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Hermetic storage of pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*)

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ABSTRACT

A laboratory scale study was done to store pearl millet [*Pennisetum glaucum* (L.) R.Br.] and sorghum [*Sorghum bicolor* (L.) Moench] in hermetic conditions. The effectiveness of hermetic storage of millets was assessed for control of rice weevils [*Sitophilus oryzae* (L.)] at three levels of grain m.c. (10, 12, and 14% w.b.) and two types of storage containers, PVC bin and grain bag. Storage trials were conducted for a period of 3 months on grain bulks of size 15 kg. The insects were introduced within the bulk and mortality of insect samples was monitored by means of insect cages at 30, 60 and 90 d. For both pearl millet and sorghum, oxygen depletion and carbon dioxide elevation were maximum at 1.7% and 19.4%, respectively, on the 90th day for grain at 14% m.c. The creation of hermetic conditions was found to be not as strong in grain bags in the same period (11.4% O_2 and 12.7% CO_2). Increasing the m.c. from 10 to 14% resulted in a higher rate of gas exchange. In both types of containers, complete mortality of insects were reported at 90 d, though the mortality was faster in PVC containers at 30 and 60 d at all moisture contents when compared to grain bags. No significant change in grain quality was observed in the grain bulks stored under hermetic conditions.

Key words: Hermetic, Pearl millet, Rice weevils, Storage, Sorghum

In recent years, the production and consumption of millets have increased globally as they are regarded as a health enhancing cereal. About 11 million tonnes of millets were produced in India in 2015, with sorghum [*Sorghum bicolor* (L.) Moench] and pearl millet [*Pennisetum glaucum* (L.) R. Br.] among the most important millet crops economically. Storage of raw un-dehusked millet grain for about a year is generally problem free if kept cool and dry. However, it is important to gather information on the mechanics of hermetic storage system, as some of the traditional methods of storing millets in steel drums are essentially airtight and hermetic in nature. Multilayered polythene hermetic bags are available commercially for storing grain on a small scale. An investigation is needed to determine if polythene bags and traditional airtight systems are effective in creating hermetic conditions and killing target organisms. Millet growers recently have organized themselves into larger entities such as producer companies to achieve the benefits of scale and look for adoption of new technologies for bulk handling and storage of grain. The potential of airtight storage for commercial adoption on a large scale requires investigation.

A laboratory study of hermetic storage of pearl millet and sorghum was undertaken for a period of 90 days using rice weevils [*Sitophilus oryzae* (L.)] as target pests. Specifically the study aimed at verifying the development of modified atmospheric conditions for the selected millet grains in two types of storage structures and at 3 moisture levels (10,12 and 14% mc).

MATERIALS AND METHODS

The sorghum and pearl millet, were drawn from the grain harvested in November 2014 and were supplied by a local trader in Coimbatore of southern India. The grains were cleaned free from dust and foreign matter using a specific gravity separator. The initial moisture content (m.c.) of pearl millet and sorghum when procured was 11.5% (w.b.). The m.c. of these

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grains was stabilized to 10, 12 and 14% (w.b.) for experimentation.

Two types of storage structures, rigid PVC bin and grain bag, were used in the study. The grain bags are referred as International Rice Research Institute (IRRI) Super bag commercially and are supplied by Grain Pro in Mumbai. The PVC bin was fabricated using a hollow PVC pipe and covered at both ends with caps (Fig. 1a). The bin was 0.16 m in diameter and 0.80 m high. Provisions were made at three levels for monitoring the gas concentrations and mortality of insects. The sampling locations were marked as C1, C2 and C3, respectively, and were located at 0.20 m, 0.40 m and 0.60 m from the top of the bin. At each location, Teflon coated silicon septum or septa were positioned and supported by a brass nut. At 90° to the gas septum, sampling holes were drilled in the bin wall for insertion of insect cages (Fig. 1b). The insect cage was made of PVC pipe of 0.019 m diameter and 0.2 m long with wire-mesh windows and the ends were sealed with cork. The sampling holes at three locations were closed with end caps.

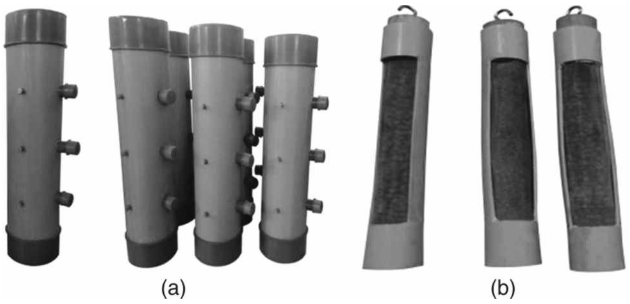

Fig. 1. (*a*) PVC bins with ports for gas sampling; (*a*) and (*b*) Insect cages

Fig. 2. Hermetic grain bags containing pearl millet (*a*); wovenpolythene bags with grain bags inside (*b*).

The hermetic grain bag fits as a liner inside existing storage bags (e.g. woven polypropylene or jute bags) as shown in Fig. 2a.The bags act as a gas and moisture-proof barrier, which guards against the ingress of water vapour while retaining low oxygen and carbon dioxide levels created by the respiration of the commodity and insects. The grain bag is a 3-layer co-extruded plastic with thickness of 0.078 mm, and a permeability of 3×10^{-6} m^3 m^{-2}d of oxygen and 8 $\times$ 10^{-3} kgm^{-2}d of water vapour. They are sealed using nylon ropes and placed inside the woven bags as shown in Fig. 2b.

About 100 adult insects of *S. oryzae* per kg of grain were introduced into the grain samples used in the experiments. Cleaned grain was conditioned to have three levels of moisture 10,12 and 14%. The insect cages with 20 adult rice weevils and 25 g of grain were pushed into the grain bag. Using these cages the mortality of insects was monitored in the storage period at 30 d intervals up to 90 d. The gas concentrations within the bin and bag were tested at an interval of 3 days using MAP analyser (Make: PBI Dansensor Model: checkmate). The temperature and humidity inside the grain were monitored using electronic meters (OM-43 internal sensors).

The grain quality change was estimated in terms of protein content and the viability of grain was tested at the end of the storage trials.

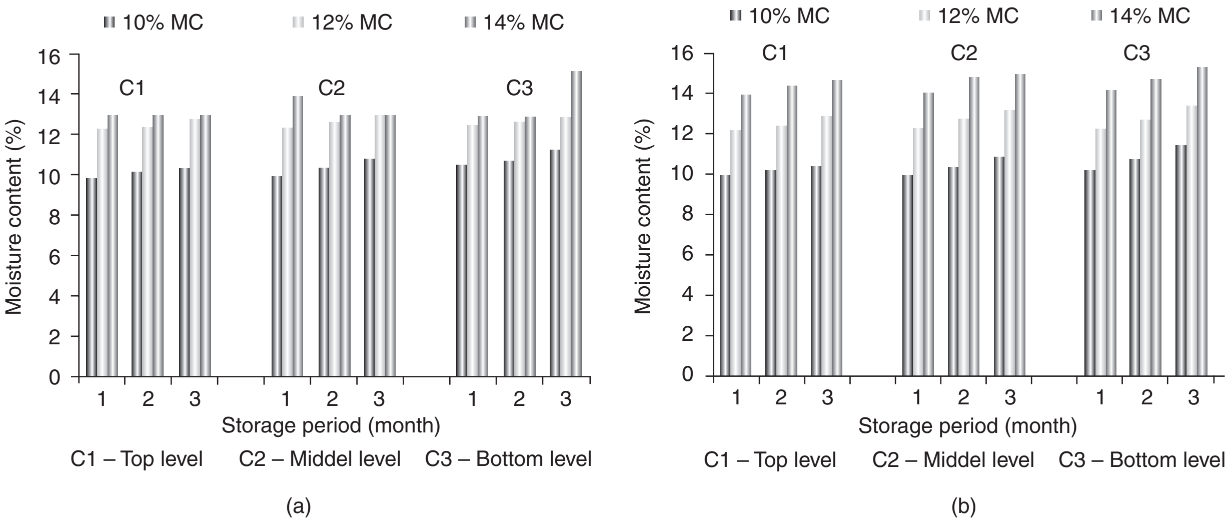

Fig. 3. Changes in grain moisture during storage at the top, middle and bottom of PVC

RESULTS AND DISCUSSION

Establishment of hermetic conditions

Overall there was an increase of 1.5% moisture in all the grain samples tested (Fig. 3a, b). There was also an incremental change in temperature above the ambient level; however, the relative humidity of the storage space was found to be lower by about 10% during the entire period of storage. The temperature of grain in the grain bag was lower than that of PVC bins. The temperature and humidity recorded inside the grain bin and bag are shown in Fig. 4a, respectively, against the ambient temperature and humidity.

Airtight storage resulted in rapid depletion of O_2 and accumulation of CO_2 in the inter-granular space (Figs. 5, 6). The CO_2 accumulation followed similar trends in both pearl millet and sorghum in PVC bins. In grain bags, the hermetic conditions (O_2 depletion and CO_2 accumulation) achieved were less severe. Moisture content played a significant role on the level of CO_2 accumulation in both pearl and sorghum grains in PVC bins and the trend was similar in grain bags. Our results are similar to the results reported by Hyde and Oxley (1960) and Asanga and Mills (1986), who had stated that grain m.c. influenced significantly the CO_2 concentration in the stored grain bulk. This result indicates that microorganisms play a significant role at high moisture content, though in this study no visible moulds were observed during the storage period of 90 days. The CO_2 generation in the stored grain bulk is mainly from the respiration of insects and other microorganisms and the contribution of grain respiration is insignificant.

Mortality of insects

At the end of the storage trial at day 90, insect mortality was 100% in all the grain samples tested both in bins and bags, though 90% mortality was detected at

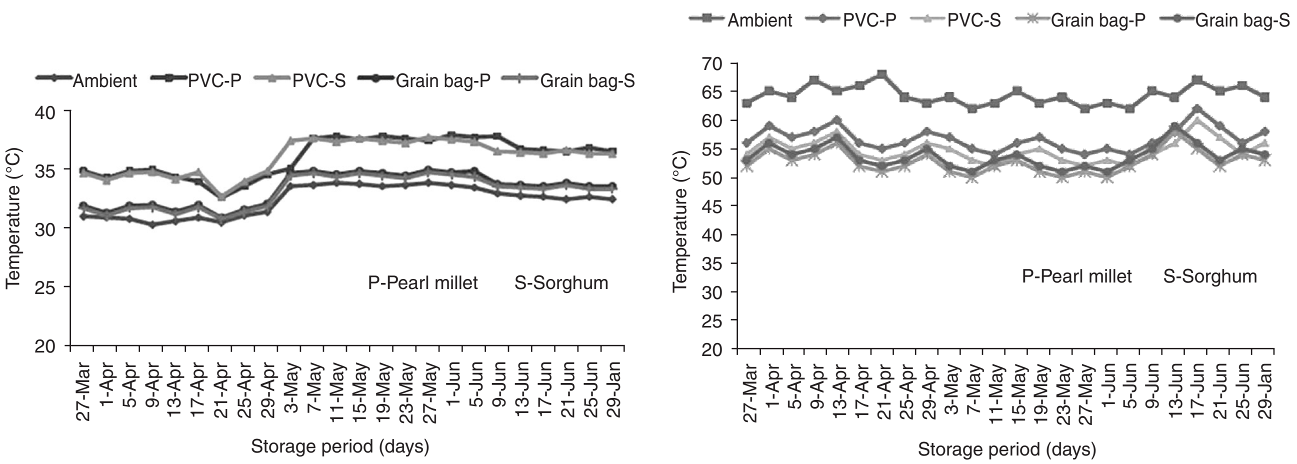

Fig. 4. Grain and ambient temperatures during storage (*a*); and relative humiditiy of grain and atmospheric air during storage (*b*)

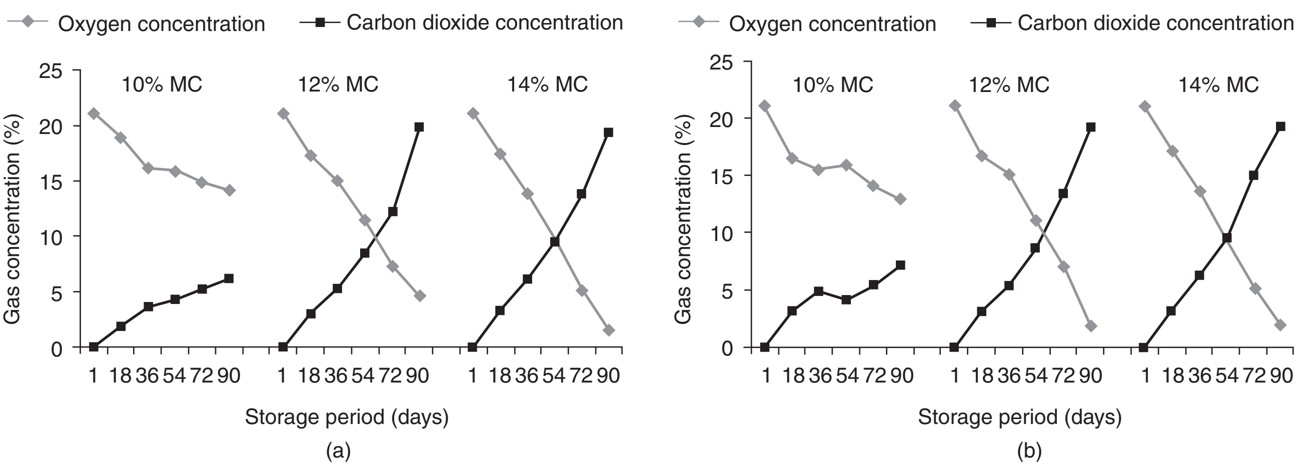

Fig. 5. Oxygen depletion and CO_2 generation in millets stored in PVC bins (*a*) pearl millet; (*b*) sorghum

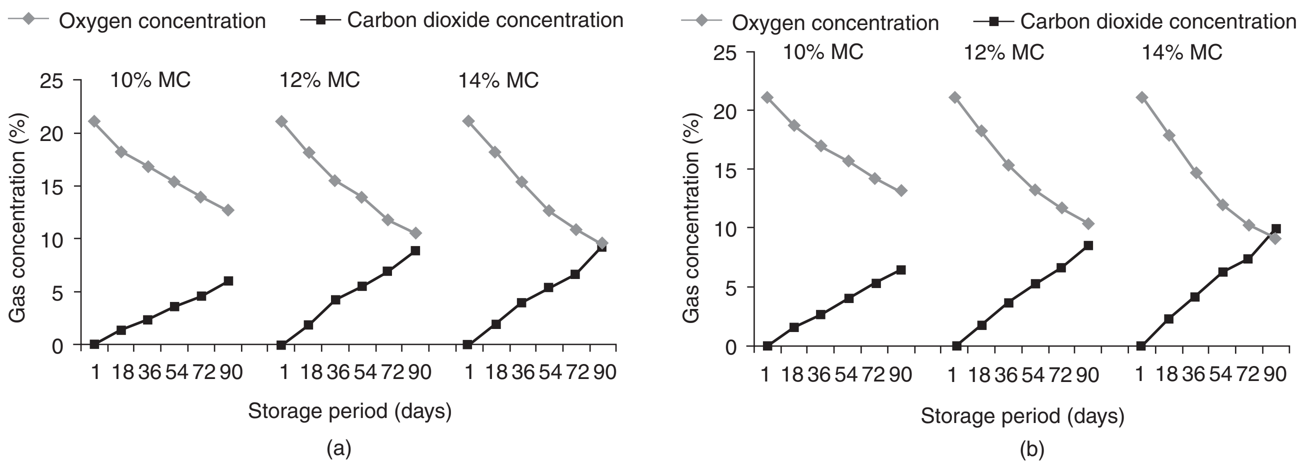

Fig. 6. Oxygen depletion and CO_2 generation in millets stored in grain bags (*a*) pearl millet; (*b*) sorghum

the 60th day in most of the samples (Figs. 7 and 8). At the 30th day about one-third of the insects were killed in pearl millets for both the types of storage whereas, 45–50% of the insects were killed in sorghum. Oxygen depletion to 7% from the initial value appears to be an important factor in causing insect mortality though the atmosphere detected at the end of 60 days of storage were generally lethal to the rice weevils. This is in accordance with the results reported by Hyde (1962). The mortality pattern is not significantly different from each other in case of PVC bins and grain bags. The new adult emergence was found to be 150–170% in the first 30 days and about 40% at the end of 60 days as revealed by the cage samples.

Grain quality

The grain quality was assessed in terms of weight loss, change in protein content and germination potential. At the end of 3 months of storage, significant weight loss was recorded for both the grains at 14% m.c. (w.b.) in PVC bins as well as grain bags. The weight loss was about 27% maximum for pearl millets and sorghum stored in grain bags whereas the maximum loss was about 20% for both the grains at the end of 90 days of storage in PVC bins. There was no significant difference in weight losses among the treatments at 30 and 60 days of storage (Fig. 9)

There was no significant difference in the protein content of pearl millet and sorghum when stored up to 60 d in PVC bins or grain bags at all levels of moisture content tested. However, there was a reduction in protein content of about 0.5% in pearl millet stored up to 90 d in both the types of storages. In sorghum stored for 90 days, the protein content was slightly reduced by about 0.15%. The seed germination tests done by standardized procedure using wet paper towel method

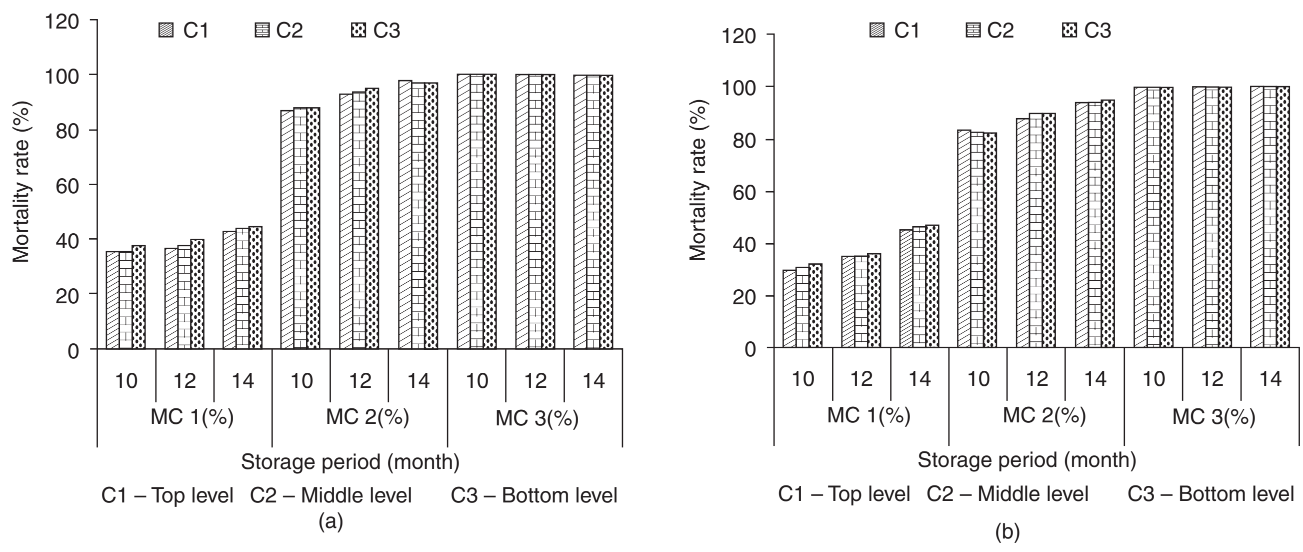

Fig. 7. Mortality of rice weevil (*S. oryzae*) adults stored in PVC bins (*a*) pearl millet; (*b*) sorghum

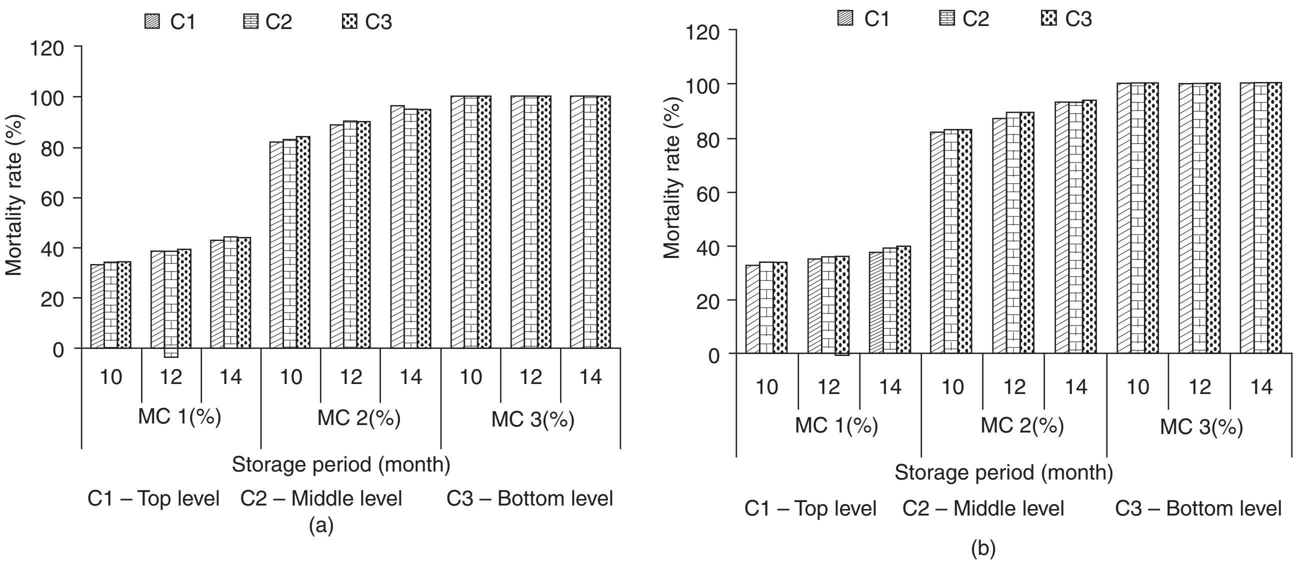

Fig. 8. Mortality of rice weevils (*S. oryzae*) adults stored in grain bags (*a*) pearl millet; (*b*) sorghum

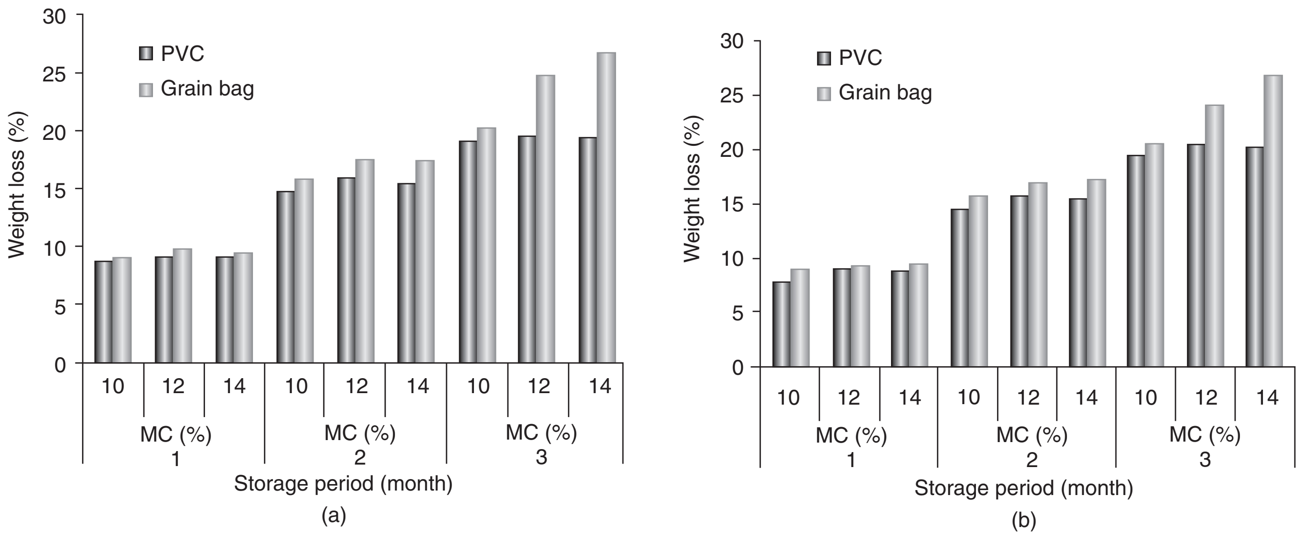

Fig. 9. Weight loss of hermetically stored pearl millet (*a*) and (*b*) sorghum

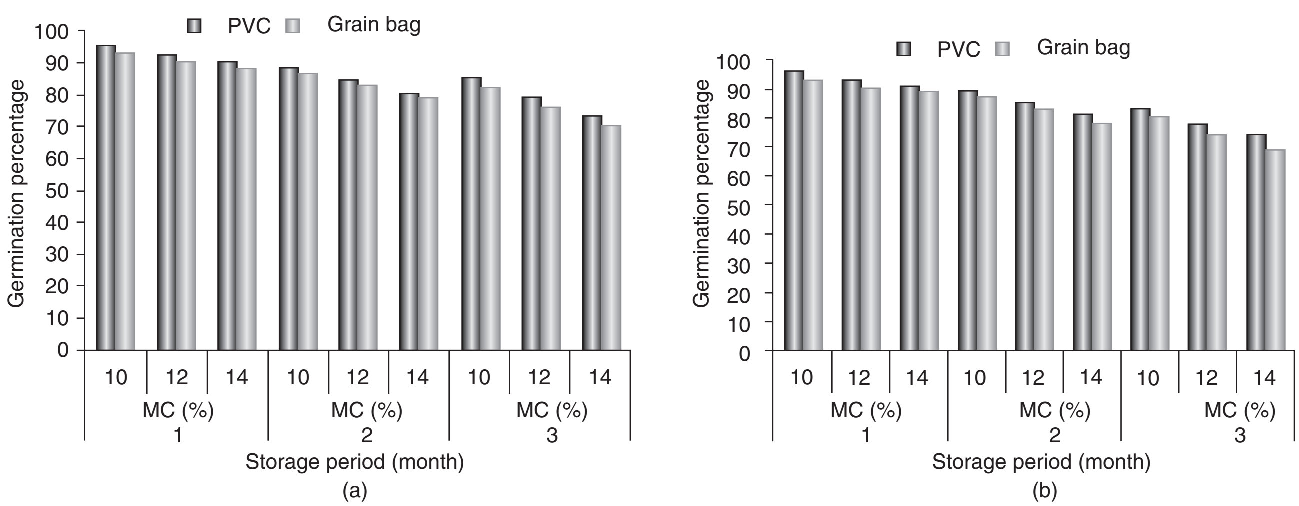

Fig. 10. Loss of viability of hermetically stored millets (*a*) pearl millets; (*b*) sorghum

indicated that there was a significant interaction between grain moisture and storage period on the viability of seeds. Overall a fall in viability of 20% was observed with sorghum stored at 14% m.c. in a grain bag for 90 d. The reduction in viability of seeds was about 17% in pearl millets stored for 90 d (Fig. 10).

CONCLUSION

Pearl millet and sorghum grains were stored hermetically in PVC bins and grain bags for a period of 90 days. For a moisture range of 10–14% (w.b.), storage of both the grains with a known number of insects had modified the inter-granular atmosphere to lethal levels in about 20 days. Near complete mortality of the adult rice weevils (*Sitophilus oryzae*) in bioassay cages was obtained in about 2 months. At the end of 3 months of storage, complete mortality of the *S. oryzae* adults were observed with no significant changes in grain quality aspects such as protein content and viability. However, there was a significant weight loss in the grains stored under hermetic conditions. The grain bag was successful in controlling the infestation though the atmosphere generated was less lethal when compared to PVC bins.

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