# Effect of temperature, relative humidity and moisture content on germination percentage of wheat stored in different storage structures

**A. A. Sawant[1*], S. C. Patil [2], S. B. Kalse[2], N. J. Thakor[3]**

(1. *Assistant Professor, Department of Agricultural Process Engineering, CAET Dr. BSKKV Dapoli;*

2. *Senior Research Fellow, Department of Agricultural Process Engineering, CAET Dr. BSKKV Dapoli;*

3. *Head, Department of Agricultural Process Engineering, CAET Dr. BSKKV Dapoli*)

**Abstract:** The paper presents information regarding the pattern of changes in the environmental conditions (i.e. temperature, relative humidity and moisture content) on the stored wheat in Galvanized Iron Corrugated (GIC) silo, Godown storage and CAP storage. The grain moisture content in the silo increased from 11.20% to 17.08 % wet basis (w.b.), in bag storage increased from 11.20% to 17.25%, and in CAP storage increased from 11.20% to 17.19% wet basis (w.b.) during the storage period from April 06 to November 06. The moisture content of the wheat grain then slightly decreased during the storage period from November 06 to April 07. The temperature of the grain inside silo was 29.30˚C while at the end of the storage period, the temperature was 42.90˚C. The initial grain temperature inside Godown storage was 29.30˚C and at the end of the storage period, it was 32.31˚C. The initial grain temperature inside CAP storage was 29.10˚C and it increased to 39.94˚C at the end of the storage period. The relative humidity in the silo was 16.1% lower than the ambient relative humidity. The germination percentage of grain inside the silo was decreased from 86.70% to 78.60%, in Godown storage it decreased from 86.70% to 53.30%, and in CAP storage it decreased from 86.70% to 46.60% during the storage period from April to September.

**Keywords:** temperature, moisture content, relative humidity, germination percentage, wheat, GIC, silo, Godown, CAP

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## 1 Introduction

The storage of food grain is practiced from the era of the beginning of civilization. It is an important problem because the production of grain crops is seasonal and location

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[*] **Corresponding author: Er. A. A. Sawant,** Assistant Professor, Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli Dist: Ratnagiri-415 712. Email: abhimanavi@gmail.com, apedapoli@gmail.com

specific (Sawant, 1994); however, consumption of food grain is throughout the year and is not location specific. Storage of food grain is necessary in order to ensure constant supply for the year and also to provide to distant areas.

Wheat is the second most important food crop of India after paddy, which contributes nearly one-third of the total food grain production. India holds the second place among the wheat-growing countries of the world. The total world wheat production is estimated at 656.06 million tones in 2009-2010. The production of wheat in year 2009-2010 was 80.6 million tones. The wheat area has increased from 12.8 million ha in 1966-1967 to 26.8 million ha in 2009-2010. During the same period, the production has increased from 11.4 to 73.8 million tones and the productivity has gone up from 887 kg/ha to 2707 kg/ha. Also the production of wheat can be taken only once in a year and needs storage (Singh, 2010).

Storage of wheat is very important in Konkan (coastal) region of Maharashtra state as the climate of Konkan region has high average rainfall of 3525 mm, relative humidity in the range of 70% to 98%. The temperature of the Konkan region varies from 18 to 35˚C (Gattani, 2008). This high humid climatic condition is not suitable for cultivation of wheat in this region. Therefore the state government and people of this region have to import wheat from the neighboring wheat regions for regular consumption and to make buffer stock for the rainy season of four months and also for the season that its demand is at peak. They use this stored wheat when required. However, due to very high relative humidity in this region (70% to 98%), it is difficult to preserve the quality of the wheat for consumption throughout the year using traditional methods of storage.

Primary aim of storage is simply to prevent deterioration of the quality of grain. This is done indirectly through the control of moisture and air movements, and through preventing attack of microorganisms, insects and rodents. Farmers throughout the world, in every country at hot or cold climate store grain. They may store in traditional storages like earthen pots, in pits or in a granary, or modern storages either in bulk or in reasonably sophisticated storages. They store some large quantity of grain.

Galvanized Iron Corrugated (GIC) silos are self-roofed and well equipped modern silos. GIC silos are suitable for use throughout the year including hot summer, heavy rain fall and cold winter as well. No attempt has been made so far to study long term storage behavior of wheat in GIC silos on experimental basis in high humid climate of Konkan region.

Many times cover and plinth (CAP) storages are practiced to store the food grain in the country in addition to Godown storage when grain is in excess. Therefore, this is also one of the promising storage methods need to be investigated for its suitability for the storage of food grain in humid climate.

The most important physical factor in grain storage is moisture content because it affects the growth of mould, with which all stored grain is infected. It is generally accepted that climatic condition leads to physical changes in stored bulk grain through the movement of moisture which leads to deterioration.

This study was implemented to investigate the changes in the temperature, relative humidity (RH) and moisture content of freshly harvested bulk wheat during a storage period of twelve months in the humid climate of the Konkan region. The climate of this region is hot and humid (April 2006 to April 2007). This study was carried out at the Department of Agricultural Process Engineering, CAET, Dapoli, (M. S.) India.

## 2 Literature Review

Prabhakar and Mukherjee (1977) studied the extent storage of seeds at low temperature (10°C to 15°C) and also maintained seed moisture at a favorable level (10%) and there by germination potential at a high level for a considerable period (270 days). Room temperature (26°C) or high temperature (32°C or 35°C) resulted in the decline environment delayed the decline in germination potential of the storage.

Birewar (1981) highlighted the magnitude of storage losses in India and the importance of scientific storage for minimizing losses. It dealed with various improved storage structures at farm level. The role of IGSI, Hapur in design, construction and popularization of modern storage structures has been described. He also mentioned construction details of a number of structures.

Singh and Singh (1981) studied the effects of methods and duration of storage on seed germination and seedling vigor in papaya (Carica papaya L.). They found that cold stored papaya seeds maintained significantly higher germination and better seedling vigor than the room stored seeds. With the increase in the duration of storage, seed germination decreased after 20 months at room temperature whereas it declined marginally during the same period when kept in the cold storage. Irrespective of the storage conditions, seeds kept in sealed polythene bags or plastic bottles had better germination and seedling vigor than in paper and cloth bags.

Gough (1985) studied the physical changes in large-scale hermetic grain storage. Moisture content (m.c.) and temperatures were measured in two 1300 t semi-underground hermetic concrete silos filled with maize, which was stored for nearly three years in an upland equatorial climate. Gradual cooling of the maize took place in the first year of storage and the temperature remained constant thereafter.

Siebenmorgen et al. (1989) described a storage technique in which grain was piled on large, flat surfaces and covered with an airtight liner. A synopsis of the concept and the development of grain storage was given. Temperature and relative humidity data collected while monitoring a field scale unit equipped with an aeration system was presented. The results of the monitoring study indicated that the bunker storage system with aeration system used could effectively cool the grain mass to a typically safe storage temperature of 10°C.

Sawant (1994) described the modern grain storage methods such as Godown storage and silo systems for reducing storage losses. He compared Godown storage and silo storage with respect to functional, structural and financial aspects, which revealed the superiority of silo system. Comparison was also given between metal silos and RCC silos. He found GIC silos advantageous.

Rondon et al. (2001) studied the effects of moisture content and temperature during storage on germination of the achenes of Bidens garddneri baker. Bidens gardnery is a herbaceous species of the cerrados, whose seeds are light sensitive at 25°C, but they become indifferent to light when stored in soils. Achenes were stored in darkness or light, in closed bottles, at $4^{o}$C and $25^{o}$C. He found that the achenes that not previously imbibed showed sensitivity to light during germination.

Dejene, Jonathan and Sigvald (2004) studied the impact of grain storage methods on storage environment and sorghum grain quality. The experiment was conducted at Hararghe, Ethiopia. The farmers stored their sorghum grain in underground pits during a period of 24 months. Temperature and moisture content were higher in the soil pits than in the bins, cements and dung pits. The bins maintained the lowest temperature and grain moisture content. Bulk density of the samples from the soil pits decreased by 9%, while the changes in the other three storage methods were not significant. Regression analysis of percentage germination on grain storage period showed that germination of samples from soil pits decreased by 6% per storage month.

Holly (2006) determined germination quality of the wheat by the between paper method. Ten seeds from each sample with three replications were selected at random. These seeds were then placed at a suitable spacing on a moistened filter paper. This paper was then covered with another moistened paper. The sample was then left at room temperature for seven to eight days. The samples were first checked for the first count after four to five days. The samples were then removed after seven days for final count. The numbers of seeds sprouted were counted and germination percentage was calculated as:

$$\text{Germination} = \frac{\text{Number of seeds sprouted}}{\text{Total number of seeds taken}} \times 100 \tag{1}$$

Thilakarathna, Palipane and Muller (2006) studied quality change and mass loss of paddy during airtight storage in a Ferro-cement bin in Sri Lanka. An airtight storage system, based on a Ferro-cement bin, was developed. The objective of this study was to evaluate the storage system in terms of paddy quality and mass loss. Samples were drawn before and after storage from this bin and a control to analyze moisture content, thousand-grain mass, insect infestation, mould, germination rate and head rice yield. Germination rate, however, decreased from 85% to 0% in the airtight bin, whereas it was still 38% in the control. The study showed that airtight Ferro-cement bins provided a safe and convenient method for farmers in the tropics to preserve their harvest for later sale at a higher price. Further work is necessary to develop strategies for avoiding the decrease in germination capacity.

Alam, Islam and Hasanuzzaman (2009) studied the performance of alternate storage devices on seed quality of boro rice. Different storage devices used in this study were: $T_1$ = Organic Cocoon, $T_2$ = Rexin Cocoon, $T_3$ = Polythene bag, $T_4$ = Poly + Gunny bag, and $T_5$ = Gunny bag. He found that germination percentage of Boro seeds stored in organic cocoon was significantly the highest (91%) compared to that of rexin cocoon (87%), Polythene bag (80%), polythene in Gunny bag (79.667) and Gunny bag (68%). Seeds stored in an organic cocoon performed better in maintaining higher germination due to lower moisture content (12.10%) below the critical level (14%), reduced oxygen level (4.9%) and higher proportion of dead insects (97%) caused by reduced oxygen.

## 3 Materials and methods

The storage performance of wheat for long term storage was evaluated using GIC silos, CAP storage and Godown methods.

The silos were manufactured and installed by M/s Shirke Construction Equipment Pvt. Ltd, Pune (Figure 1). The Silo was installed on a Reinforced Concrete Platform 40 cm high from the ground level. In the CAP storage, RCC platform of size 9 x 8 m was used as plinth and a polythene sheet was used for covering the gunny bags. The capacity of CAP storage was 750 kg. The wheat was also stored in the Godown of Department of Agricultural Process Engineering, CAET Dapoli. The capacity of the Godown storage was also 750 kg. Fifteen similar bags were laid in five layers with three bags in each layer.

Figure 1  Galvanized iron corrugated structure for storage of wheat

The study was performed to evaluate the storage performance of wheat (Triticum aestivum).  Lok1 variety of wheat was used for the study.  The 50 kg capacity of gunny bag was used in CAP storage and Godown storage.  Total number of bags used in this study was thirty.  The size of the bag was 75 × 30 × 25 cm.

Different types of instruments were also used for the measurement of environmental parameters (temperature and relative humidity) inside the storage structure.  The temperature and relative humidity sensors' positions in silo are shown in Figure 2 (they are located in the top, middle and centre position of the silo).

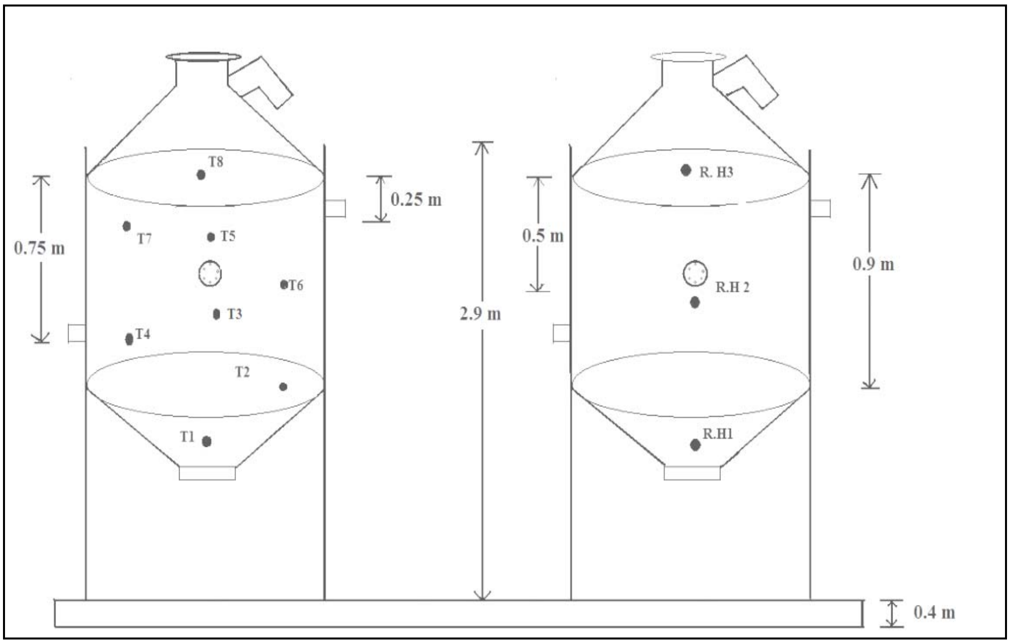


Figure 2 Temperature and relative humidity sensors' positions in the silo

A data logger model TC-800D (Make: Ambetronics, Mumbai) was used to record the temperature in the silo. The instrument had eight thermocouple sensors K of a length of 15 cm and a wire of length 3 m. The data store capacity of the instrument was 5000 readings of all eight channels. The supply needed for the instrument was a 230 V AC supply. It had a high accuracy of ±0.25 % and a temperature range for measurement of –200 to 400°C. A temperature and relative humidity controller model TRH-401 (Make: Ambetronics) was used to record the relative humidity in the silo. This instrument measured RH between 0 – 100% with an accuracy of ± 2% and the temperature between –40°C to 120°C with an accuracy of ± 0.5°C. The supply voltage was 230 V AC. The sensor type for RH was a capacitive polymer sensor and for temperature it was a band gap temperature sensor. Thermocouples were used in measuring the temperature inside the bags of CAP storage and Godown. The temperature range was –50°C to 150°C. The length of the sensor was 15 cm with a wire of 1m length. The temperature was measured using thermocouples in each bag of CAP storage and Godown. Ambient temperature was recorded with glass thermometer (Make: Paico Deluxe). The thermometer had temperature range of 0 to 100°C.

Moisture Content: A hot air oven (Make: Quality Instruments, Kudal) was used in the moisture content determination. The temperature for moisture measurement was maintained at 130°C ±1°C and the sample was kept for two hours (AOAC Method). The moisture content was determined by AOAC. Moisture content was determined by drawing samples from the top, center and bottom of the silo. The moisture content was calculated by the oven dry method. The moisture content was determined at weekly intervals.

The moisture content, percentage on wet basis (w.b.) is expressed as follow:

$$\text{Moisture Content (w.b.)} = \frac{(W1 - W4)}{W1} * 100 \tag{2}$$

where,

$W_1$ = weight of sample taken, g
$W_2$ = weight of empty moisture dish, g
$W_3$ = weight of moisture dish along with the sample after drying, g
$W_4$ = weight of the sample after drying, g

The germination quality of the wheat was determined by the between paper method (Holly, 2006). Ten seeds from each sample with three replications were selected at random. These seeds were then placed at a suitable spacing on a moistened filter paper. This paper was then covered with another moistened paper. The sample was then left at room temperature for seven days. The samples were first checked for the first count after four days. The samples were then removed after seven days for the final count. The number of the seeds sprouted was counted and germination percentage was calculated as:

$$\text{Germination (\%)} = \frac{\text{Number of seeds sprouted}}{\text{Total number of seeds taken}} * 100 \tag{3}$$

## 4 Results and discussion

### 4.1 Grain moisture

The relationship between grain moisture content in GIC silos, Godown and CAP storage with storage period is shown in Figure 3. The initial moisture content of wheat when procured was 11.20% (w.b.). The moisture content of wheat showed increasing trend with respect to the storage period. This may be due to the increase in the growth of insects which resulted in the increase in moisture as during the respiration of insects and wheat, both of them released water.

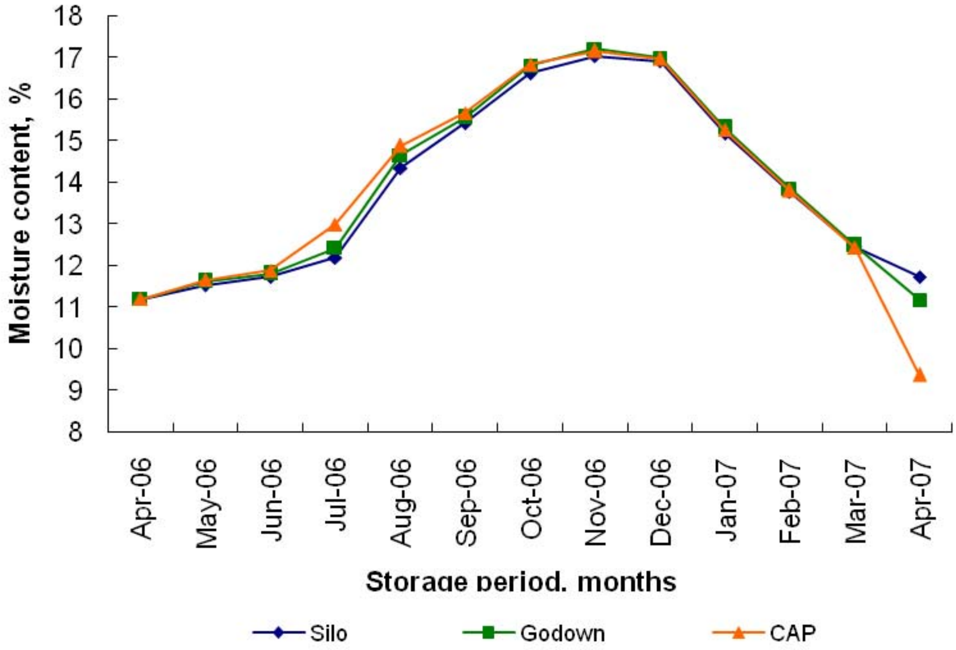


Figure 3 Variation of moisture content in GIC silo, Godown and CAP storage with storage period

In case of CAP storage, the wooden dunnage provided at the bottom of bags soaked water during the rainy season. It resulted in the increase in the moisture content at the bottom layer of CAP storage. Similarly it may also due to frequent removal of the cover that kept over the stack for recording the daily observations of study. All these reasons cumulatively increased the moisture content of wheat in the storage. The grain moisture content in the silo increased from 11.20% to 17.08%, moisture in bag storage increased from 11.20% to 17.25%, and moisture in CAP storage increased from 11.20% to 17.19% (w.b.) during the storage period from April 06 to November 06. The moisture content of the wheat grain then slightly decreased to 2% - 3% because of the summer season of the storage period from November 06 to April 07.

## 4.2 Grain temperature

Initially the temperature of the grain inside the silo was 29.30˚C, while at the end of the storage period, the temperature was 42.90˚C. The relationship between the ambient temperature and temperature inside the silo was given in Figure 4. It shows that during the first four months the inside temperature was nearly the same (29.30˚C) and lower than the ambient temperature (31˚C). At the same time, it was also observed that the condition of the grain during this period was good as there was very less insect infestation occurred during the first four months. However, after the fifth month onwards up to the twelfth month, the inside temperature showed increasing trend and was higher than the ambient temperature. The major reason for the increase in temperature inside the silo was higher insect infestation.

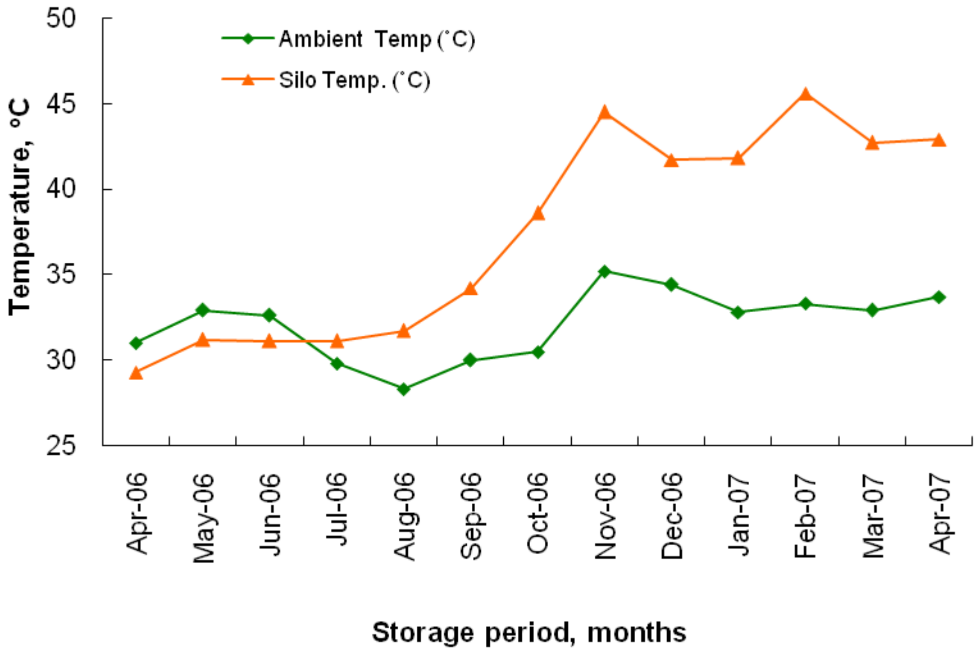


Figure 4 Relationship between the ambient temperature and the temperature inside the silo

The initial grain temperature inside Godown storage was 29.30˚C and at the end of the storage period, it was 32.31˚C. The relationship between the ambient temperature and the temperature inside the Godown was given in Figure 5. The trend shows that the change in the grain temperature inside the Godown storage was irregular for the first two months (April and May). The grain temperature was lower than the ambient temperature for these two months. The reason for this change during these months is that the insect infestation was low. For the next four months, the grain temperature was slightly higher than the ambient temperature. During this phase, rainy season started which might result in higher insect infestation.

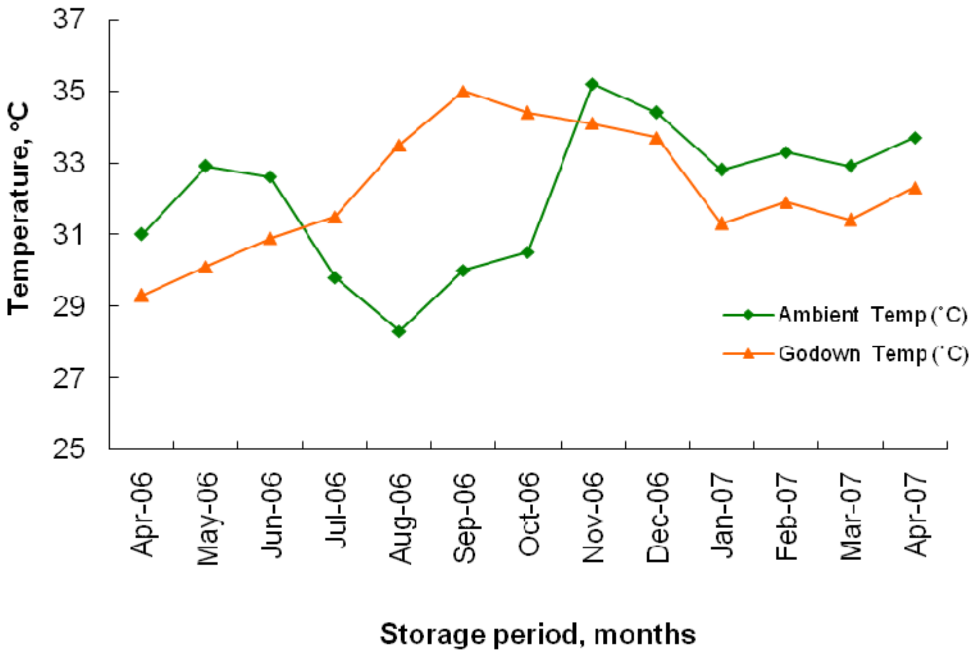


Figure 5  Relationship between the ambient temperature and the temperature inside the Godown

The change in overall monthly grain temperature inside the CAP storage is shown in Figure 6. The initial grain temperature inside CAP storage was 29.10˚C and it increased to 39.94˚C at the end of the storage period. The inside temperature was lower than the ambient temperature for the first two months (April and May, i.e. at the beginning of the experiment). But after two months of the storage period, the insect infestation of the grain increased with inside temperature started increasing. This might be due to the insects released heat during respiration.

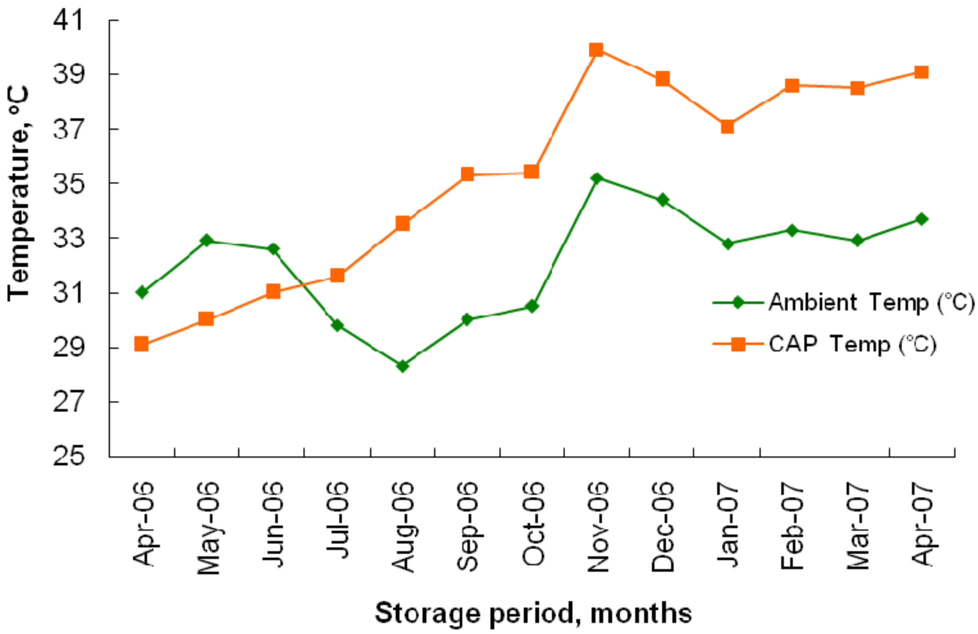


Figure 6  Relationship between the ambient temperature and the temperature inside the CAP

The temperature in all the three storages showed an increasing trend with time. In silo, the increase in the temperature was from the fifth month. Increase in temperature up to 28.42˚C caused growth of insects. The attack of insects in CAP storage and Godown storage was much earlier than in silo. Hence the condition of the wheat in silo was good for longer period of time as compared to CAP storage and Godown storage. A common phenomenon occurred in all the storages was that the temperature of the grain in all the storages increased after a certain period of time. It might be due to the infestation of insects. The increase in temperature was due to the heat released during the respiration of wheat grain and increase in the count of insects during storage. As the grain being a living entity, it also respired and released heat. This heat was also responsible for the increase in the temperature of the grain inside all three storage methods.

### 4.3 Grain relative humidity (RH)

The relationship between the ambient relative humidity and the relative humidity inside the silo in the storage period was shown in Figure 7. The relative humidity in the silo was lower than ambient relative humidity. The reason is that the storage structure was airtight. However, the relative humidity in silo showed increasing trend with respect to ambient RH at the end of storage period. The reason may be due to the entry of prevailing moist air in the silo from outlet provided for feeding, discharge as well as outlet kept for temperature and RH measurement sensors.

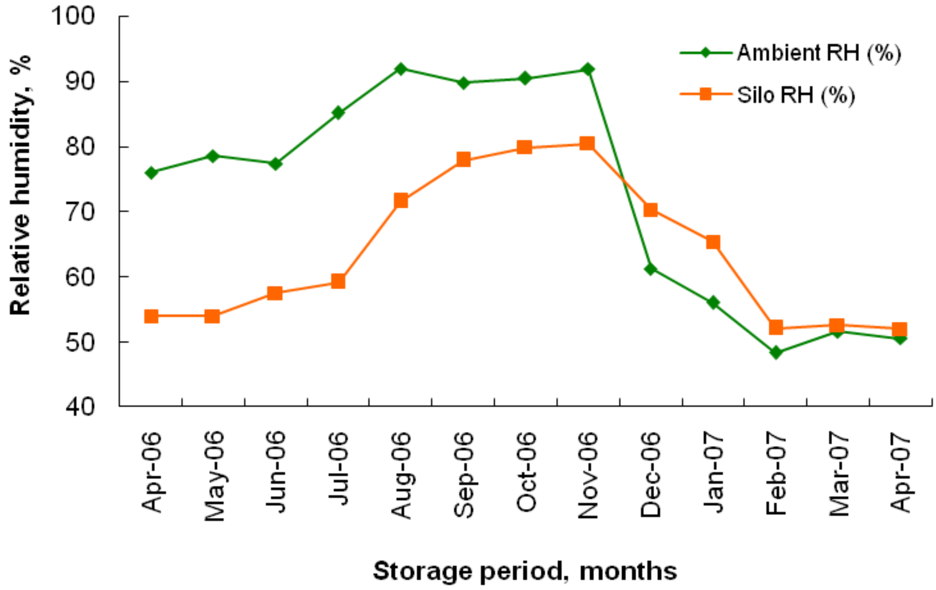


Figure 7 Relationship between the ambient relative humidity and relative humidity inside the silo with storage period

The change of ambient RH and RH of wheat inside Godown storage as storage period advanced is shown in Figure 8. Initially the relative humidity in the Godown storage was 55.60%. After the first six months (April 06 to October 06) the relative humidity increased. This may be due to as Godown was not airtight and the ambient relative humidity was high due to the rainy season. After rainy season (October 06 to April 06), the ambient relative humidity was lower as compared to monsoon. Therefore RH during the last six months (i.e. during winter and part of summer season) showed the declined trend.

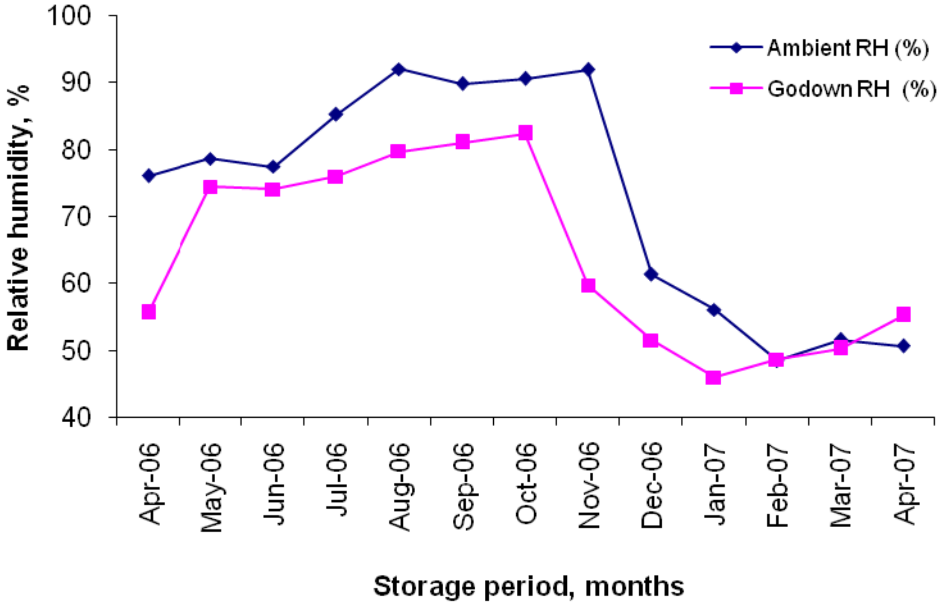


Figure 8 Relationship between the ambient relative humidity and relative humidity inside the Godown with storage period

The change of ambient RH and RH of wheat inside CAP storage as storage period advanced is shown in Figure 9. Initially the relative humidity in the CAP storage was 54.20%. For the first six months the relative humidity increased. This may be due to as CAP storage was also not airtight and the ambient relative humidity was high due to rainy season. After rainy season the ambient relative humidity was lower as compared to monsoon. This has affected the relative humidity of the grain inside the CAP storage. Therefore the relative humidity during the last six months (i.e. during winter and part of summer season) showed the declined trend.

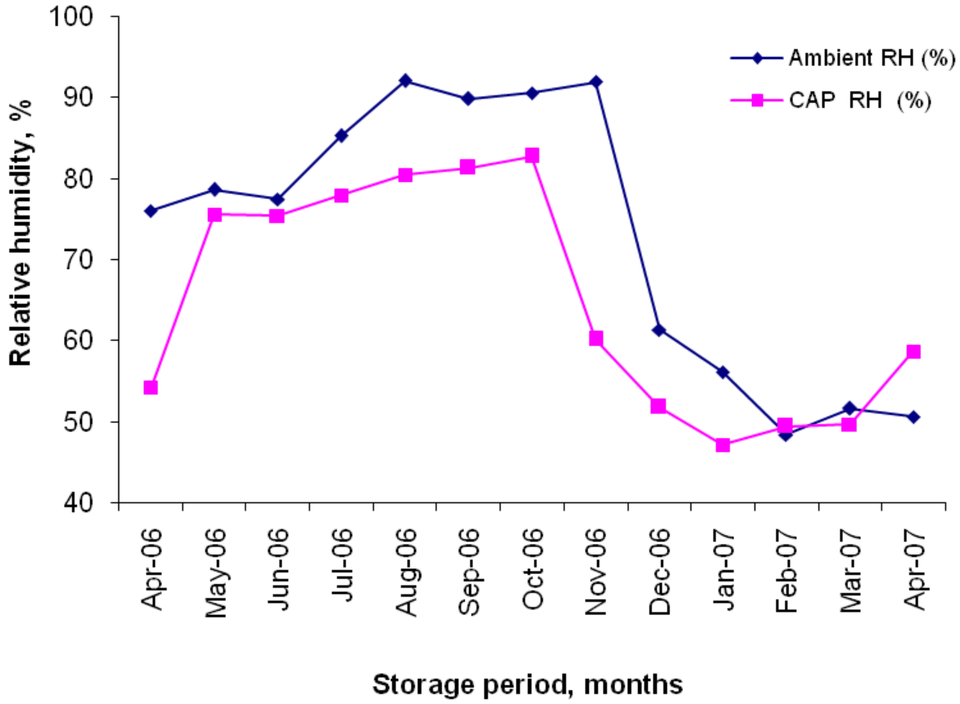


Figure 9 Relationship between the ambient relative humidity and relative humidity inside the CAP storage with storage period

**4.4 Germination percentage**

The variation in germination percentage during the storage of wheat in silo, CAP storage and Godown storage is shown in Figure 10. In the beginning, the germination of wheat was 86.70%. The germination percentage was good during the initial months. It decreased to 92.3% at the end of storage period. In the end, the germination was very low in all the three storages. The germination of silo was good (about 80%) for five months. In case of Godown storage, it was good for the first month only, while in CAP storage it was 76.70% after the first month. The insect infestation was the most important factor that affected the germination. In silo, the germination percentage was higher as compared to that in CAP storage and Godown storage. This is the reason for the difference in germination percentage of the three structures.

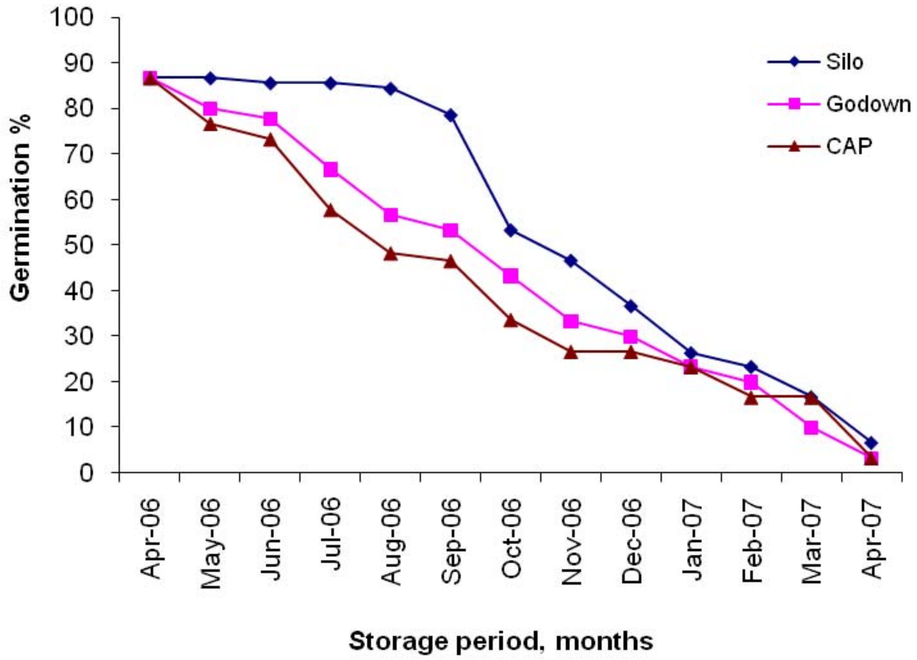


Figure 10 Variation in germination percentage during the storage of wheat in silo, CAP storage, and Godown storage

## 5 Conclusions

The following conclusions may be drawn from this study:

1) The effect of outside (ambient) temperature was 14.3% less than silo temperature, lower temperature of wheat stored in silo when compared with Godown and CAP storage.
2) The grain moisture in the silo increased from 11.20% to 17.08% (w.b.), in bag storage the moisture increased from 11.20% to 17.25%, and in CAP storage, the moisture increased from 11.20% to 17.19% during the storage period April 06 to November 06.
3) The temperature in all the three storages showed an increasing trend with time.
4) Initially the temperature of the grain inside the silo was 29.30˚C while at the end of the storage period, the temperature was 42.90˚C.
5) The initial grain temperature inside Godown storage was 29.30˚C and at the end of the storage period, it was 32.31˚C.
6) The initial grain temperature inside CAP storage was 29.10˚C and it increased to 39.94 ˚C at the end of the storage period.
7) The relative humidity in the silo was 16.1% lower than the ambient relative humidity. The reason is that the storage structure was airtight.
8) Initially the relative humidity in the Godown storage was 55.60%. After the first six months (April 06 to October 06) the relative humidity increased. This may be due to Godown was not airtight and the ambient relative humidity was high due to rainy season.
9) Initially the relative humidity in the CAP storage was 54.20%. For the first six months the relative humidity increased.
10) Germination of wheat stored was better maintained in silo throughout the storage period when compared with that of Godown and CAP storage method.
11) The attack of insects in CAP storage and Godown storage was much earlier than in silo. Hence the condition of the wheat in silo was good for longer period of time as compared with CAP storage and Godown storage.

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