INTRODUCTION

Cereals, that are grown throughout the world belong to a great grass family, known as Poaceae. Paddy (Oryza sativa L) belongs to the family Poaceae. The paddy has a wide range of cultivation. It is grown in the tropics as well as in temperate zone. In some parts of the world, rice is grown from sea level upto an altitude of about $1.5 \times 10^5$ cms. For example, on Mysore plateaus, which have an elevation of about $9 \times 10$ cms, rice is an important crop and grown in all seasons of the year giving heavy yield (Grist, 1965; Rao 1987). Rice can also be grown at a wide range of rainfall. In some of the districts of Western Ghat, where the rainfall exceeds 500 cms in the year, rice is grown as an important crop. Even where the rainfall is about 62.5 cms in the growing season, rice can be grown successfully as a rainfed crop. So rice is an excellent cereal crop that can be cultivated at a wide range of conditions, i.e. latitude, altitude, rainfall, temperature and distance from the coast. In tropical country, rice is the most important cereal crop which replaces all other cereals as the basic and indispensable food. It provides the major food for over half the population of the world. In Assam, one of the most popular improved varieties of rice among the farmers is Aijong. Various names representing Aijong are Ponni in Tamilnadu, Joy Bangla in some parts of Assam, Aijoni in parts of Assam, (Nagaon, Jorhat and adjoining areas). The standard and scientific name is Mahsuri, which is accepted internationally.

Mahsuri is derivative line resulting from an Indica-Japonica hybridization programme in Malaysia. It is known that
the variety owes its genetic origin to the cross:

(Maying Ebos 80/2 x Taichung - 65) x Maying Ebos 80/2

The variety was tested and released in Tamilnadu State in 1971 and subsequently introduced in Assam a decade back. Mahsuri is gaining rapid popularity in Assam covering a substantial area throughout the entire state in Sali season. The primary reasons for its popularity in Assam are wide adaptability, relatively higher genetic production potential, fine and highly acceptable grain type-medium slender, high market price, and it can withstand occasional flashes of floods causing submergence. The variety being weakly sensitive to photoperiod, it can more or less be grown in three well-defined seasons of Assam, i.e. Sali, Ahu and Boro seasons. Above all, it is best suited in Sali season of June/July to December. Even early transplanting from late May onwards is advisable for maximising yield-rate and to avoid the cold spell during November - December.

Traditionally, the plant is tall and the height ranges from 140 - 155 cm depending on land situation. Being weak strawed, the variety is susceptible to occasional lodging. The seed to seed duration depends on the particular season in which the variety is grown. The key climatic factors determining the duration is temperature. Low temperature during the growth and development phases of the variety lengthens the duration. Mahsuri is a long duration variety requiring 140 - 150 days when transplanted in normal Sali season. The paddy grain exhibits a marked variation in grain size and colour of the hull and the kernel.
The harvesting time of Mahsuri varies depending on seasons under which it is cultivated. Mahsuri that is cultivated in Sali season, requires 180 to 190 days to attain maturity and is harvested in the month of May and in the Ahu season it requires 131 days for its maturity. But the time of cultivation and harvesting period, in Assam is delayed or not uniform throughout the state owing to fluctuating weather conditions. The delayed harvesting on the other hand causing loss of seed moisture content leads to increased number of sun-cracked and broken grains. The percentage of sun-cracked grains increased at 15-16% seed moisture content and that indicates that the rice grains become more susceptible to the environmental conditions such as humidity and temperature. The optimum time of harvesting for maximum head rice recovery for different varieties after flowering is variable. The proper time of harvesting also brings better quality rice. Early harvesting on the other hand, results less yield, poor quality grains and large number of grains or immature grains. The immature grains when dried from the threshing floor will not only be of lower grain weight, but also break large quantity during milling operation, and results in lowering of quality of rice (Govindaswami and Ghosh, 1969 ; Bhole et al. 1970 ; Agarwal 1976, 1977). The moisture content of the grain could be a very good indicator for determining the correct stage of harvesting time. If it is harvested at a higher moisture content, the method of drying paddy becomes an important factor which might be responsible for causing further breaking during milling. The harvesting time depending on seed moisture varies in different countries. The recommendation of International Rice Research Institute suggests that the moisture content of the
Drying is the general process that removes moisture from the grains for safe storage and preservation of quality, nutritive value and viability. The seed quality and appearance can be preserved by thrashing seed produce on cemented floors or on ground covered with tarpaulin. In many parts of India, the thrashing is still done on mud-plastered floors. This may spoil seed appearance and sometimes affect seed germination and vigour due to the absorption of moisture by seed from such floors (Agrawal, 1986). In the north east part of India, particularly in Assam, the drying of paddy grain after harvest is a problem because of occasional rainfall, heavy night dew, cloudy weather and fluctuating high and low temperature and is impossible to achieve a satisfactory drying. Because of the prevailing climatic factors the practice of storage of undried cereal grain is common in Assam. Hyde (1965) indicated that the storage of undried cereal grains in the temperate countries has increased, and as a result of which the high seed moisture content favours the growth of mould and subsequently leads to the deterioration of paddy grains. White (1987) pointed out that the moisture content of the seeds is one of the most important factors influencing the period of the seed for which they maintain their viability. High
moisture content at harvest can not only increase the liability of the seeds to thrashing damage, but also, later in storage, it decreases viability of seed, enhances mould growth, causes heating damage, ageing, and increases insect damage.

In India, the following three methods are employed for drying of paddy seeds as pointed out by Bhole et al. (1970) : (a) sun drying, (b) mechanical drying and (c) chemical drying.

Sun-drying is a traditional process, probably practised by farmers since the beginning of the farming history. There are several ways of drying. Sometimes, grains are dried before harvesting on the plant till the proper moisture content is attained. Farmers also use to dry the harvested crops by binding them in small bundles and hanging on bamboo racks. The most common method is to dry the grains after thrashing by spreading them over an open yard, and periodically stirring till it attains the desired moisture content.

Sun-drying is not uniform, and uncontrolled, which results in sun-cheeks or crack in the kernels, which when milled turns into fragments because of such cracks. Moreover, because of damp climate and long continuation of monsoon in the North East India, proper and quick drying is not possible. This slow drying is harmful and leads to the growth of moulds and loss of flavour, and deterioration starts with the development of varying quantities of mycotoxins (Christensen and Kaufmann, 1968; Hesseltine, 1974; Scoot and Futrell et al. 1970; Krishnamachari et al. 1975; Gangopadhyay and Chakrabarti, 1981; Bilgrami et al. 1981; Mall et al. 1983; Nusrath et al. 1983; Bilgrami,
With the faster improvement of agriculture and the scientific equipment in India, there are a number of scientific machineries with the help of which the farmers can dry the grains up to a desired moisture content.

The knowledge of storage of grains probably started since the beginning of cultivation. Storage of grain is necessary for any country that may have excess or deficit in food grains. The government of a country must need a grain storage as a buffer reserve stock to meet the vagaries of nature (Bhole et al. 1985; Rao, 1987). The question of storage of paddy grains comes after harvesting. Although in certain places of Assam, storage is done before thrashing and in the form of bundle, after proper drying, in most part of the state, the grains after thrashing and drying are stored in the granary. Thus the grain is stored only in unhusked condition as paddy or rough rice. The quality seed is a major determinant of the quality and quantity of output of a crop. The quality of paddy seed is primarily influenced by environmental factors, from the time of reaching the physiological maturity by the seeds till the time of harvest. At this stage of ripening, weathering damage is serious problem and seeds of many crops including paddy lose their viability and vigour (Agarwal, 1986). At this stage of physiological maturity, several factors like soil condition, deficiency of mineral nutrients during growth, weather stresses, fluctuation of temperature and atmospheric humidity, disease etc. may also deteriorate seed quality by reducing viability and vigour. At the
time of harvesting and cleaning, the seeds possess a high moisture content. Seed deterioration is generally rapid during this period, because this is a long period for transporation of crop from field to thrashing floor, from thrashing floor to processing plant and from processing plant to storage structure. Under such condition, if drying prior to storage is not proper, storage moulds may grow on seed and heating may occur and cause losses to seeds in storage. Post harvest losses of grains in tropical and subtropical countries have been reported by many workers (Schroeder and Sorensen, 1961; Christensen and Kaufmann, 1969; Neergaard, 1977). The general maturity of the grain is also a factor affecting deterioration in storage. The infection of grains in storage may differ in different cases. It may be intraembrial, extraembrial, systemic, local or organ specific. The site of infection may be seed coat as in pea, pepper or embroy as in cereal grains (Suryanarayana, 1978; Mehrotra, 1987). It is generally known that the storage fungi first grow within and on the inner layer of the seed coat probably because these tissues are frequently low in polyphenolic compounds (Mehrotra, 1987). It has also been reported that the seed moisture content in storage may also be affected by the type of storage structure and location and ground where it is constructed. The reason for an increase in the moisture content in the bottom seeds is moisture penetration through the concrete floor. There is a constant flow of moisture vapour from the wet ground through the floor that has no moisture vapour barrier into the seed storage granary. The moisture is not evenly distributed in the stored seeds. Seeds being hygroscopic dessicant, the bottom seeds absorb the moisture, and until these bottom seeds
reach equilibrium with the rate of moisture entry, the seeds above do not absorb moisture. Thus the bottom seeds may attain moisture content of 15 - 16% long before the upper seeds (Agarwal, 1986). The principle of successful storage depends on the eventual purpose to which the seeds will be put; such as seeds for growing must be able to germinate nearly 100% and produce vigorous seedlings in the field; on the other hand, seeds for processing may only be required to be undeteriorated and free from contamination. In practice, the latter requirement appears to go along with maintenance of a reasonably high germinative capacity, although the seeds may not be capable of successful seedling establishment (Suryanarayana, 1978; Vijayalakshmi and Rao, 1985; Dey and Mukharjee, 1986; Carol and Colin, 1980; Doijode, 1988; Miah and Pakir, 1989). During storage, several factors other than intrinsic changes in the seeds themselves may reduce the viability of seeds (Carol and Colin, 1980). In storage generally, the grains are attacked by rodents. These animals consume grains and also damage and contaminate the whole lot by their excreta, making a suitable substrate for the growth of a different category of insects, mites, fungi and bacteria, as they are very dependent on relative humidity and temperature within the grain store, and resulting an accelerating decline in viability. Mehrotra (1983b) pointed out that Aspergillus flavus is more frequent on cereal grains in India than Aspergillus parasiticus. According to Carol and Colin (1980), the toxin can persist in the seeds long after signs of fungal infections have disappeared. They mention the case of Maize, where the grain was still toxic 12 years after the fungal attack had ceased. Mycotoxins vary in their affects and range of
toxicity. Some are relatively specific to one or two species, while others appear to be general poisons.

The climatic factor of the entire globe is not uniform, hence the method of storage is not same in different countries. In India, the farmers store the paddy grains in storage structures which are made of locally available materials. Such type of storage structure may be unfit for long term storage of paddy grains. Generally, the paddy grains after thrashing are stored in heaps on ground for a period of few days to a month depending on weather conditions. The grains are then transferred to traditional storage structures. The locally made traditional storage structures in rural areas of India are Khattis, Bukharis, Thekkas, Kothar-type structures, Strawbins, Mudbins, Pitcher, Mora, Duli, Gunny bags etc., which are still in use without any scientific modification. The size, shape and the material used in the construction of the above structures are quite different in different regions. It has been reported that the substantial losses occur during storage period, owing to fungal infestation upto 30% of the harvested produce and production of fungal metabolites; (Christensen and Kaufmanr, 1969; Neergaard, 1977; Prasad et al. 1986, 1988).

Assam is situated in the north eastern part of India, and is surrounded by a number of hill states. Owing to its peculiar geographical location, it enjoys high relative humidity in 10 months of the year (Sreenivasan, 1980). Owing to fluctuating weather conditions, temperature, high rainfall and relative humidity throughout the year, harvesting, drying and storage of paddy grains are a major problem in the region. The traditional
storage structures used by the farmers are generally constructed with the locally available materials like bamboo, timber, thatch, cowdung-mud mixture etc. These are Ton, Duli, Thatch-roofed Bharal, Tin-roofed Bharal etc., as known by the local names.

Ton is a small cylindrical structure, about 45 cms in diameter and 45 cms 60 cms height. It is made by thinly interwoven narrow and thin bamboo slices, and the inner side of the bamboo netting is lined with a layer of paddy straw of about 5 cms thick. The clean and dry seeds for the purpose of growing a new generation of crop are stored here, for a short period of about 3 - 4 months, i.e. from the time of harvest to the time of sowing. After putting the seeds in it, the mouth is sealed with paddy straw and bound with the bamboo slices of the Ton itself.

Duli is a medium-sized structure, with the shape of a deep bowl of about 120 cm - 150 cms in height and about 120 - 150 cms diameter of the open mouth. It is made of closely woven thin bamboo sticks and the outer surface is thinly plastered with cowdung-mud. It is kept on a raised bamboo frame, about 90 cms above ground. Thus its mouth remains open. The whole structure is kept in some place inside the dwelling house.

The Bharal is relatively a bigger structure. Depending on the amount of the grains to be stored, it may have different height and floor area, and a height of the floor is raised from the ground by about 90 cms. The floor and the four walls are made of woven bamboo slices plastered with cowdung-mud. The roofing is done by either thatch or tin, and there is no ceiling.
The growth of a number of field and storage fungi of seed-borne nature on grains in ambient storage structures have been reported by several workers (Christensen and Kaufmann, 1969; Neergaard, 1977; Suryanarayana, 1978; Carol and Colin, 1980; Basak and Mirdha, 1985; Gajapathy and Kalyana Sundaram, 1986; Shetty and Shetty, 1988; Srinivasulu et al. 1990; Vaid and Sharma, 1992). Similarly, the association of storage fungi in various seeds in storage has been reported by several workers (Bhole and Khare, 1982; Kumar et al. 1983; Deena and Basuchaudhary, 1984; Singh et al. 1984; Ashraf et al. 1985; Popoola and Akueshi, 1986; Singh and Chand, 1986; Charajan and Taran, 1992; Katiyar and Dubey, 1992; Ankaiah et al. 1992; Kumar and Chnabra, 1992; Sharma et al. 1992; Mukewar, 1992).

Christensen and Kaufmann (1969) pointed out that there are six major types of losses caused by fungi growing in storage granaries. These include decrease in germinability, discolouration of parts or all the seeds or kernels, heating and mustiness, various bio-chemical changes, production of toxins which may be injurious to human and animal beings, if consumed, and the losses in weight. Generally, two groups of fungi are involved in storage grains. Christensen and Kaufmann (1965, 1969) pointed out the distinction between the two ecological groups of fungi, field and storage fungi. Field fungi are those that attack the seeds on developing plants in field, the mature seeds and seeds after harvesting, but before thrashing. The field fungi may be pathogenic or saprophytes. The common field fungi are species of Alternaria, Curvularia, Epicoccum, Fusarium, Helminthosporium etc., and in some seeds the pathogen may be Fusarium moniliformae and species of Verticillium (Malone and Musket, 1964). It is
known that most of the storage fungi are species of *Penicillium* and *Aspergillus*. They are active at a relative humidity ranging from 70 - 90%. It is generally known that the storage fungi don't invade seeds before harvest, but may be present on seeds in very low percentage, as below one per cent (Christensen and Kaufmann, 1969; Christensen, 1971). They may also be present as dormant mycelia within the tissue of pericarp or seed coat (Suryanarayana, 1978). It has been reported that the longevity of seeds kept in storage is predominantly dependant on the moisture content of the seed, temperature and relative humidity in the store room or granary. Seeds are hygroscopic and its moisture content varies with the variation of the atmospheric humidity. Herrington (1972) indicated approximate percentage of moisture content in some different kinds of seeds that are to different degrees of relative humidity of the air. The moisture content or equilibrium relative humidity (ERH) or water activity (AW) is by far the most important factor in grain storage. Different kinds of grains may have different "critical moisture" at which they can get heavily infested; for example 23% in Bengal gram, 16% in Rice, 10% in Ground nut (Majumder et al., 1965). It has been reported that the seed moisture content above 13% is unsafe for storage and under such conditions fungi flourish. Generally, 14 - 18% seed moisture is congenial for supporting the growth of *Aspergillus*, 16 - 20% for *Penicillium*, *Mucor*, *Rhizopus*, *Chaetomium* etc. (Mehrotra, 1987). It is generally known that the high moisture content and the nutrient content of the grain in the field before harvest harbour a different flora than that in storage. Mehrotra and Dwevedi (1980) pointed out that *Alternaria alternata* and *Cladosporium cladosporoides* are the most common as
field fungi. The ambient temperature and relative humidity in the
sub-tropic and tropics are usually adverse for storage of seeds,
(Delouche et al., 1973). In storage with the increase of
temperature, the biological activity of seeds, insect and mould
increases. The increase of mould activity in storage,
deteriorates the seeds by lowering the nutrients of seeds,
germinability and vigour. Agarwal (1986) stated that the low
temperatures are effective in maintaining seed quality, even
though relative humidity might be quite high. Christensen and
Kaufmann (1965), Christensen (1973) are of the opinion that the
cardinal temperature, for the growth of storage fungi are 0.5°C,
30 - 33°C and 50 - 55°C.

The relative humidity plays the most important part for
the longevity of seed in storage, because seed moisture content
is directly related to the relative humidity of the atmosphere
(Delouche et al., 1973). The relative humidity and the
temperature are the most important factors that determine the
storage life of seeds. Equilibrium moisture content for a
particular kind of seed at a given relative humidity, tends to
increase as temperature decreases and deterioration of storage
seeds progresses. So the maintenance of seed moisture content
during storage is a function of relative humidity, and to some
extent temperature (Agarwal, 1986). Under open storage
conditions, the seed moisture content fluctuates with changes in
relative humidity. The relative humidity of the storage
atmosphere plays an important role in regulating the activity of
microorganisms. Neergaard (1979) stated that the storage fungi
grow at moisture contents in equilibrium with relative humidities
ranging from 65 - 70 to 85 - 90 per cent. It is known that the relative humidity plays an important role in seed moisture content of paddy in storage. At the time of harvesting, the flora of grains and seeds includes very many genera of bacteria, mould, yeasts and actinomycetes, which more often come not from the soil and harvesting machinery but from air and other sources. The moulds are represented by a great variety of species of the most widespread nature belonging to the genera Alternaria, Cladosporium, Vorticillium, Fusarium, Mucor, Rhizopus, Penicillium and Aspergillus. It has been reported that Penicillum and Aspergillus are only present at low levels on grains and seeds at the time of harvesting, but they are adapted to relatively dry substances and can proliferate during storage. On the other hand, other genera are more hydrophilic and multiply less actively or regress. These observations lead to a classification of cereal fungal species into field mycoflora and storage mycoflora. Anon (1946, 1964) stated that the stored paddy seeds in ambient condition owing to the activity of storage fungi, is a matter of worldwide problem.

At present, in this field various reports from a number of countries reveal that the losses are due to the activity of fungi associated with the seeds in storage and are influenced by storage container and duration of storage period, moisture content of the seeds, relative humidity of the atmosphere, temperature etc. (Schroeder and Sorensen, 1961; Baldacci and Corbetta, 1964; Christensen et al., 1965, 1967; O.U. 1972). Mian and Fakir (1989) also reported the same and listed a number of fungi dividing as field and storage fungi. Neergaard (1979) reported the increase of seed moisture content is due to the
increase of humidity during humid months in storage of paddy. It has been reported that the growth, development and activity of microorganisms such as fungi increases along with the rise of the above factors. Vidyasekharan et al. (1973) and Bilgrami et al. (1979) reported the spoilage of cereal grains in storage by seed-borne fungi. In this regard, mention may be made about the loss of 30% of harvested product reported by Christensen and Kauimann 1965, 1969; Neergaard 1977; Christensen and Sauer 1982. Tiwari 1993, reported that the germinative capacity of grains and their baking quality are also lowered when microorganisms multiply and as a result of microbial metabolism, qualitatively and quantitatively alters carbohydrates, lipids and proteins and reduce the nutritive quality of the product.

The aim of the present investigation has, therefore, been to analyse seed-borne fungi of paddy stored in different storage structures at different months and also to determine the activity of seed-borne fungi as well as certain physiological aspects.