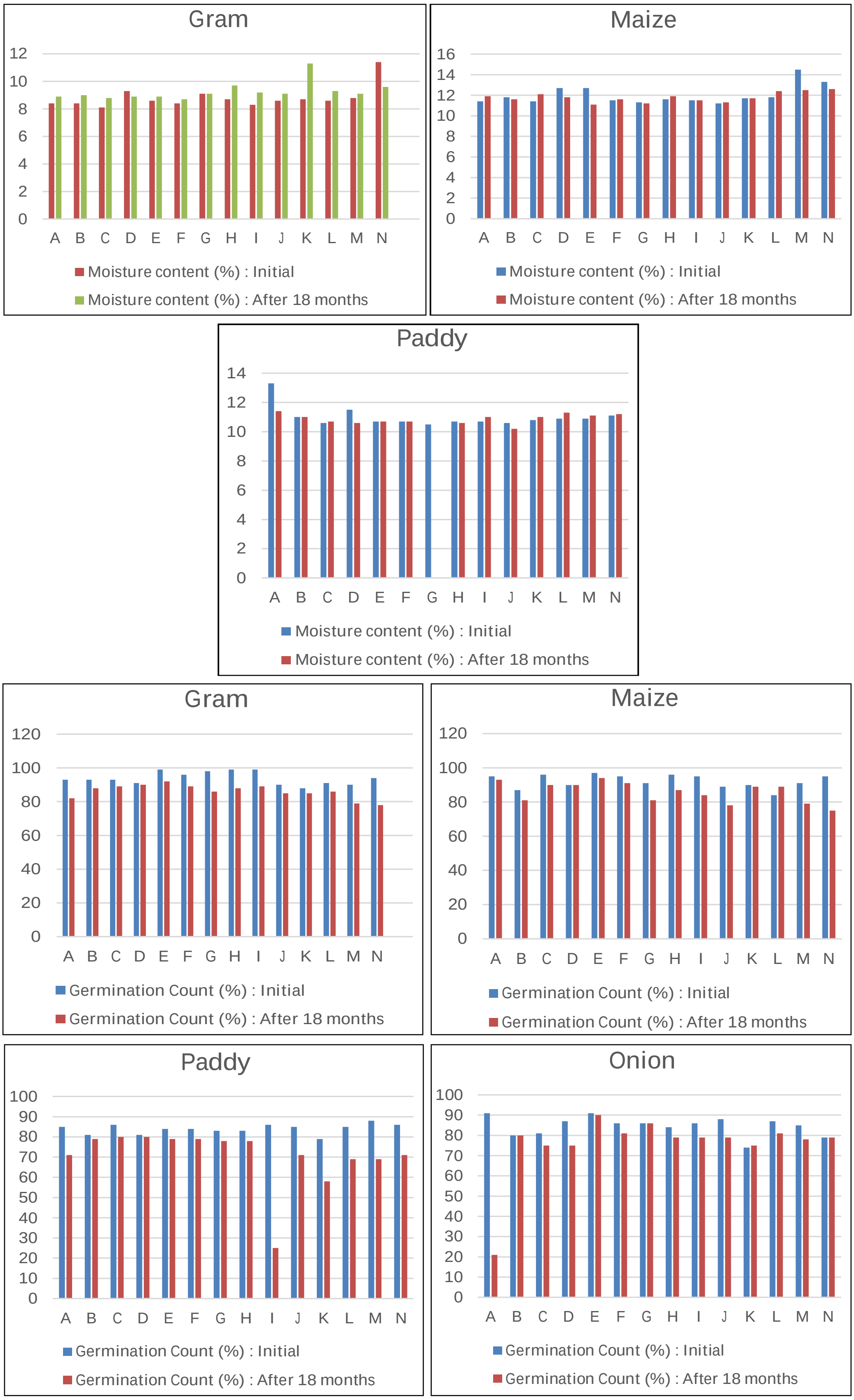


Fig 5: GC and MC for the seed tested at different locations in the SSUs.

Appendix -A Table A-1: Location details of SSU - Field testing.

Location code	Locations in Maharashtra
A	IIT Bombay, Powai, Mumbai
B	Sahyadri School, Krishnamurti Foundation India, Dist. Pune
C	BAIF Central Research Station, Urulikanchan, Pune
D	Shri Vithal Education and Research Institute (SVERI), P.B.No.54, Ranjani Road, Pandharpur
E	BAIF Office, Amarai Campus, At/PO/Tal-Jawhar, District Palghar
F	Vanavasi village, BAIF Amarai Campus, At/Po/Tal-Jawhar, District Palghar
G	BAIF Office, Ettapalli, Gadchiroli
H	Maharashtra Seed Corporation, Murtizapur Road, Shioni, Akola
I	Mahatma Phule Krishi Vidyapeeth (MPKV) Rahuri, District Ahmednagar
J	Uttan Krishi Sanshodhan Sanstha (UKSS), Keshav Srushti, Uttan Road, Bhayandar (West)
K	Harankhuri Village, BAIF Office, Tal-Dhadgaon, Dist. Nandurbar
L	Mahatma Phule Doodh Dairy, Dhole wadi, Rajapur Road Taluk Sangamner, Akole
M	Kukadeswar Village, BAIF office, Tal. Junner, Dist. Pune
N	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth,Dapoli, Dist. Ratnagiri

during the transportation to different locations. The germination count of the paddy seeds kept inside the earthen pots drastically dropped to 68 % after 18 months of storage. Since the germination counts of these seeds were less than the minimum acceptable limit, they cannot be used for further sowing. Fig 4 shows typical storage conditions maintained in one of the SSUs. As seen in Fig 4, while the outside temperature at location "A" was below 30°C, the inside temperature was maintained below 20°C. Similarly, whereas the Relative Humidity (RH) outside ranged between 70 to 90% the RH value inside was maintained constant at about 75%. Maintaining the storage conditions with constant relative humidity and temperatures below 20°C has enabled retaining the MC and GC within acceptable limits as prescribed by ISTA as seen in Fig 5, which shows the graphical representation of the germination count and the moisture content observed during the test results. Mbofung *et al.* (2013) reported that soybean seeds that were given storage treatment had higher viability and vigour than soybean seeds that were not treated with low temperature and air humidity. Seeds stored at 15°C and 20°C have higher germination rates than seeds stored at room temperature. As seen in the graphs, the average variation for MC (Final - Initial Moisture) after 18 months of field-storage were found to be: for maize 0.28% (range 0 to 2%), for gram 0.44% (0 to 2.6%) and for paddy 0.14% (range 0 to 1.9%). Similarly, the measurements on GC indicate average variation as follows: Gram 7.71% (range 1 to 16%), paddy 9.10% (range 1 to 19%), Onion 4.38% (range 0 to 12%) and maize 6.42% (range 0 to 20%). While conducting the data analysis for MC and GC at all locations we observed an outlier due to measurement error as follows - for paddy MC at location G and GC at location I and GC of onion at location A. In order to have meaningful statistical analysis, these outliers emerging due to measurement errors were removed for computing the average values. The SSU did not guarantee the storage of groundnuts. The oxidation of lipids and increase in the content of free fatty acids during the storage period are the main causes of the fast deterioration of these seeds (Rana and Biradarpatil, 2018), making them unsuitable for storing inside the SSU.

CONCLUSION

Climate change and agriculture are intensely interrelated global processes and therefore a change in climate affects agriculture production (Ahlawat, 2015). It is estimated that crop production loss in India by 2100 AD could be 10-40% despite the beneficial effects of higher CO_2 on crop growth (Agarwal, 2008). In this scenario, it is relevant to preserve the indigenous seed varieties which can withstand drastic climatic conditions such as drought and flood. The objective of the developed SSU is to preserve such indigenous seed varieties that are traditionally conserved by the small-scale, marginal farmers.

Laboratory test conducted has provided a clear indication that the traditional storage units are not appropriate to store seeds providing acceptable seed germination. A gradual reduction in germination count of the seeds from 54% to 0% in traditional storage (gunny bags) within 8 months brings forth their unsuitability for using them for sowing purposes. The moisture increase consequently provokes fungal growth on which insects thrive, in turn making the storage of seeds in traditional units ineffective beyond 3 months of storage. The SSU built to provide constant RH and temperature below 20°C could maintain the required germination count as prescribed by the seed standards. The SSU field test clearly indicated that except for groundnut the other seeds such as paddy, maize, gram and onion could be stored up to 18 months without losing seed viability. The design specification of the TEC device provides a temperature difference of 18°C, the SSU could maintain a temperature inside below 20°C. Therefore, we recommend the use of such a device - which is affordable at the same time - for farmers and farmer producer companies for a decentralised storage capacity of 100 to 200 kg.

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