EVALUATION OF STORAGE STRUCTURES FOR SAFE STORAGE OF SEEDS AND *IN SITU* FUMIGATION ALONG WITH STUDIES ON REACTION OF SORGHUM GENOTYPES TO RICE WEEVIL ATTACK

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Dedicated

To

My Beloved Parents

Department of Seed Technology
University of Agricultural Sciences
Bangalore

CERTIFICATE

This is to certify that the thesis entitled "EVALUATION OF STORAGE STRUCTURES FOR SAFE STORAGE OF SEEDS AND IN SITU FUMIGATION ALONG WITH STUDIES ON REACTION OF SORGHUM GENOTYPES TO RICE WEEVIL ATTACK" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE(AGRICULTURE) in SEED TECHNOLOGY to the University of Agricultural Sciences, Bangalore, is a bonafide record of research work carried out by Mr. K.Nagarajaiah under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other of similar titles.

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INTRODUCTION

Seed production technology is a specialised field which aims at maximising both quantity and quality of the seed. Although procedures and practices are generally the same as those of grain production, some are unique to seed production; particularly the post harvest procedures that are unique to seed production are quick drying, cleaning, grading, treating, packaging and storage, distribution and marketing.

With an increase in the production of food grains through good quality seeds and adoption of improved agro-technology in the country, the problem of storage is assuming greater significance and as such the study of storability of the crop, storage structures and the insects associated with stored products is receiving greater attention of researchers.

The losses incurred in the course of cultivation of a crop falls into two categories viz., losses incurred in the preharvest stages and that incurred in the post harvest stages. The preharvest losses are due to weeds (33 per cent), plant diseases (26 per cent), and insect pests (20 per cent). The post harvest losses are by storage pests (7 per cent) and rodent (6 per cent) (Mukherjee and Ray, 1975).

Post harvest losses of food grains occur at various stages. An expert committee (Anon., 1971) estimated the post harvest losses to food grains to be 9.33 per cent occuring at different stages which included threshing yard (1.68 per cent), transport (0.15 per cent), processing (0.92 per cent) and storage (6.58 per cent). In India, the annual losses of food grains stored in godowns resulting from insect infestation was about 5 million tonnes (Neelakanta, 1972). According to Girish and Krishna murthy (1972), the losses caused in wheat, maize, jowar, rice, barley and pulses due to stored grain insects were to the magnitude of 3,3,2,2 1 and 5 per cent respectively with an average of 2.5 per cent. It has been recently estimated by the Pesticide Association of India that the annual loss due to pests and diseases was around Rs.5000 crores or 18.40 per cent of the total production. In another loss estimation study, Purnanandam (1976) observed that about 6.58 per cent of the total losses estimated were due to faulty storage of grains which were damaged by insects (2.55 per cent), rodents (2.50 per cent) and moisture (0.68 per cent). The above review reveals the role played by the insects among the other factors in causing storage losses.

The seeds which absorbed moisture from the atmosphere during rainy season in storage, spoiled more due to heat damage, development of free fatty acidity, insect damage, loss of viability and off odour's due to attack by saprophytes (Farid *et al.*, 1965a).

Storage structures used for storing seeds also influence the extent of infestation which varies with the construction materials used, heat conductivity, allowing for aeration etc.

Jowar (*Sorghum bicolor* Pers) ranks fourth in importance among the world cereals, exceeded in area and production by wheat, rice and maize only. Jowar is an important food crop of India, accounting for an area of 16.964 million hectares with a production of 8.1 million tonnes (Anon., 1977a). It is also an important cereal crop of Karnataka with an annual production of 17.90 lakh tonnes which is about 27.9 per cent of the total cereal production (Anon., 1977b) of the state.

Prevett (1975) claimed that *Sitophilus oryzae*(L. innaeus) would certainly rank high among the stored product pests. The global survey of pesticide suceptibility of stored grain pests conducted by the Food and Agricultural Organisation revealed that in India, *Sitophilus oryzae* was a major pest on cereals and millets like rice, wheat, jowar, barley, etc., along with *Sitotroga cerealella* (Oliver) and *Rhizopertha dominica* (Fabricius) (Champ and Dyte, 1977).

Usman and Puttarudraiah (1955) published a comprehensive list of stored grain pests and considered the rice weevil as a major pest of jowar throughout the then Mysore State. They also reported that infestation started in the field on the standing crop of the jowar.

The above review clearly establishes the fact that jowar sustains post harvest losses due to insect pests in storage of which, S.oryzae dominates. Jowar, like rice is also stored in both large scale and small scale for later use for food as well as for seed purposes. The present investigation was undertaken with the following aims which will help in the small scale storages of Jowar seeds.

1. Studies on the relative efficacy of seven storage structures in protecting the seed from insect infestation.
2. Studies on the relative influence of storage structures on the action of fumigants.
3. Determination of the optimum seed moisture for growth and development of S.oryzae.
4. Evaluation of sorghum genotypes for their relative susceptibility to the attack of S.oryzae.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Literature pertaining to relative efficacy of storage structures in checking insect infestation, relative influence of the storage structures on the action of fumigants, optimum seed moisture for growth and development of *Sitophilus oryzae* (Linnaeus) and evaluation of sorghum genotypes for their relative susceptibility to *S.oryzae* are reviewed in the following pages.

2.1 Relative efficacy of the storage structures in checking insect infestation

2.1.1 Incidence of *Sitophilus oryzae*

A survey made by Jain (1965) at northern states of India revealed that *Sitophilus* spp to be predominant pests of food grains like, maize, bajra, jowar and many other crops among the store pests.

The extent of losses due to insect pests including *Sitophilus* spp in storage of food grains (bajra, jowar, maize, millets, rice and wheat) of Gujarat farmers was estimated to be 1 to 5 per cent (Auren, 1970).

Gahukar (1972) in his pest infestation survey on stored cereals in Southern India found, among the common pests infesting stored cereals *S.oryzae* to be the most important destructive store pest along with *Trogoderma granarium* Everts., *Rhizopertha dominica* Fab., *Tribolium castaneum* Hebst. and *Sitotroga cerealella* Oliver.

2.1.2 Influence of different storage containers on population buildup, insect damage, weight loss and viability of stored seeds

Bertrand (1941) claimed that rice weevils were found dead after nine months of storage in steel drums. Ozburn *et al*.,(1960) found insignificant changes in moisture content, insect damage and viability in Guinea corn (*Sorghum vulgare*) of 10 per cent moisture content when stored in 44 gal. metal drums, stored for a period of 30 months. Studies on the relative suitability of cement and aluminium bins for storing wheat made in India revealed that grains stored in concrete bins absorbed moisture from the atmosphere during rainy season and was spoiled due to heat damage, development of free fatty acids, insect damage and lost its viability when compared to that in aluminium bins (Sarid *et al*., 1965a)

Sarid *et al*., (1965b) indicated that the moisture content was found to increase in wheat stored in gunny bag than in the bulk lot at places having higher relative humidity. The loss of germ portion due to *T. granarium* feeding has found to be higher in grains stored in jute bugs than in bulk. Venkata Rao *et al*.,(1958) found adult population rising up to 35,000 per bag and weight loss to 31.5 per cent, after

after 5 months in gunny bag contained with 5 lbs of jowar in which 5 pairs of S.oryzae were released in.

Ramasivan et al. (1966) in his review on seven kinds of underground and about 40 kinds of above ground structures, stated that only in the above ground structures S.oryzae, one of the major pest alon with S.cerealella, T.castaneum and R.dominica were redorded and he further claimed that Soryzae and R.dominica were able to penetrate even through the mud plasters.

Parvathappa et al., (1972) in their study on comparitive storability and quality of jowar in underground structures stated that in Galige (bamboo bin) of above ground structures, there was decrease in germination from 89 to 75 per cent and S.oryzae cound increased from 41 to 34 and kernel damage from 2 to 12 when stored for 90 days, and he claimed bamboo bin to be superior to jute bags.

Girish et al. (1972) found more spoilage due to insects in the top layers than in deeper layers of jowar grains stored in underground structures called 'Khatties'.

Ramasivan et al. (1966) in their study on losses of wheat during storage, they found 65 per cent insect damage in mud pots and 16 per cent in metal drums, quantitative loss of 2.03 per cent in tins and 2.25 per cent in bags and weevilled grains of 2.3 per cent in tins and 2.9 per cent in bag storages. Further, they also recorded 100 per cent loss of viability in germ eaten grains and 65.9 per cent loss in weevilled seeds.

Ramasivan et al., (1968) found that farmers sold only 14.8 per cent of their total produce and retained the rest (76.6 per cent) in storage structures which included mud pot, jute bags, tin drums, thekkas and kuthlas. Most of these structures excepting tin drums had insect damage by S.oryzae, R.dominica and T.castaneum due to presence of cracks and crevices. The grains stored over 2 to 6 years, the losses sustained was lowest in metal drums (16 per cent) thekkas (35 per cent) and highest (100 per cent) in open cement tanks. The receptacles showing 69 per cent to 82 per cent infestation of all the structures, metal drums was found most superior followed by jute bags.

Srivastava et al., (1973) in their case study on the storage practices in villages and losses caused by insect damage reported, a weight loss of 9.7 per cent and kernel damage to the tune of 30.1 per cent. Insect S.oryzae was the predominant pest in all the containers along with R.dominica and Tribolium spp. The sound grain percentage was more and weevilled grain percentage was less in drums and bag storage as compared to other structures. Population count (in 50 g. of grain sample) was the least in metal drums followed by gunny bag and the least percentage of weight loss was observed in metallic drums.

Girish et al.,(1974) in their survey on storage losses in farm stores using Tin canister, Topara (Bamboo bin), wooden boxes and metal drums for storing seeds, in different regions of Uttara Pradesh reported that loss in weight of wheat stored was maximum (0.6 per cent) in Topara where as no loss was observed in other containers. Further, loss in viability of seed from 7.0 to 22.0 per cent was observed in different storage structures.

Maximum weevilisation (10 per cent) germ eaten grains (15 per cent) and weight loss (4.02 per cent) were observed in the grains stored for 10 months in kuthalas at Bhatnagar. The ratio between grain loss, weevilisation and germ eaten was 1: 2.48 : 3.73. The farmers who stored in metal bin lost only 0.4 per cent of wheat by weight (Doharey et al., 1975).

Bhardwaj et al., (1977) claimed, in their weight loss assessment study in wheat after 8 to 10 months of storage at Uttara Pradesh, that moisture content of the grain, percentage of weevilisation, percentage of germ eaten, percentage weight loss and percentage of germination were 11, 5.1, 2.6, 2.5 and 82.5 respectively.

In their comparitive evaluation of storage bins like plywood, ferrocement and HMHD (high molecular high density polyethylene plastic) bins of 0.5 to 3.0 tonnes capacity Krishnamurthy and Majumder (1978) reported that the plywood bin had good qualities such as high degree of gas worthiness, fairly high amount of Co_2 accumulation, very less kernel damage and viability of 90 per cent even after one year of storage. Plastic and metal drums were also good but the dissadvantages with the former was its low durability and the latter was very expensive.

2.1.3 The effect of different storage structures on seed viability

Champion (1930) showed in pine seeds, drop in germination from 82 per cent to 72 per cent at the end of two years when sealed in tin cans and to 69 per cent when stored in gunny sack under roof of an open shelter. According to Krishna swamy (1952) 70 per cent germination in Sorghum was observed even after 26 months of storage in sealed bottles, where as in sorghum stored in gunny sacks, the germination percentage dropped to 4 to 38 in 1½ years.

Toole et al., (1961) from Cuba claimed that kneaf seed could be stored in 10 mil. polyethelene container with no loss in germination for 15 months and at the end of 27 month germination dropped to 35 per cent. Commercial seed lots of sweet sorghum var. sugar drip stored in a warehouse at 66 to

87°F (a) in steel drums (b) in jute bags lined with polyethylene and (c) in close mesh jute bags, registered percentage of germination above 70 per cent for 27 months in (a) for 24 months in (b) and 20 months in (c) (Peel, 1962). Singh and Tripathi (1968) storing maize seeds of 8 to 10 per cent moisture in thick, thin plastic bags and sealed tins showed no loss in viability for 12 months. Further, seeds with 12 per cent moisture stored in sealed tins maintained highest germination compared to thick and plastic.

2.1.4 The effect of insect infestation on viability of seeds

Pingale (1953) in an experiment with wheat stored in bamboo bins plastered with mud and cowdung and 10 pairs of *S. oryzae* released in it, reported a reduction in germination percentage from 90 to 10 at the end of 6 months. Incidentally he claimed an increase in the percentage of holed grains from 0 to 90 per cent.

Working on the relationship between extent of damage and germination of jowar (P.J.4K) infested by *S. oryzae*. Yadav *et al.*, (1968) found that increased damage by developing grub resulted in decreased germination percentage.

Srivastava *et al.*, (1971) found in bag storage, in cooperative seed stores, a loss in viability of seeds (jowar and wheat) to the extent of 95 per cent in weevilled grains and 100 per cent in germ eaten grains. Gordon *et al.*, (1972) found that seeds of *Pinus merkusii* which were badly infested by *Dioryctia* sp. had their germination reduced by 5 to 89 per cent. In their investigations on the assessment of quality loss in wheat damaged by *T. granarium*, Girish *et al.*, (1975) found initial germination of 100 per cent (sound grain was 95 per cent) coming down as the kernel damage increased, with no germination in the case of 100 per cent damaged kernels ultimately.

2.1.5 Some aspects of seed storage

Hurd (1921) found that wheat seeds with rupture seed coat injury was often invaded by moulds. Intact seed coats offorded absolute protection. Invasion was more rapid when rupture was over the endosperm than when it was over the embryo.

Accumulation of Co_2 in sealed storage was observed to be effective in the prevention of heating, insect infestation and fungal invasion (Vayssiere, 1948).

Harrington (1960) in his general dissoussion on moisture relationship in seeds to storage conditions, postulated that cause of deterioration was the local exhaustion of food reserves under high moisture contents, not high enough to allow for translocation of food reserves. According to Giles (1965), air tight storage of threshed grain gave complete insect control, little practical success was achieved in mud granaries treated with bitumen or in sealed clay pots.

2.2.1 Influence of storage structure on the action of fumigants

Darragh (1931) claimed that when the harvested maize cob infested by rice weevil at field level was fumigated in metal bins with Carbon disulphide (CS_2) at the rate of 5 lbs. per 1000 C.ft for 48 hour controlled the rice weevil fully. Lindgreen et al., (1954), in their investigation on the relative efficiency of ten fumigants against S.oryzae including other store pests in metal chamber of 100 C.ft, found ethylene dibromide and ethylene dichloride to act against S.oryzae with an exposure periods of 6 hour and 2 hour, respectively. Fumigation of maize with 12.5 per cent moisture content in a plant consisting of series of steel bins (4000 bags capacity each) with Aluminium phosphide at the rate of 10.2 tabs/ton killed all the insect S.oryzae and T.castaneum according to Davies (1958). Cornes and Oyeniran (1968) claimed that when fumigation of maize in an Aluminium silo was done using 1 : 1 ED/CT at 1 gallon/5 tonnes of grains with an exposure of five days, only one T.castaneum beetle was revealed in the bottom sample, where as the top showed moderate though reduced infestation by both S.oryzae and T.castaneum. Thiem and Boge (1975) in their investigation on the control of pests of stored grains in an aluminium silo found the considerable losses of phosphine gas, especially through seals at segment rings, manholes, inlet portions of silo. With additional sealing for *S.oryzae* and *T.granarium* at 10 tabs/tonne were necessary to achieve successful control with adequate exposure time in cold season.

Krishnamurthy and Sheshagiri Rao (1950) found complete mortality of *Sitophilus*, *Rhizopertha*, bruchids in wooden box of 3.5 C.ft. when treated with mixture of ED/CT (chlorosol) at the rate of 40 lbs/2000 C.ft with an exposure period of 3 days.

Muthu and Pingale (1955) found that the mixture of ED/CT controlled the larval and adult stages of *S.oryzae* when treated at 30 lbs/1000 C.ft. in a gunny bag under tarpauline. The eggs and pupae were more resistant. They also found that EDB tried in gunny bag containing jowar seeds infested by *S.oryzae* at 30 cc gave complete mortality of the pest. Laxman Rai *et al.*, (1964), in their study on sacked wheat attacked by common store grain pests, when treated with ED/CT (3 : 1) and phostoxin at 20 tabs/1000 C.ft. and 2 tabs/tonne, respectively, with exposure periods of 2 days and 7 days killed most of the pests. The phostoxin gave complete mortality and was superior to ED/CT. Halliday (1967) in his field studies on the fumigation of stocked bags lined with polythene of milled rice, jowar and other crops with phosphine found effective in control of pests like S.oryzae T.castaneum and R.dominica when treated with dosage of 2 tabs/ton with exposure period of 7 days. In their study on assessment of value of phosphine and EDB for control of pests S.oryzae and T.castaneum in maize grain stored in polytheneX lined sacks, Cornes et al., (1969) found them to give good control of store pests with 2 phostoxin tablets/ 150 lbs of maize, where as EDB did not penetrate the grain efficiently and killed insects in upper half of the sack only. Proctor and Ashman (1972) in their study on controlling insects in groundnut using phosphine in polyethylene lined sacks found complete mortality of insect pests when concentration x time productxx for phosphine exceeded 50 mg.h/ litre. Phosphine fumigation on rice stored in jute bags lined with polyethylene, at 2 tabs/tonne of Detia Ex-B releasing (11 gms of phosphine gas) with 7 days exposure killed all the adults of S.oryzae (Cogburn, 1974).

According to Robertson (1968) reinfestation by S.zeamais on maize was observed in sacks heavily after fumigation with phostoxin as compared to in concrete and carrogated silo. ED/CT mixture, EDB and Aluminium phosphide at the rate of 140, 60 and 4.5 g/Cu. meter, respectively in Kothis, kuthlas and tin drums gave efficient control of Sitophilus and

Rhizopertha among many other store pests (Girish *et al*., 1972). The control of latent infestation was maximum in tin drums. Shayesteh (1975) using phostoxin to control *S. granarius* and *T. confusum*, found the fumigant applied at 1-3 g/ton of wheat with 72 hours of exposure time, in air tight wooden boxes gave complete mortality. In gunny bag lined with polythene, fumigant gave complete mortality at 1-5 g/sack and similarly at 6 to 9 g. phostoxin per ton gave complete control of wheat pests in mud store house with wooden roof having 1150 kgs of wheat.

2.2.2 Delayed action of fumigants on insects

Lindgren *et al*., (1954) in their experiment on relative effectiveness of 10 fumigants to adults of stored product pests, found that the insects died on different days even when they were provided with favourable food, moisture and temperature of 78°F and 70 per cent relative humidity for 4 days after fumigation. Fumigation with EDB at 32 g/Cu. meter and an exposure period of 48 h would be just adequate to disinfest the mill (Khare *et al*., 1966). He also showed that immediately after fumigation there was cent per cent kill in the caged insects placed in the ground floor and there was only 91 and 98 per cent kill in the caged insects placed on I and II floors, respectively and this rose to 100 per cent after incubation. Similarly, after incubation nearly cent per cent mortality was obtained in insects collected from I and II floors inspite of lesser mortality immediately after fumigation, indicating there by that EDB had a delayed action on the surviving insects.

2.2.3 Reinfestation in storage containers after fumigation

Davies (1958) in his experiment on maize fumigated against *S.zeamais* with aluminium phosphide at 10-12 tabs/ton found reinfestation by potentially dangerous population of *Tribolium* and *Sitophilus* group. According to Lallan Rai *et al.*, (1964) in sacked wheat under rubberised gas proof when fumigated with ED/CT at 20 lbs/1000 Cu.ft with 48 h exposure time, there was incidence of *S.oryzae* emerging at the rate of 2 per kg of wheat. Maize, under fumigation with ED/CT (1 : 1) in an aluminium silo against *T.castaneum* and *S.oryzae* at the rate of 1 gallon/5 tonne was observed to be reinfested after one month and after 2 months, a "damageable population built up" was seen (Cornes and Oyeniran, 1968).

2.2.4 Effect of fumigants on seed germination

Roarch and Cotton (1930) claimed that the mixture of ED/CT (3 : 1) did not affect viability of wheat seeds regardless of concentration, the length of exposure and moisture content. Caswell and Clifford (1958) found the grains of 5 maize varieties suceptible to a fumigant ED/CT when tested at 10, 20 and 40 ml/cu.ft. of storage space, the seedling growth was reduced.

Girish *et al.*, (1972) in their review remarked that, wheat, jowar, bajra, maize, peas and beans samples with different moisture contents when fumigated with EDB at 60 and 120 mg/m^3 at temperature of 82–84°F with exposure time of 7 days, did not affect germination.

According to Zutshi (1966), photoxin had no adverse effect on germination of the seeds even at 2-3 times higher dosage and the exposure period was given. He also pointed out that in certain cases, the fumigant increased germination capacity of seeds. Rout and Mohanty (1967), claimed no impairement to rice germination even after the exposure to the highest phosphine concentration of 5 mg/litre for 72 hour.

2.2.3 Toxicity of fumigants

Bond *et al.*, (1967), in his experiment on the influence of oxygen on the toxicity of fumigants to *S.granarius*, found an increase in toxicity with decreasing oxygen concentration until the later was reduced to one per cent in storage structures.

Punj and Girish (1969) claimed that EDB was most toxic to both larvae and pupae of *T.granarium* followed by CS_2 and ED/CT.

2.3 Effect of grain moisture on rice weevil development

Grain moisture plays a very vital role in making the kernels suceptible for the attack and development of stored grain pests. Mathlein (1938), in his investigations on biology and control of S.oryzae showed that the lowest moisture content that permitted development and oviposition was little under 10 per cent, This species reproduced normally in wheat with a moisture content of 9.9 per cent but scarcely did when it was 9.5 per cent. Chatterjee (1953) claimed that at 12 per cent moisture content the per cent damage was high (30.2 per cent), at 8 and 2 per cent moisture content the damage was 18.4 per cent and 12.8 per cent respectively. In the same experiment he found the highest and lowest weight loss at 12 per cent moisture content (7.5 per cent loss) and 8.0 per cent moisture content (4.1 per cent loss), respectively. Howe (1965) fixed the minimum relative humidity for increase to epidemic numbers of S.oryzae on cereals, as 60 per cent. While reviewing the workdone on the effect of moisture content on development of store pests, Pingale and Girish (1967) remarked that optimum conditions were largely obtained when moisture content was 14 per cent, the lowest humidity at which weevils were developed was 60 per cent in S.oryzae and moisture content had to be in excess of 12 per cent if rapid multiplication of weevil was required. According to Pourite (1967) when immature stages of S.oryzae were reared at 10 per cent as compared to 14 per cent food moisture content, the resulting adults were significantly lower fecund. Mookherjee *et al.*, (1968) claimed that the damage in paddy, wheat, maize, barley, jowar and bajra varied from 0 to 70 per cent, 0-100 per cent, 0-100 per cent, 0-5 per cent, 0-22.7 per cent and 0-11 per cent respectively, due to *S.oryzae* in the seven different ecological zones of the country. Population increase at 75 per cent RH and lowest at 60 per cent and 90 per cent RH was found and it was concluded that 15.2 per cent moisture content as optimum for favouring the development of *S.oryzae* (Karansingh *et al.*, 1973). Karansingh *et al.*, (1974) claimed the oviposition and development of *S.oryzae* in wheat to be best at 15.0 to 15.5 per cent moisture content. All maize varieties, according to Karan Singh *et al.*, (1975), were immune to the attack at 45 per cent RH, poor oviposition at 60 per cent RH and optimal at 75 per cent RH. Krishnamurthy *et al.*, (1976) were of the view that there was increased percentage of damage with increase in moisture content in stored seeds showing 38, 55 and 69 per cent damage at low, medium and high moisture content respectively. They also found that the percentage weight loss in seed during storing increased from 35 to 54 per cent and on to 68 per cent with increase in seed moisture content. Thyagarajan (1980) in his seed moisture studies on *R.dominica* found wider developmental period at highest and lowest grain moisture contents and optimal at 13.5 to 15.0 per cent grain moisture contents, further he found the highest growth index at the above optimal grain moisture levels.

2.4. Testing of sorghum genotypes for their relative suceptibility to the attack of *S.oryzae*.

Pant *et al.*, (1964) in his studies on relative resistance of maize varieties to *S.oryzae* found that no variety was completely resistant to the attack of pest. The seeds of Ganga 101 hybrid, Deccan hybrid, Rudrapur D.T.C., Melan white D.T.C. and Ganga-1 hybrid were significantly less suceptible while rest of the varieties were more suceptible, the most suceptible one being udaipur white D.T.C. Dang and Pant (1965) in their study on relative suceptibility of 64 pure lines of sorghum to *T.castaneum* grouped depending upon the analysis of variance into 4 classes depending on degree of suceptibility. The average number of adults observed on I, II and III are 2-5, 7-13 and 14-20 and number of varieties included are 3, 13 and 30 respectively under these categories. Pauline and Davey (1965) claimed that the sorghum genotypes were of two types, namely, with vitreous endosperm and mealy endosperm. The seeds with predominantly vitreous endosperm were less attacked by weevil than those in which the majority had a mealy endosperm. Seeds of vitreous varieties had lower moisture content than mealy ones at the same humidity level. The seeds examined by X-ray showed, significantly more eggs in seeds of the mealy than of the vitreous variety and they inferred that hardness of the seed was the principal factor responsible for resistance to weevil attack. Puttarudrappa _et al._, (1971) found 11.96 to 31.34 per cent seed damage in nine varieties of sorghum with the population averaging 7.20 to 21.23 _S.oryzae_/ bottle. As per the report of Widstrom _et al._, (1972) total beetles emerged and total weight loss were good indicators of suceptibility. Stevens and Mills (1973), comparing techniques for screening sorghum for resistance to rice weevil found free choice random distribution and no choice confined tests to be equally good for evaluating resistance. Insect developmental period was correlated with the suceptibility of the varieties. Grain size, protein content and hardness of the grain did not seem to have direct bearing on the suceptibility of the varieties (Khokhar and Gupta, 1974). Bhatia _et al._, (1975) rated the varietal resistance on the basis of relative number of adults emerged, wheat varieties were screened on the basis of number of adults of _S.oryzae_ that emerged from the culture and the time taken to reach the adult stage (Chahal and Labh Singh, 1975). Rout _et al._, (1976), testing rice against _S.oryzae_, found the Rajeswari was the most and Vijaya the least suceptible as indicated by measurements on the duration of development of number of first generation adults that emerged and found negative (-ve) correlation between the hardness of the grain and suceptibility. Grains of the more suceptible varieties produced heavier adults, but there was no consistent relation between suceptibility and the content of starch and protein in the grain. Krishnamurthy _et al._, (1976) claimed that the largest population of _S.oryzae_ was present in seeds of M-35-1 (60) followed by CSH_4 (22) and CSH_1 (19), while CSH-5 and CSH-2 had lesser incidence (15, 12 and 11 respectively). The percentage of damage was lowest in M-35-1 (22 per cent) followed by CSH-5 (34 per cent) and the damage was more than the 60 per cent in other hybrids. The per cent seed loss was greater in hybrids CSH-1, CSH-2, CSH-3 and CSH-4 (19 to 24 per cent) than in hybrid CSH-5 and variety M-35-1 (both 14 per cent). Doraiswamy _et al._, (1976) screened sorghum varieties based on number of adults emerged from 100 seeds and found characters such as seed colour, seed weight and seed volume had no association with the relative incidence of _S.oryzae_ and also showed that seed hardness had a negative correlation with suitability or otherwise of sorghum.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

Investigation on the relative efficacy of storage structure in checking the insect infestation on stored sorghum seeds, their relative influence on the effectiveness of fumigants in the controle of *Sitophilus oryzae*, determination of optimal grain moisture in sorghum for rice weevil infestation and development as well as screening of sorghum genotypes for their relative suceptibility to infestation by *S.oryzae* were carried out at the department of seed technology, Agricultural College, Bangalore during 1979-80.

3.1.1 Study on the relative efficacy of the storage structures in checking insect infestation in stored sorghum seeds.

With a view to compare the relative efficacy of seven storage structures, namely, metal bin, plywood bin, plastic bin, gunny bag lined with polythene, vadai, earthern pot and bamboo bin, some of them being widely used in the rural areas and other improved storage structures which are in use/coming into use, models of these structures (Fig.1-7) were made. The dimensions, volume, seed holding capacity, shape, etc., of these models are furnished in table-I and are briefly described below.

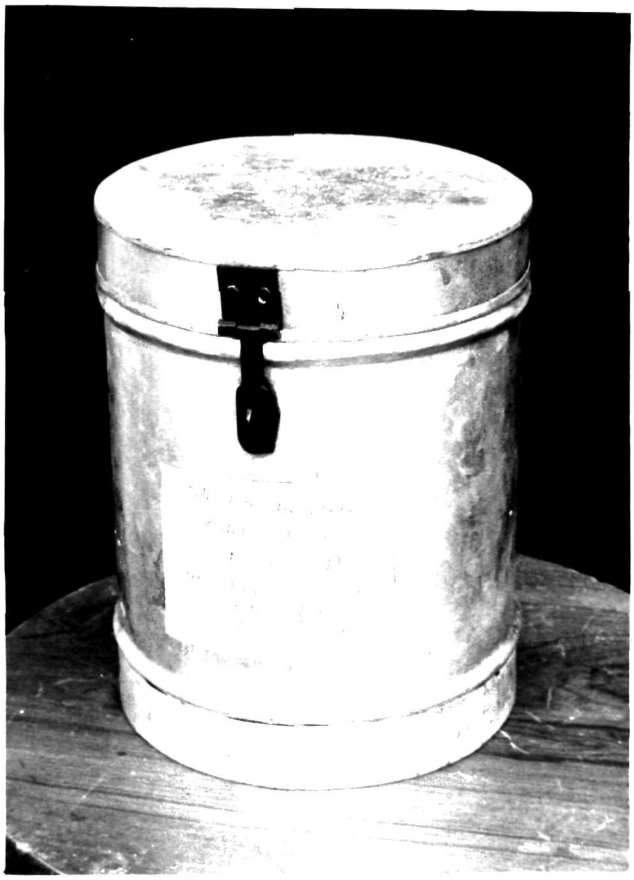

Fig.1. Metal bin Model

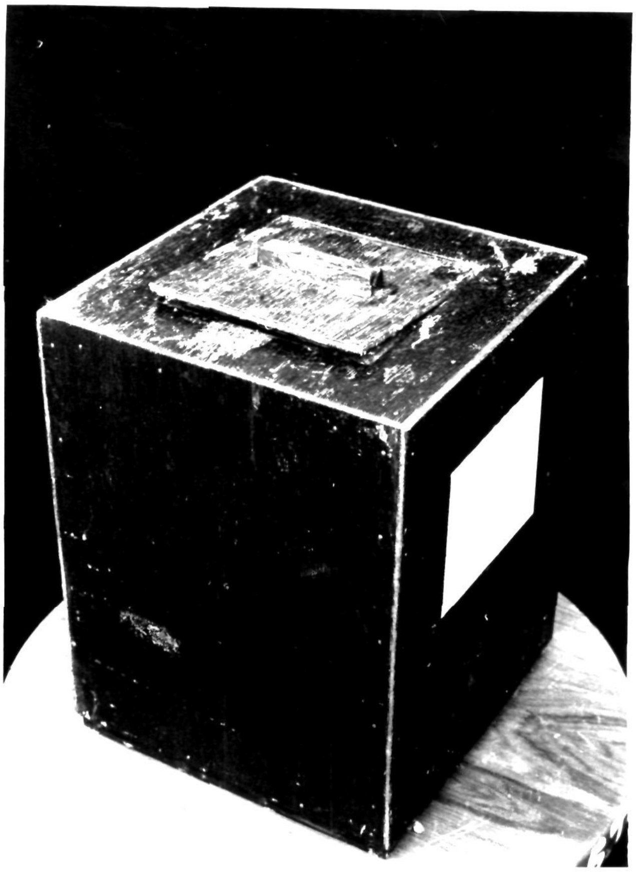

Fig.2. Plywood bin Model

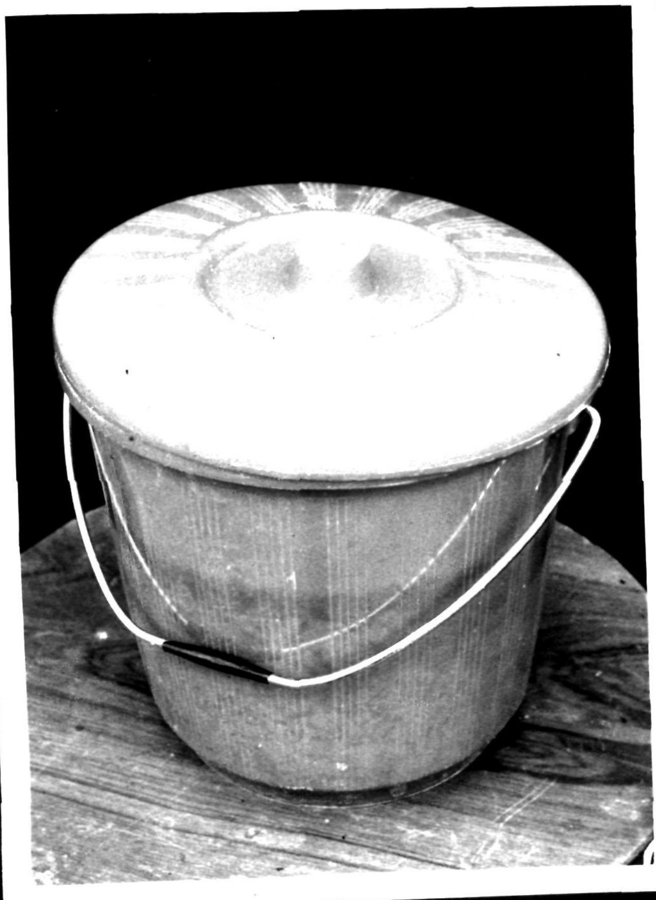

Fig.3. Plastic bin Model

Fig.4. Gunny bag lined with polythene

Fig.5. Vadai Model

Fig.6. Earthernpot model

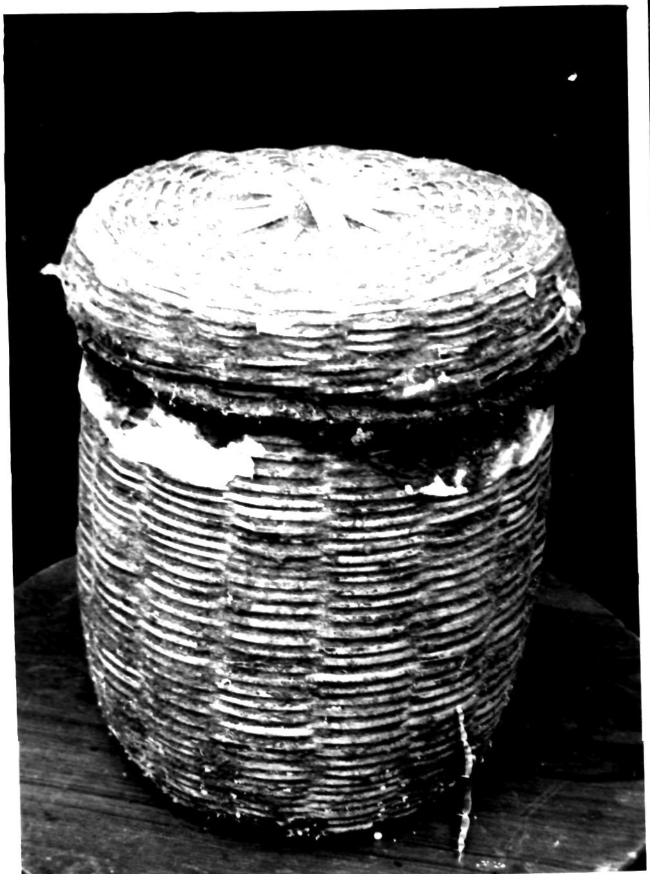

Fig.7. Bamboo bin model

Table No.I: Storage structures evaluated in the present study

Sl. No.	Storage structures	Materials used in for construction	Shape of the structure	Dimensions in cms.	Volume in C.mt/(C. ft)	Holding capacity	Remarks
1.	Metal bin	Galvanised iron sheet	Cylindrical	H=21.38 r= 9.52	0.0061 (0.2189)	5 kgs	Modelled after drum storage structures like metal drum, Asphalt or coal tar drum for storing indoor with varieties of seeds. The joints are sealed with enamel paint.
2.	Plywood bin	Processed and treated plywood	Cuboid	L=20.32 B=20.32 H=23.36	0.0097 (0.3407)	5 kgs	Obtained from IPIRI Tumkur Road, Bangalore.
3.	Plastic bin	High molecular, high density polythelene	Bucket with tight lid	H=20.32 V= 8.99	0.0052 (0.1822)	5 kgs	Obtained from shops in city market, Bangalore
4.	Gunny bag lined with polythelene	Gunny bag and polythelene bag	Gunnybag	L=71.12 B=46.22 H=varies from30.48 to 38.1	0.1126 (1.4745)	7 kgs	Gunny bag with ¼ quintal seed holding capacity which was lined with polythelene sheed of 700 gauze further folded to provide 7 kg capacity.
5.	Vadai	Burnt clay	Barrel	H=16.05 r= 9.52	0.0046 (0.1615)	5 kgs	Modelled after the vadai that are in use in rural areas.
6.	Earthern pot	Burnt clay	Narrow neck curved outwards with enlarged bottom	H=27.15 r= 9.52	0.0077 (0.2716)	5 kgs	Modelled after earthern pots or kalasige being used in rural areas.
7.	Bamboo bin	Bamboo mat	Folded into cylinderical shape	H=23.87 r= 9.65	0.0070 (0.2466)	5 kgs	Modelled after thombe or thadike or kadike being used in rural areas

Metal bin

Storing in metal bin is commonly referred to by the farmers as Drum storage in our state. This drum storage could be seen all over the state where in Kerosine metal drum or in asphalt or coal tar drums are used for storing various kinds of crop seeds and grains. These structures are usually indoor type because of the reason that the bin is made up of Galvonised steel sheets which is good conductor of heat, this property being not desirable with the materials used in fabrication of storage bins. Metal bins are claimed to be moisture proof, air tight and long durable and enables easy portability. Cost is relatively more than any of the other structures. Metal bins usually are fabricated and supplied by KAIC (Karnataka Agro-industries corporation). A bin of 0 to 5 tonne capacity bin costs as much as Rs.210.

Plywood bin

This structure is developed by the Indian plywood Industrial Research Institute (IPIRI), Bangalore. Processed and treated wood is used in the construction of bins of varying capacity from small (0.5 tonne) to relatively large capacity of 30 tonnes. The storage bins of indoor and outdoor types; circular and rectangular shape; pre-fabricated, knockdown and portable varieties; and for insitu construction are available. Important properties such as non-corrosiveness and resistant to acidity and salinity are attributed to the plywood bin.

These structures are considered to be nearly impervious to moisture and gas. A bin of 0.5 tonne capacity costs Rs.130 and 10 tonne capacity costs Rs.1430 during 1978.

Plastic bins

Plastic cylindrical buckets and small drums with lids are used to store the seeds/grains as well as processed food materials at domestic level and grossery shops. Plastic bins are known to be moisture proof and airtight but vulnerable to fire, it is very much suceptible to heat and fire hazardars. It is durable and easily transportable. It costs less but this structure is not produced as a storage bin commercially.

Gunny bag lined with polythelene

Gunny bags or cloth bags lined with polythelene sheet are being usually used commercially to store seeds in seed industry. Few kgs to many tonnes of seed are stored in these as in cap storage adopted by Food Corporation of India. The structure is not rodent proof nor fire proof. It is moisture vapour proof. The interlining with polythene film is believed to ward off cross infestation. Mainly used by seed dealers in the state, the cost of the structure is cheaper than any of the above mentioned structures ie., Rs. 8 to 10/bag.

Vadai

Commonly called as Adakalu, Madeke and Kanaja, these structures are made of burnt and unburnt clay and made by village pot makers to the desirable capacity. Varying in shape from cylindrical to round, these structures may be of one piece or three or four rings, joints being sealed with mud. The structure with higher capacity are usually with both ends open. The diameter of the central ring is bigger than that of the bottom and top rings and the whole structure looks like a barrel. The bottom most ring has an opening to serve as an outlet. The inlet is normally covered with a thin stone slab. The capacity varies from 200 kg to 1000 kg. The cost of vadai varies from rupees 60 to 75/piece. Seeds and grains of food crops, pulses, oilseeds are stored in these structures. Rat damage is not noticed in these structures and are not known to be air tight.

Earthern pot

Commonly called as Galagi, Madeke and Kalasige, the storage structures are made of burnt clay. They vary in shape but usually be round. Narrow opening inlet at the top is normally covered with burnt clay lid. The capacity varies from 5 kg to 200 kgs and each piece costs about Rs.2/- to 20/-. Structure are known to be air tight.

Bamboo bin

Bamboo bin is known in the rural areas as Thombe, Kadike, Thadike, Ponaka and Gummi. These are indoor cylinderical structures made out of bamboo splits, woven to give a circular barrel shaped structures with one side or two side being open. The structure will be placed in a corner of the house and plastered a the base as well as sides with mud or cowdung. The floor of the house will be the floor of the structure, outlet and roof are not provided. After filling the grain, structure are covered with paddy straw and plastered with mud or cowdung. The capacity varies from 0.5 ton to 1.0 metric ton with the approximate cost varying from Rs.20/- to Rs.50/- a piece. Life of the structure depends upon the maintenance.

3.1.2 CSH-1 seed

CSH-1, hybrid jowar seed was used in the experiment. The seed, produced in summer 1978 was obtained from a seed producer at Melur in Anekhal taluk. It was then fumigated before the start of the experiment and following observations on the seed were gathered:

Initial moisture content	= 11.00 per cent
Initial germination	= 67.00 per cent
Thousand Seed weight	= 30.76 g
Holed seeds due to insect emergence	= 0.8 per cent

3.1.3 Test insect

Rice weevil, S.oryzae (curculionidae, coleoptera) was used in the study. Initially the insect was obtained from Central Food Technological Research Institute (CFTRI), Mysore. The insect was then cultured on jowar seeds for further needs in the structure.

3.1.4 In the experiment each storage structure was filled with 3 kg of CSH-1 hybrid jowar seeds and 50 insects of 15 days old S.oryzae were released on them. The structures were then sealed apropriately by using cellophane tapes (Metal bins, plywood bins), plastic insulated metal clips (Gunny bag lined with polythelene) held along the fold, and with red earth cowdung slurry (Vadai, Earthern pot and Bamboo bin). The seven treatments were replicated thrice. The studies were made for a period of five months. The data collected on the following aspects were subjected to statistical analysis.

3.1.5 Sampling

For the purpose of observations, samples 300 g of seed was taken at random from different places and from different depths using small triers. After the analysis of the samples for different parameters, the sampled seed material was returned back to the respective structures except for 5 g of seeds which was utilised for estimating moisture percentage as well as 400 seeds for germination test.

3.1.6 Observations

The following were the observations made on the sample drawn from all the treatments every month.

a) Live and dead *S.oryzae* beetles in 300 g sample

The structures were shaken well before sampling. Three hundred gram of seed was sampled out and sieved for seperating grain and beetles, live and dead beetles were counted and recorded. The live and dead beetles were transfered back into the respective storage structures after counting.

b) Per cent adult nibbled and holed seeds

100 seeds were picked at random from the sample, drawn every month from each treatment structures. The seeds were observed individually under bright light for the nibbling damages such as scratches and scrapings by *S.oryzae* which was expressed in percentage.

The same 100 seeds selected for adult nibbling damage observation were observed individually for emergent holes caused by the adult beetle while emerging out of seeds and was expressed in percentage.

c) Weight loss in grams

Thousand seeds were randomly counted out of the monthly sample from each treatment by using counting board (Fig.8). The initial weight was recorded in grams. Subsequently similar observations were made at monthly interval. The difference between two such observations is the weight loss (in grams).

d) Percentage of germination

To find out the effect of insect damage and storage structure on seed germination, the latter was tested. The method adopted was by 'paper towelling' method, where in 100 seeds (Fig.9) replicated four times obtained from the monthly sample of each structure were subjected for germination test in germination chamber. The temperature and relative humidity of the germinator were maintained at 25-30°C and 85 to 90 per cent RH, respectively. Two counts were made, the first being on 5th day and the second on 10th day (Anon, 1966). Number of normal, abnormal, and dead and diseased were counted and expressed in percentage.

e) Seed moisture in percentage

5 g of seeds was set apart from monthly sample drawn from each structure for estimating the per cent seed moisture. The moisture content of the seed was determined by the

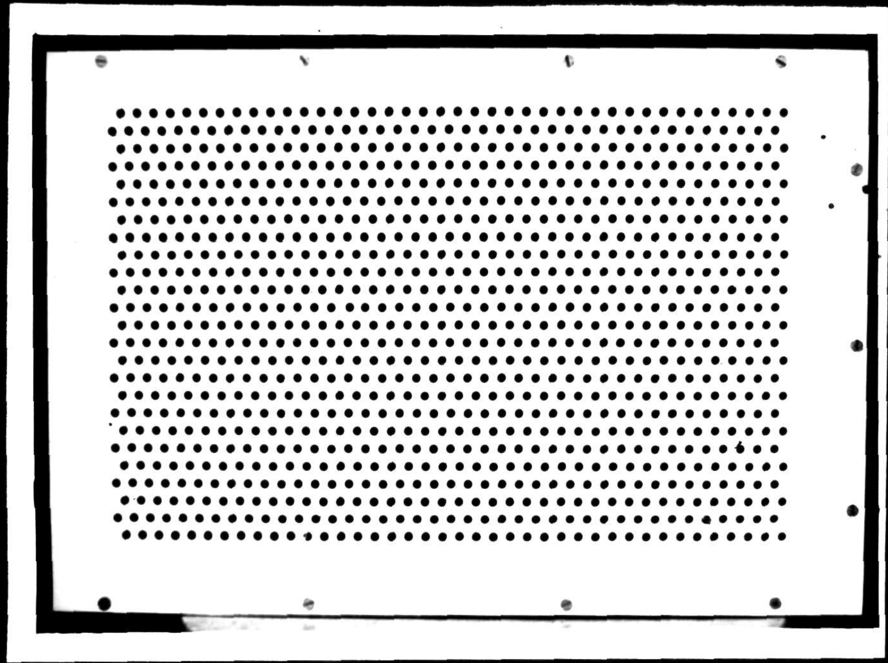

Fig.8. Seed counting board

Fig.9. Paper towel method for standard germination test

'gravimetric method'. Five g seeds were heated in an electrical oven maintained at 130°C (±2°C) for a period of two hours. The final weight was recorded and the moisture content was calculated in percentage on wet basis.

f) Total developmental period

To know whether the storage structures exercised any influence on the total developmental period, a study was conducted where in 5 pairs of one day old beetles were enclosed on 20 sound jowar seeds in a 5 cm x 2 cm glass vial for a period of 24 hours. At the end, the beetles were removed and the vials with seeds along with eggs placed in respective treatment structures. The time of emergence of beetles were noted and from there, the total developmental period was calculated.

g) Population of live and dead beetles at the end of study

To determine the population build up over five months period in different treatment structures, the entire 3 kg seeds were sieved and the beetles were collected in a tray. The live and dead beetles were counted and recorded for each structures in all replications, seperately.

h) Loss in weight of seeds at the end of study

The loss in weight suffered due to infestation by

S.oryzae in different storage structures, the contents of each structures were sieved so as to seperate all the beetles and their excreta from the seeds. The seeds, then was weighed, the weight of 400 seeds and 5 g seeds taken out for germination test and moisture content estimations respectively during all the five months were added to the above weight. The loss in weight of 3 kg of seeds was computed by deducting the weight of seeds noted at the end of study in each structures.

3.2 Influence of storage structures on the effectiveness of fumigants

A study was carriedout to determine the influence of different storage structures on the relative effectiveness of two fumigants during April-July 1979. For this purpose, the seven storage structures mentioned and described earlier were used. Each structure was filled with 3 kg of CSH-1 hybrid jowar seeds,(3.1.2). Into each structure, 250, 15 days old, unsexed *S.oryzae* beetles were released. Twentyfour hours after release, fumigation was carriedout using two fumigants namely EDB and ED/CT at 0.409 kgs/100 C.m and 2.727 kgs/100 C.m respectively. The dosage required per structure was computed volume/volume basis (Table-II). The measured quantity of fumigants was administered into absorbent cotton

Table No.II: Dosage of Fumigants

Storage structures	Vol.in C.mt/ (C.ft)	Fumigants	
		EDCT/ structure(ml)	EDB/structure (ml)
1. Metal bin	0.0061 (0.2139)	1.47	0.14
2. Plywood bin	0.0097 (0.3407)	2.35	0.22
3. Plastic container	0.0052 (0.1822)	1.25	0.12
4. Gunny bag lined with polythene(700 gauge)	0.1126 (1.474)	10.18	0.93
5. Vadai	0.0046 (0.1615)	1.11	0.10
6. Earthern pot	0.0077 (0.2716)	1.87	0.17
7. Bamboo bin	0.0070 (0.2466)	1.70	0.16

wool on a piece of paper kept on surface of seed mass and then structures were closed and sealed appropriately.

Cellophane tape was used to seal the metal bin, plywood bin and plastic container. The polythene bag (lining) was heat sealed and the outside gunny bag was folded and secured with a rubber band. The vadai, Earthern pot, and Bamboo bin was sealed at inlet using slurry made up of cowdung and red earth in 1 : 1 proportion. The treatments were replicated two times. After an exposure period of 5 days, the following observations were made:

1. Extent of mortality of beetles among 250 beetles released after 120 hours of exposure.
2. Time taken for death of residual population of the beetles.
3. Percentage of damage to seeds as influenced by structures and fumigants.
4. Effect of structures and fumigants on seed germination expressed in percentage.

After above observations the seed material was returned to respective storage structures and then structures were sealed at inlet portions. One and half month later (46th day) the structures were opened to record the following observations:

1. Number of beetles found emerged.
2. Per cent adult nibbled and holed seeds.
3. Percentage of germination.
4. Loss in weight of stored jowar

The data was statistically analysed.

3.3 Determination of optimum seed moisture for the attack growth and development of S.oryzae

To determine the optimum seed moisture, for the development of S.oryzae, an experiment was conducted during January-March, 1979. In which adequate quantity of jowar seeds with an initial moisture content of 11 per cent, spread in petri-dishes, were kept in dessicators maintaining different ranges of relative humidities by virtue of saturated solutions of appropriate salts contained in those dessicators. The different salts used were as follows:

Salts	RH maintenance in per cent	Salts	RH maintenance in per cent
Zinc chloride	10	Sodium nitrate	63
Potassium acetate	22	Sodium chloride	75
Magnesium chloride	32	Potassium chromate	86
Potassium carbonate	43	Potassium nitrate	90
Magnesium nitrate	51	Water	100

As the moisture content of the seed was greatly influenced by the surrounding atmospheric humidity and thus seeds with different moisture content was obtained in different RH which were determined by 'dry oven method' (Anon, 1950). Four weeks after introduction of seeds into those surrounding atmosphere. As it look a maximum of 8 days for the seeds to attain equilibrium moisture content (hence forth refered to as EMC) through desorption and 27 days through adsorption (Rangaswamy, 1973) in case of jowar seeds, a safe limit of 4 weeks was allowed to facilitate the jowar seeds to attain EMC with corresponding relative humidities. Such conditions grains numbering 50 were then introduced into specimen tubes of (5 cm x 2 cm) along with 5 pairs one day old *S.oryzae* beetles and kept in the respective dessicators. Altogether there were 10 treatments replicated three times. After one day, the beetles were removed from the specimen tubes which were then covered with muslin cloth. Total developmental period, number of beetles emerged, per cent adult nibbled and holed seeds were recorded. The growth index was computed as per method described by Punj (1967).

3.4 Evaluation of sorghum genotypes for their relative suceptibility to the attack of *S.oryzae*

Seventeen sorghum genotypes were screened for their relative susceptibility to *S. oryzae* during March-May, 1979. The genotypes, comprising hybrids, varieties and inbred were obtained from sorghum breeder, Regional Research Station, UAS, Dharwad. These were free from insect infestation initially. The 17 genotypes tested were CSH-1, CSH-2, CSH-5, CSH-6, CS3541, SB-401, SB-461, SB-905, SB-1066, SB-1079, A, B, C, D, E, F and 148.

The seeds of all genotypes were conditioned at 30°C under 75 per cent RH for 10 days to raise moisture content to 13 to 14 per cent as suggested by Singh *et al*., (1968).

3.4.1 Free choice random distribution test

Round plastic germination tray (Fig. 10) was divided into seventeen compartments by erecting card board pieces at the periphery of the tray, then centre of the tray was kept open without any dividing wall where *S. oryzae* were released. Five gram each of 17 genotypes were kept in each compartment and 200, 7 days old beetles were released in the centre. The 17 treatments, were replicated thrice. Tray was covered with a see through polythene on which pin holes were made for the purpose of aeration. Number of beetles congregating at each genotypes was noted every day, over a period of a week. At the end of this period of observation, seeds of 17 genotypes were each transferred into the specimen tubes (5cm x 2cm size) and covered with muslin cloth. The study was

Fig. 10. Random distribution test for screening genotypes-plastic box with required compartments.

conducted at 28 ± 2°C under 75 per cent RH. The relative suceptibility was determined thus:

1. Number of beetles congregating at seeds of genotype of each on every day over one week.

2. Number of beetles emerging commencing from 24th day after enclosing seeds.

3. Per cent adult nibbled and holed seeds.

4. Reduction in weight of 5 g of seeds (in g).

3.4.2 No choice confined test

Under this testing situation seeds of 17 genotypes were screened for their relative suceptibility to S.oryzae by enclosing 5 g of conditioned seeds along with 5 pairs of 3 days old S.oryzae in a '5cm x 2cm' specimen tube. After one day, by which time egg would have been laid, the beetles were removed from the tubes which were then covered with muslin cloth. The experiment consisted of 17 treatments and was relicated three times, and was conducted at 28 ± 2°C and 75 per cent RH. Teh amount of relative suceptibility was based on the following observations.

1. Number of beetles emerging from 5 g seeds.

2. Weight of 5 beetles.

3. Total developmental period (days).

4. Per cent adult nibbled and holed seeds.

5. Reduction in weight of 5 g seeds.

The data was subjected to statistical analysis and varieties were grouped into least suceptible, moderately suceptible and highly suceptible categories based on mean and standard deviation.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

4.1 Evaluation of Storage Structures

The study to evaluate seven storage structures (models) namely metal bin, plywood bin, plastic bin, gunny bag lined with polythene, vadai, earthern pot and bamboo bin for their relative efficacy in efficient seed storage and protecting seeds from insect infestation was carried out over a period of five months. The results are detailed in Table III to VII.

4.1.1(a) Live Beetles

The sample drawn from all the seven storage structures revealed the minimum number of living beetles in gunny bag lined with polythene during all the five months of study period (2.00, 38.66, 78.33, 155.66, 200.66). The maximum number of living beetles were found in bamboo bin during all the five montns of the study (3.66, 67.66, 131.00, 254.33, 299.66).

None of the storage structures differed significantly between themselves during the first month. However, in the subsequent months gunny bag lined with polythene, plastic bin, plywood bin and metal bin although did not differ significantly among themselves but differed significantly from

Table No.III: Insect survival, seed damage, seed weight loss and germination in different storage structures during first month

Mean Monthly Atmospheric Temperature : 23.8°C   Mean Monthly Room Temperature : 25.71°C
Mean Monthly Atmospheric RH : 79%   Mean Monthly Room RH : 76.20%

(Initial 1000 seed weight : 30.76 g)

Sl. No.	Storage structures (treatments)	No.of beetle/ 300 g sample		% seeds damaged		Weight loss in g	% of germination			Temperature in the storage (°C)	RH in the storage (%)	Moisture content of seeds (%)
		Living	Dead	Adult nibbing	Holed seeds		Normal	Abnormal	Dead & diseased			
1.	Metal bin	2.33	1.33 (1.34)*	14.33	2.00	0.02	67.00 (54.92)**	1.33 (5.33)	31.66 (34.24)	29.3	65.0	12.95
2.	Plywood bin	2.33	0.66 (1.05)	13.33	2.33	0.04	66.00 (54.32)	1.66 (5.54)	32.33 (34.65)	28.0	65.3	13.50
3.	Plastic bin	2.00	0.66 (1.05)	16.00	3.00	0.04	65.33 (53.94)	1.33 (5.33)	33.33 (35.25)	27.0	65.0	13.23
4.	Gunny bag lined with polythene	2.00	1.00 (1.22)	13.66	3.33	0.08	66.00 (54.27)	1.66 (5.54)	32.33 (34.63)	27.6	67.6	12.96
5.	Vadai	4.33	0.33 (0.87)	21.66	4.66	0.27	66.00 (54.27)	1.00 (5.13)	33.00 (35.05)	27.0	67.0	12.63
6.	Earthern pot	3.66	0.00 (0.70)	19.33	4.66	0.52	66.33 (54.33)	1.66 (5.54)	32.00 (34.44)	27.3	67.0	12.53
7.	Bamboo bin	3.66	0.00 (0.70)	20.33	5.33	0.67	66.33 (54.33)	1.66 (5.54)	32.00 (34.45)	28.00	67.0	12.10
Source: C.D.5%		-	0.36	3.24	1.70	0.07	-	-	-			

Note: * The values mentioned in the parenthesis are square root transformed values
** The values mentioned in the parenthesis are Angular transformed values

Table No. IV: Insect survival, seed damage, seed weight loss and germination in different storage structures during second month

Mean Monthly Atmospheric Temperature : 25.3°C Mean Monthly Room Temperature : 27.96°C
Mean Monthly Atmospheric RH : 57% Mean Monthly Room RH : 66.04%

(Initial 1000 seed weight : 30.76 g)

Sl. No.	Storage structures (treatments)	No. of beetle/300 g sample		% seeds damaged		Weight loss in g	% of germination			Temperature in the storage (°C)	RH in the storage (%)	Moisture content of seeds (%)
		Living	Dead	Adult nibbing	Holed seeds		Normal	Abnormal	Dead & diseased			
1.	Metal bin	34.33	8.00	12.66	5.00	0.32	64.00 (53.46)	1.66 (7.33)	34.33 (35.86)	28.0	59.0	12.00
2.	Plywood bin	36.33	9.00	14.33	4.33	1.07	63.66 (52.93)	2.00 (7.95)	34.33 (35.86)	28.0	64.0	12.20
3.	Plastic bin	38.66	9.33	16.00	4.33	0.58	63.33 (52.53)	1.66 (7.33)	35.33 (36.47)	28.0	60.0	12.10
4.	Gunny bag lined with polythene	38.66	11.00	13.66	5.33	0.63	62.66 (52.53)	2.00 (8.13)	35.33 (36.47)	27.0	50.3	11.96
5.	Vadai	56.33	7.33	21.67	8.00	1.00	61.00 (51.35)	1.66 (7.15)	37.33 (37.65)	28.0	49.0	11.20
6.	Earthern pot	52.33	6.00	21.00	10.33	1.22	59.33 (50.38)	1.66 (7.33)	39.00 (38.64)	28.0	48.6	11.16
7.	Bamboo bin	67.66	5.33	22.67	10.66	1.67	59.66 (50.76)	1.66 (7.33)	38.66 (38.45)	28.6	56.3	11.00
Source: C.D.5%		12.83	-	3.35	2.62	0.26	1.54	-	1.50			

Note: The values mentioned in the paranthesis are Angular transformed values

Table No.V: Insect survival, seed damage, seed weight loss and germination in different storage structures during third month.

Mean Monthly Atmospheric Temperature : 27.8°C Mean Monthly Room Temperature: 29.59°C
Mean Monthly Atmospheric RH : 58.0, Mean Monthly Room RH : 64.91%

(Initial 1000 seed weight : 30.76 g)

Sl. No.	Storage Structures (treatments)	No.of beetle/ 300 g sample		% seeds damaged		Weight loss in g	% of germination			Temperature in the storage (°C)	RH in the storage (%)	Moisture content of seeds (%)
		Living	Dead	Adult nibbing	Holed seeds		Normal	Abnormal	Dead & diseased			
1.	Metal bin	80.00	15.66	25.33	9.00	0.62	62.66 (52.33)	2.00 (7.95)	35.33 (36.47)	27.6	61.3	12.60
2.	Plywood bin	80.00	17.66	24.00	8.00	1.05	62.33 (52.16)	2.33 (8.74)	35.33 (36.27)	28.0	57.6	12.33
3.	Plastic bin	80.33	18.66	22.00	9.33	0.64	62.00 (51.94)	2.00 (7.95)	36.00 (36.27)	28.0	64.0	12.33
4.	Gunny bag lined with polythene	78.33	22.33	22.00	11.66	0.82	61.66 (51.74)	2.66 (9.36)	35.66 (36.53)	28.0	61.6	11.86
5.	Vadai	106.33	15.00	33.66	17.00	1.03	59.66 (50.57)	2.66 (9.36)	37.66 (37.85)	28.0	54.0	11.06
6.	Earthern pot	106.66	11.33	27.66	12.00	1.33	58.66 (49.99)	2.33 (8.56)	39.00 (38.64)	28.0	53.3	11.20
7.	Bamboo bin	131.00	11.00	35.66	15.33	1.71	57.00 (49.02)	2.66 (9.08)	40.33 (39.42)	28.0	58.3	11.10
Source: C.D.5%		24.84	-	9.10	3.33	0.30	1.03	-	1.39			

Note: The values mentioned in the parenthesis are angular transformed values

Table No.VI: Insect survival, seed damage, seed weight loss and germination in different storage structures during fourth month.

Mean Monthly Atmospheric Temperature : 23.2 °C
Mean Monthly Atmospheric RH : 61.00%
Mean Monthly Room Temperature : 28.64 °C
Mean Monthly Room RH : 67.58%

(Initial 1000 seed weight : 30.76 g)

Sl. No.	Storage Structure (treatments)	No.of beetle/ 300 g sample		% seeds damaged		Weight loss in g	% of germination			Temperature in the storage (°C)	RH in the storage (%)	Moisture content of seeds (%)
		Living	Dead	Adult nibbing	Holed seeds		Normal	Abnormal	Dead & diseased			
1.	Metal bin	157.00	29.33	32.00	13.33	1.25	60.33 (50.96)	2.66 (9.36)	37.00 (37.46)	31.6	64.3	12.50
2.	Plywood bin	156.33	31.00	31.66	16.33	1.38	59.66 (50.57)	2.66 (9.36)	37.66 (37.86)	29.6	53.6	12.4
3.	Plastic bin	154.33	33.33	29.33	15.33	1.39	59.33 (50.37)	2.33 (8.74)	38.33 (38.25)	30.0	68.0	12.6
4.	Gunny bag lined with polythene	155.66	39.33	38.00	17.00	1.38	60.00 (50.76)	3.00 (9.98)	37.00 (37.46)	28.6	60.0	12.26
5.	Vadai	204.33	27.33	43.00	21.00	1.73	57.00 (49.02)	3.00 (9.88)	40.00 (39.23)	28.0	53.0	12.10
6.	Earthern pot	211.66	22.66	45.00	24.66	1.76	57.66 (49.41)	2.66 (9.36)	39.66 (39.03)	28.6	54.3	12.0
7.	Bamboo bin	254.33	21.66	46.00	27.33	1.84	55.00 (47.86)	3.00 (9.88)	42.00 (40.40)	30.6	51.3	12.0
Source: C.D.5%		44.05	-	6.33	6.73	-	0.96	-	1.03			

Note: The values mentioned in the paranthesis are Angular transformed values

Table No.VII: Insect survival, seed damage, seed weight loss and germination in different storage structures during fifth month.

Mean Monthly Atmospheric Temperature : 25.4°C Mean Monthly Room Temperature : 26.12°C
Mean Monthly Atmospheric RH : 75.5% Mean Monthly Room RH : 79.12%

(Initial 1000 seed weight : 30.76 g)

Sl. No.	Storage structures (treatments)	No.of beetle/ 300 g sample		% seeds damage		Weight loss in g	% of germination			Temperature in the storage (°C)	R.H in the storage (%)	Moisture content of seeds (%)
		Living	Dead	Adult nibbing	Holed seeds		Normal	Abnormal	Dead and diseased			
1.	Metal bin	204.33	49.33	39.66	20.00	1.74	58.00 (49.6)	3.00 (9.88)	39.00 (38.64)	29.0	74.0	13.03
2.	Plywood bin	203.33	50.00	39.33	21.00	1.79	56.00 (48.44)	3.33 (10.50)	40.66 (39.62)	28.0	73.0	13.2
3.	Plastic bin	200.33	51.66	41.00	23.00	2.01	55.00 (47.86)	2.66 (9.36)	42.33 (40.59)	29.0	74.0	13.23
4.	Gunny bag lined with polythene	200.66	57.66	42.33	28.00	2.20	57.00 (49.02)	3.66 (11.02)	39.33 (38.84)	28.0	72.6	13.00
5.	Vadai	252.33	41.33	48.00	40.66	2.71	52.00 (46.14)	3.66 (11.02)	44.33 (41.74)	27.0	71.0	12.63
6.	Eartnern pot	258.66	37.66	53.00	38.33	2.80	53.00 (46.72)	3.66 (11.02)	43.33 (41.16)	27.0	72.0	12.36
7.	Bamboo bin	299.66	38.00	5[illegible].66	44.66	3.25	57.00 (45.57)	3.66 (10.86)	45.35 (42.32)	26.0	69.0	12.00
Source: C.D.5%		43.94	-	4.35	10.[illegible]	[illegible].33	1.[illegible]	-	1.96			

Note: The values [illegible] are angular transformed values bamboo bin, earthern pot and vadai. The ranking of the storage structures based on this parameter was thus: gunny bag lined with polythene > plastic bin > plywood bin > metal bin > vadai > earthern pot > bamboo bin.

4.1.1(b) Dead beetles

The highest number of dead beetles was recorded in gunny bag lined with polythene (1.00, 11.00, 22.83, 39.33, 57.66 beetles) during the entire five months period which was significantly superior to bamboo bin which recorded the lowest (0.00, 5.33, 11.00, 21.66, 38.00 beetles) number of beetles. However, during the first month metal bin (1.33 beetles) had a slight edge over gunny bag lined with polythene (1.00 beetles). In the second month, treatments showed no significant difference among themselves. During third and fourth months a significant difference was noticed between gunny bag lined with polythene (22.33 and 39.33 beetles) and bamboo bin (11.00 and 21.66 beetles) and earthern pot (11.33 and 22.66 beetles) respectively. In the fifth month no significant difference was noticed between or among the first four structures (T_1 - T_4) but gunny bag lined with polythene (57.66 beetles) differed significantly from earthern pot (37.66 beetles), bamboo bin (38.00 beetles) and vadai (41.33 beetles). Based on the above two parameters living and dead beetles, the results have revealed gunny bag lined with polythene as the superior structure followed by plastic bin, plywood bin, metal bin, vadai, earthern pot and bamboo bin.

4.1.2 Seed Damage

4.1.2(a) Adult nibbling

Results of the study on the percentage of seed damaged by adult nibbling revealed that the seed damage was minimum in plywood bin (13.33, 14.33, 24.00, 31.66, 39.33 per cent) and maximum in bamboo bin during all the five months of study (20.33, 22.67, 35.66, 46.00, 59.66 per cent).

During and upto first three months, the difference between plywood bin, metal bin, plastic bin and gunny bag lined with polythene was not significant but they differed significantly from vadai, earthern pot and bamboo bin. However, during the fourth month plastic bin (29.33 per cent), plywood bin (31.66 per cent) and metal bin (32.00 per cent) were on par but differed significantly from gunny bag lined with polythene (38.00 per cent). The latter was on par with vadai (43.00 per cent) but differed significantly from earthern pot (45.00 per cent) and bamboo bin (46.00 per cent). In the fifth month plywood bin (39.33 per cent) differed from metal bin (39.66 per cent), plastic bin (41.00 per cent) and gunny bag lined with polythene (42.33 per cent) in its performance of keeping seed damage to the minimum but the difference was not significant.

However, vadai (48.00 per cent), earthern pot (53.00 per cent) and bamboo bin (59.66 per cent) differed significantly among themselves and were significantly inferior to the above structures. Making use of the above parameter, the storage structures were ranked as follows: plywood bin > metal bin > plastic bin > gunny bag lined with polythene> earthern pot > vadai > bamboo bin.

4.1.2(b) Holed seeds

The minimum per cent holed seeds were recorded (Fig.11) from metal bin (2.00, 5.00, 90.00, 13.33 and 20.00 per cent) during all the five months of storage which was significantly less than bamboo bin (5.33, 10.66, 18.33, 27.33 and 44.66 per cent). During first month metal bin (2.00 per cent), plywood bin (2.33 per cent), plastic bin (3.00 per cent) and gunny bag lined with polythene (3.33 per cent) were all on per with each other. Earthern pot (4.66 per cent), vadai (4.66 per cent) and bamboo bin (5.33 per cent) differed significantly from the above four structures. Same trend was seen to be maintained throughout five months period of study with metal bin, plywood bin, plastic bin and gunny bag lined with polythene recording 20.00, 21.00, 23.00 and 28.00 per cent holed seeds, respectively, which were not significantly different among themselves, but differed significantly from

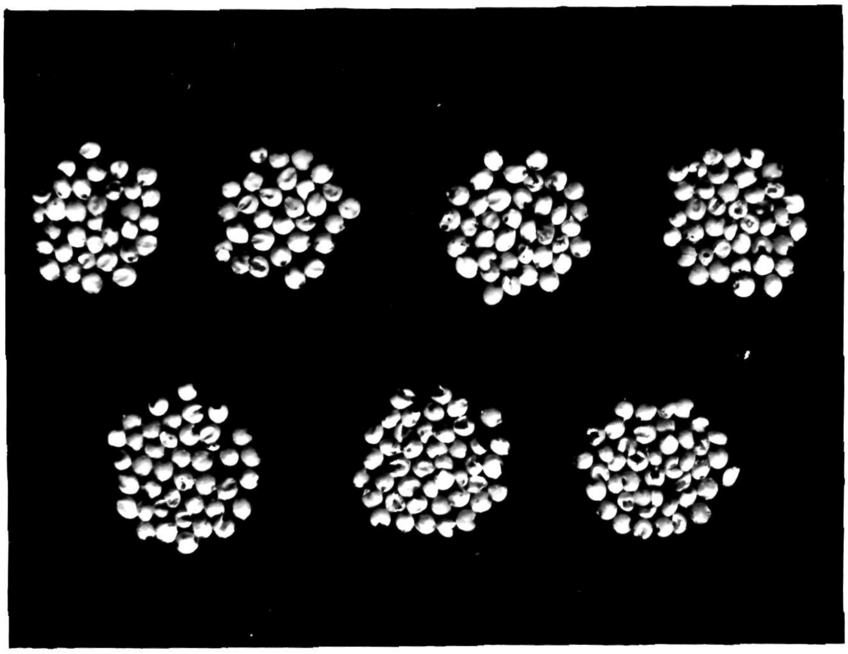

Fig.11. Holes seeds observed in different storage structures.

Upper row (L to R) : Metal bin, Plywood bin, Plastic bin, Gunny bag lined with polythene.

Lower row (L to R) : Vadai, Earthern pot, Bamboo bin.

earthern pot (38.33 per cent), Vadai (40.66 per cent) and bamboo bin (44.66 per cent) at the end of the period of study.

Based on the per cent seed damage, the structures occupied following positions: metal bin > plywood bin > plastic bin > gunny bag lined with polythene > earthern pot > vadai > bamboo bin. The efficiency of first four storage structures was almost an equal performance excepting slight non-significant differences.

4.1.3 Weight loss (in g)

The weight loss due to larval feeding and adult nibbling was observed to be the lowest in metal bin (0.02, 0.32, 0.62, 1.25, 1.74 g) during five months of study period which was significantly lower than vadai (0.27, 1.00, 1.03, 1.73 and 2.71 g), earthern pot (0.52, 1.22, 1.33, 1.76 and 2.80 g) and bamboo bin (0.67, 1.67, 1.71, 1.84 and 3.23 g).

During first month of storage, metal bin (0.02 g), plywood bin and plastic bin (0.04 g), and gunny bag lined with polythene (0.08 g) were all on par with each other, all of them differed significantly from vadai (0.27 g), earthern pot (0.52 g) and bamboo bin (0.67 g), the lost three structures showing significant differences. In subsequent months till fourth month metal bin was on top with the least loss incurred (0.32, 0.62, 1.25 g) followed by plastic bin (0.58, 0.64, 1.39 g) and gunny bag lined with polythene (0.63, 0.82, 1.38 g) all three being significantly superior to plywood bin (1.07, 1.05, 1.38 g loss). During fifth month metal bin (1.74 g), plywood bin (1.79 g) and plastic bin (2.01 g) were all at par but differed significantly from gunny bag lined with polythene (2.20 g), which, in turn was observed to differ significantly from vadai (2.71 g) and earthern pot (2.80 g) and the last two were on par, but significantly was superior to bamboo bin (3.23 g) which accounted for the highest loss in weight of seeds. Following is the ranking of seven storage structures based on loss in seed weight: metal bin > plastic bin > gunny bag lined with polythene = plywood bin > vadai > earthern pot > bamboo bin.

4.1.4 <u>Germination</u>

4.1.4.(a) <u>Normal seedlings</u>

The percentage of normal seedlings obtained by standard germination test conducted on samples drawn from seven storage structures on monthly interval was the highest in metal bin (67.00, 64.00, 62.66, 60.33 and 58.00 per cent) followed by plywood bin (66.00, 63.66, 62.33, 59.66, 56.00 per cent) gunny bag lined with polythene (66.00, 62.66, 61.66, 60.00, 57.00 per cent) and plastic bin (65.33, 63.33, 62.00, 59.33, 55.00 per cent) during first four months of storage. Vadai (66.00, 61.00, 59.66, 57.00, 52.00 per cent), earthern pot (66.33, 59.33, 58.66, 57.66, 53.00 per cent) and bamboo bin

(66.33, 59.66, 57.00, 55.00, 51.00) recorded significantly lower percentage of normal seedlings as compared to the above four structures. Vadai and earthern pot did not differ significantly between themselves but differed significantly from bamboo bin. In the fifth month of storage, metal bin (58.00 per cent) was on par with gunny bag lined with polythene (57.00 per cent) but differed significantly from ply wood bin (56.00 per cent), plastic bin (55.00 per cent), earthern pot (53.00 per cent), vadai (52. per cent) and bamboo bin (51.00 per cent). The ranking based on their relative favourability for normal seedlings over five months of storage was as follows: metal bin > plywood bin > gunny bag lined with polythene > plastic bin > vadai > earthern pot > bamboo bin.

4.1.4.(b) <u>Abnormal seedlings</u>

Plastic bin accounted for (1.33, 1.66, 2.00, 2.33, 2.66) the least percentage of abnormal seedlings. It was followed by metal bin, earthern pot, plywood bin, vadai, bamboo bin and gunny bag lined with polythene. F-test proved to be non-significant during all the entire five months period of study and as such the percentage of abnormal seedlings in different ~~storage~~ storage structures did not differ significantly.

4.1.4.(c) Dead and Diseased

The least percentage of dead and diseased were observed in metal bin (31.66, 34.33, 35.33, 37.00, 39.00 per cent) during all the entire five months of study period, followed by gunny bag lined with polythene, plywood bin and plastic bin all four structures being on par with each other. The bamboo bin had the highest percentage of dead and diseased (32.00, 38.66, 40.33, 42.00, 45.33 per cent) seeds. During first month of storage none of the seven structures showed significant differences. In the second month metal bin, gunny bag lined with polythene, plywood bin and plastic bin accounted for significantly less dead and diseased seeds than vadai (37.33 per cent), bamboo bin (38.66 per cent) and earthern pot (39.00 per cent), the last three being on par with each other. During third to fifth month vadai with 37.66 40.00 and 44.33 per cent and earthern pot with 39.00, 39.66 and 43.33 per cent dead and diseased seeds were on par but proved significantly superior in recording less dead and diseased seeds than bamboo bin which accounted for the high per cent of dead and diseased seeds 40.33, 42.00 and 45.33 compared to all.

4.1.5 Weight loss (at the end of study)

Metal bin registered the least loss in weight of seeds (273 g constituting 9.1 per cent) compared to the highest loss in weight of seeds by bamboo bin (429 g constituting

14.30 per cent), which was significantly inferior to all other (Table VIII). Metal bin, plywood bin (278.33 g constituting 9.27 per cent) and plastic bin (302.66 g constituting 10.08 per cent), did not show significant differences among themselves, on the other hand, plastic bin and gunny bag lined with polythene which were on par with each other differed significantly superior in accounting for less loss in seed weight compared to vadai, earthern pot and bamboo bin. Vadai and earthern pot did not differed significantly among them. Based on the above parameter, the structures are ranked thus: metal bin > plywood bin > plastic bin > gunny bag lined with polythene > vadai > earthern pot > bamboo bin.

4.1.6 <u>Total developmental period of</u> <u>S.oryzae</u>

The studies on evaluation based on the total development period of <u>S.oryzae</u> (Table-VIII) in the seven storage structure revealed a longest period of 36.66 days in metal bin which was significantly higher compared to vadai (34.66 days), earthern pot and bamboo bin (34 days), the last two being on par. Metal bin, plastic bin (36.33 days), plywood bin (36.13 days) and gunny bag lined with polythene (36.0 days) favouring comparatively longer developmental period, were all on par. Based on the relative performance in respect of the above parameter structures occupied following positions: metal bin

Table No.VIII: Developmental period, population buildup of *S.oryzae* and final Seed weight loss in different storage structures.

Sl. No.	Storage Structures	Total developmental period(in days) of *S.oryzae*	Population build up at the end of Expt. (5 months)		Weight loss at the end of Expt. ie., 5 months in g.	% weight loss at the end of 5 months
			Living	Dead		
1.	Metal bin	36.66	11,105.00	592.55	273.00	9.1
2.	Plywood bin	36.16	11,212.66	705.00	278.33	9.27
3.	Plastic bin	36.33	11,411.33	719.00	302.66	10.08
4.	Gunny bag lined with polythene	36.00	11,415.00	681.00	320.00	10.66
5.	Vadai	34.66	12,105.33	447.66	372.33	12.41
6.	Earthern pot	34.00	12,661.33	344.66	380.00	12.66
7.	Bamboo bin	34.00	13,396.33	295.33	429.00	14.30
	Source:					
	C.D.5%	1.41	111.15	93.84	34.19	

$>$ plastic bin $>$ plywood bin $>$ gunny bag lined with polythene $>$ vadai $>$ earthern pot and bamboo bin.

4.1.7 <u>population of *S.oryzae* at the end of study (fifth month)</u>

The results of the study are presented in Table-VIII. The population of test insect at the end of study was measured in terms of number of live and dead beetles.

4.1.7(a) <u>Live beetles</u>

The least number of live *S.oryzae* were recorded from metal bin (11,105) which was significantly the lowest in comparison to bamboo bin (13,396.33), earthern pot (12,661.33), vadai (12,105.33), gunny bag lined with polythene (11,415.00) and plastic bin (11,411.33). The highest number of live beetles were recorded in bamboo bin which was significantly was most inferior ever all other structures. Metal bin was on par with plywood bin (11,212.66) but both differed significantly from all others, plastic bin and gunny bag lined with polythene too, did not differ significantly.

4.1.7(b) <u>Dead beetles</u>

Plastic bin (719.00) accounted for the highest number of dead beetles, on the contrary, the least number of dead beetles were observed in bamboo bin (295.33). Plastic bin, plywood bin (705.00) and gunny bag lined with polythene

(681.00), did not differed significantly among them. While metal bin (592.66), vadai (447.66) and earthern pot (344.66), recorded significantly lesser number of dead beetles as compared to the former three structures. Again, bamboo bin (295.33) and earthern pot (344.66) did not differed statistically in the number of dead beetles found in them.

The relative position occupied by the seven storage structures based on this parameter was as follows: plywood bin > plastic bin > metal bin > gunny bag lined with poly thene > vadai > earthern pot > bamboo bin.

Analysis of results of study based on cumulative performance of seven storage structures in respect of seven parameters, metal bin emerged as the outstanding structure, followed by plywood bin, gunny bag lined with polythene and plastic bin.

On the contrary, structures which are in use in the rural areas are observed to be inferior to the above four structures. Of the three rural structures vadai tops in the relative performance followed by earthern pot and bamboo bin. The last mentioned proving to be the most inferior of all structures tested in the study.

4.2 Studies on the relative influence of storage structures on the action of fumigants

The relative influence of seven storage structures on the action of two commonly used fumigants namely Ethylene dibromide (EDB) and Ethylene dichloride + carbon tetrachloride (ED/CT) in protecting the seeds were assessed through the extent of insect mortality, seed damage caused, seed germination and weight loss over a period of 45 days. The results are presented in Table-IX to XVI.

4.2.1 Mortality of beetles caused by fumigants and storage structures

4.2.1(a) After 120 hr of exposure

Mortality of beetles caused by two fumigants and seven storage structures were assessed after 120 hr of exposure of seeds to the action of fumigants. Further, time taken to cause the death of residual population of beetles was also examined in order to determine the varying influence of different storage structures on the action of fumigants. The results are furnished in Table-IX.

The influence of storage structure on the number of dead beetles was found to be significant. The number of dead beetles observed were more in metal bin (246.75) and the least number of dead beetles were observed in bamboo bin, metal bin, ply wood bin (245.5), plastic bin (245.0) and gunny bag lined

Table No.IX: Mortality of beetles 120 hr after fumigation and the time taken for complete kill of the residual population in different storage structures.

Sl. No.	Storage structures	No. of dead beetles			Time taken for the death of Residual Population (in days)		
		EDB	ED/CT	Means	EDB	ED/CT	Means
1.	Metal bin	246.5	247.0	246.75	1.0 (1.14)	1.5 (1.28)	1.25 (1.21)
2.	Plywood bin	243.0	248.0	245.5	0.0 (0.70)	0.5 (0.96)	0.25 (0.83)
3.	Plastic bin	244.5	245.5	245.0	0.0 (0.70)	0.5 (0.96)	0.25 (0.83)
4.	Gunny bag + Polythene.	242.0	241.0	241.5	2.0 (1.58)	2.5 (1.72)	2.25 (1.65)
5.	Vadai	230.0	225.5	227.75	9.0 (3.07)	10.0 (3.23)	9.50 (3.16)
6.	Earthern pot	235.5	232.0	233.5	14.0 (3.78)	15.0 (3.91)	14.50 (3.85)
7.	Bamboo bin	146.0	126.0	136.0	21.5 (4.67)	27.5 (5.28)	24.50 (4.98)
	Means	226.71	223.57		6.79 (2.24)	8.21 (2.48)	

	Str.	Fum.	Str. x Fum.	Str.	Fum.	Str. x Fum.
C.D.5%	8.27	-	-	0.64	-	-

Str.=Structure; Fum.=Fumigant; Str.xFum.=Interaction.

Note: Values in the paranthesis are square root transformed values.

with polythene (241.5) were all on par with each other. Earthern pot (233.5) and vadai (227.75) differed significantly from the above said four structures but did not differ between themselves.

In regard to fumigants, the difference that exists between EDB and ED/CT was in significant. However, EDB was observed to cause slightly higher mortality (226.71 beetles) than ED/CT (223.57 beetles).

The interaction effect between storage structures and mfumigants and its influence on beetle mortality, was observed to be non-significant. ED/CT's action was best pronounced in plywood bin (248.00) followed by Metal bin (247.00) and plastic bin (245.5), while that of EDB in metal bin (246.5) followed by plastic bin (244.05), plywood bin (243.00) and Gunny bag lined with polythene (242.00). EDB's killing effect was better over ED/CT in rural storage structures vadai (230.0), earthern pot (235.5) and bamboo bin (146.0). The last mentioned structure proved to be the most inferior of all structures for fumigation purpose because of lesser mortality of beetles caused by both the fumigants.

4.2.1(b) Time taken for death of residual beetle population

The time taken for death of residual beetle population was 0.25 days in plywood bin and plastic bin as compared to 1.25 days in metal bin. In gunny bag lined with polythene the time taken for death of entire residual number of beetle population was 2.25 days which was significantly longer than the time taken by first mentioned three structures. In bamboo bin the longest time (24.50 days) was required for complete kill of the beetle population. In vadai (9.50 days) and earthern pot (14.50 days) also, required comparitively a longer period for causing death of insects. These two did not differ significantly between themselves but differed significantly from all other.

Among fumigants EDB was observed to take an average of 6.79 days to bring about the death of residual population of beetles in all the storage structures as compared to 8.21 days by ED/CT. The difference between the two fumigants was non-significant.

The interaction effect was observed to be non-significant. Plywood bin, plastic bin, metal bin and gunny bag lined with polythene with EDB required less time (0.00, 0.00, 1.00, 2.00 days, respectively) compared to same structures with ED/CT which required more time (0.5, 0.05, 1.5, 2.5 days, respectively) to cause the death of beetles. On the contrary, vadai, earthern pot and bamboo bin required longer time generally, but with EDB the time taken was compa-ritively less as compared to ED/CT for the death of residual population.

4.2.1(c) Number of live among the beetle emerging 1½ months after fumigation

The structures were examined one and half month after fumigation for live and dead beetles as a reflection of initial killing action of fumigants influenced by storage structures. The results are furnished in Table-X.

Among the storage structures plastic, plywood and metal bins harboured less number of live beetles (1.5, 2.0 4.25 beetles respectively). The difference between them was insignificant. As against this, vadai, earthern pot and bamboo bin accounted for 88.0, 117.0, 133.0 number of live beetles, respectively and differed significantly among them-selves and from the above three structures. Gunny bag lined with polythene contained 10.50 beetles and was superior to vadai, earthern pot and bamboo bin.

With respect to fumigants, the structures fumigated with ED/CT recorded less number of live beetles (46.64 beetles) which is significantly lesser than structures fumigated with EDB (55.14 beetles).

Table No.X: Live and dead among the beetles emerging one and half months after fumigation in different storage structures.

Sl. No.	Storage structures	No.of living beetles EDB	ED/CT	Means	No.of dead beetles EDB	ED/CT	Means
1.	Metal bin	2.5	6.0	4.25	33.0	28.50	30.75
2.	Plywood bin	2.5	1.5	2.0	22.0	23.50	22.75
3.	Plastic bin	1.5	1.5	1.50	20.0	18.0	19.0
4.	Gunny bag + Polythene	12.0	9.0	10.50	56.5	36.0	46.25
5.	Vadai	105.5	70.50	88.0	18.5	19.0	18.75
6.	Earthern pot	119.0	115.0	117.0	24.0	31.5	27.75
7.	Bamboo bin	143.0	123.0	133.0	20.0	14.0	17.00
	Means	55.14	46.64	28.42	24.35		

	Str.	Fum.	Str.xFum.	Str.	Fum.	Str.xFum.
C.D5%	7.55	4.03	10.68	7.51	4.01	-

Str.=Structure; Fum.=Fumigant; Str.xFum.=Interaction

Note: Values in the paranthesis are square root transferred values.

The interaction effect was significant. The difference in the killing action of ED/CT and EDB when used in four structures, namely, plastic,bin, plywood bin, metal bin and gunny bag lined with polythene was not statistically significant. But, live beetles recorded in the above structures under both the fumigants were significantly lesser compared to number of beetles recorded in the other three structures, namely, vadai, earthern pot and bamboo bin under the influence of both the fumigants. In the last mentioned three structures ED/CT accounted for lesser number of live beetles than EDB.

4.2.1(d) Number of dead among the beetles emerging 1½ months after fumigation

Significantly highest number of dead beetles were recorded in gunny bag lined with polythene (46.25 beetles). This was followed by metal bin (30.75 beetles), earthern pot (27.75 beetles), which were all on par with each other. The least number of dead beetles were seen in bamboo bin (17.00 beetles) followed by vadai (18.75 beetles) and plastic bin (19.00 beetles) and plywood bin (22.75 beetles). None of these structures differed significantly. The last mentioned structures were on par with earthern pot.

With respect to fumigants, significantly highest number of dead beetles (28.42 beetles) were recorded in structures where EDB was used as compared to ED/CT (24.35 beetles).

The interaction was found to be insignificant. However, in terms of dead beetles encountered, gunny bag lined with polythene, metal bin, earthern pot with EDB recorded comparitively more number of dead beetles 56.5, 33.0 and 24.0, respectively) as compared with structures in which ED/CT was used (36.00, 28.50 and 31.5 dead beetles). Comparitively vadai, bamboo bin, plastic bin and plywood bin registered least number of dead beetles, under both EDB and ED/CT.

4.2.2 <u>Percent seed damage as influenced by fumigants and storage structures</u>

Influence of seven storage structures on the action of two fumigants in protecting the seed from insect infestation were assessed on the basis of seed damage caused by adult nibbling and larvae (holed seeds) over a period of 120 hours and one and half months. The results are furnished in Table-XI and XII.

4.2.2(a) <u>Percent seed damage by adult nibbling during 120 hr. of exposure</u>

Plastic bin with 15-75 per cent seed damage was significantly better than metal bin (21.50 per cent) and plywood bin (23.00 per cent), the latter two being on par with each other. Gunny bag lined with polythene was also on par with plastic bin and metal bin, vadai, bamboo bin and earthern pot

Table No.XI: Seed damage due to adult nibbling observed 120 hr after fumigation in different storage structures.

Sl. No.	Storage Structure	Percentage of seeds damaged By adult nibbling		
		EDB	ED/CT	Means
1.	Metal bin	23.00 (28.65)	22.00 (26.56)	21.50 (27.61)
2.	Plywood bin	24.00 (29.25)	22.00 (27.94)	23.00 (28.60)
3.	Plastic bin	16.00 (23.41)	15.50 (23.11)	15.75 (23.27)
4.	Gunny bag lined with polythene	20.00 (26.56)	17.00 (24.26)	18.50 (25.41)
5.	Vadai	23.00 (28.65)	37.00 (37.46)	30.00 (33.06)
6.	Earthern pot	26.00 (30.64)	31.00 (33.83)	28.50 (32.24)
7.	Bamboo bin	27.00 (31.30)	32.50 (34.72)	29.75 (33.02)
	Means	22.71 (28.35)	25.00 (29.70)	
	Source:	Str.	Fum.	Str.xFum.
	C.D.5%	3.47	-	4.91

Note: Values in the paranthesis are angular transformed values.

Table No.XII: Extent of seed damage caused by S.oryzae one and half months after fumigation in different storage structures.

Sl. No.	Storage structures	Percent seeds damage by Adult nibbling			Per cent holed seeds		
		EDB	ED/CT	Means	EDB	ED/CT	Means
1.	Metal bin	15.5 (23.18)*	16.5 (23.94)	16.0 (23.56)	5.5 (13.55)	3.0 (9.83)	4.25 (11.69)
2.	Plywood bin	14.0 (21.66)	11.0 (19.35)	12.5 (20.50)	2.5 (9.05)	2.0 (8.13)	2.25 (8.59)
3.	Plastic bin	13.5 (21.55)	15.0 (22.68)	14.25 (22.11)	4.5 (11.73)	4.5 (12.23)	4.5 (11.98)
4.	Gunny bag + Polythyne	15.5 (23.11)	18.0 (25.07)	16.75 (24.09)	10.0 (18.42)	6.5 (15.01)	8.25 (16.59)
5.	Vadai	22.5 (28.31)	26.5 (30.96)	24.5 (29.64)	10.5 (18.90)	12.0 (20.13)	11.25 (19.52)
6.	Earthern pot	37.0 (37.40)	25.5 (30.30)	31.25 (33.85)	13.5 (21.55)	13.0 (21.12)	13.25 (21.33)
7.	Bamboo bin	46.0 (42.70)	37.0 (37.40)	41.50 (40.05)	12.5 (20.95)	20.0 (26.50)	16.25 (23.60)
	Means	23.42 (28.27)	21.35 (27.10)		8.42 (16.27)	8.71 (16.10)	

	Str.	Fum.	Str. x Fum.	Str.	Fum.	Str.x Fum.
CD 5%	4.68	-	-	3.20	-	-

Note: *Values in the paranthesis are angular transformed values.

gave significantly the least protection with higher seed damage of 30.00, 29.75 and 28.50 per cent, respectively.

Fumigants, EDB and ED/CT did not show significant differences in their effectiveness in all the seven structures. However, numerically EDB accounted for lower per cent seed damage (22.71 per cent) compared to ED/CT (25.00 per cent).

The interaction was significant. Four structures namely plastic bin, gunny bag lined with polythene, metal bin and plywood bin using either ED/CT or EDB accounted for significantly less per cent seed damage, respectively, than vadai, earthern pot and bamboo bin both when ED/CT or EDB fumigant was used. ED/CT gave better protection over thatof EDB when used in the first four structures. It was observed to be reverse in the last three structures.

4.2.2(b) Per cent seed damage by adult nibbling 1½ months after fumigation

Lowest per cent seed damage was caused in plywood bin (12.5) followed by metal bin (16.00), plastic bin (14.25) and gunny bag lined with polythene (16.75) which was significantly less compared to vadai (24.5), metal bin (31.25) and bamboo bin (41.50).

Fumigants, though showed no significant differences between the lower seed damage (21.35) was noticed in the structures. Where ED/CT was used in comparision to EDB (23.42 per cent seed damage).

The interaction effect was found to be non-significant. Plastic bin, plywood bin, metal bin and gunny bag lined with polythene with EDB accounted for less seed damage as compared to ED/CT. But ED/CT was observed to perform better than EDB in vadai, earthern pot and bamboo bin.

4.2.2(c) Per cent holed seeds 1½ months after fumigation

Significantly the least damage was observed in plywood bin, metal bin and plastic bin (2.25 to 4.50 per cent holed seeds). Bamboo bin (16.25) showed significantly the highest per centage of holed seeds. Earthern pot with 13.25 and vadai with 11.25 per cent holed seeds were on par and the latter gave almost similar performance as gunny bag lined with polythene.

Both EDB (8.42) and ED/CT (8.71) per cent holed seeds) did not show any statistically appreciable difference between them.

The interaction was not-significant, but plywoodbin Plastic bin, metal bin and gunny bag lined with polythene accounted for less seed damage irrespective of whether EDB or ED/CT used, opposed to seed damage in vadai, earthern pot and Bamboo bin.

4.2.3 Effect of fumigants and storage structures on seed germination

The standard germination test was conducted on sample drawn from seven storage structures after 120 hrs of exposure period and 1½ months after fumigation and per cent normal seedlings, per cent abnormal seedlings and per cent dead and diseased were counted (Table-XIII and XIV).

4.2.3(a) Normal seedlings after 120 hrs of fumigation

No significant difference was found between structures. However, earthern pot registered the highest percentage of germination (65.21) followed by bamboo bin (65.0). The least germination percentage was in metal bin and plywood bin (64.0).

Fumigants were also observed to be on par with higher germination percentage (65.21) being noticed in structures where EDB was used compared to ED/CT (63.66).

The interaction effect was significant with the highest percentage of normal seedlings being observed in metal bin followed by plywood bin, plastic bin and gunny bag lined with

Table-XIII: The effect of storage structures and fumigants on per cent germination of seeds after 120 hrs of fumigation.

Sl. No.	Storage structures	% of Normal Seedlings EDB	ED/CT	Means	% of abnormal seedlings EDB	ED/CT	Means	% of Dead and Diseased EDB	ED/CT	Means
1.	Metal bin	66.5 (54.03)	62.5 (52.23)	64.0 (53.13)	2.5 (9.05)	4.0 (11.54)	3.25 (10.30)	32.0 (34.45)	33.5 (35.36)	32.75 (34.91)
2.	Plywood bin	66.0 (54.33)	62.0 (51.94)	64.0 (53.14)	3.5 (10.76)	3.5 (10.76)	3.5 (10.76)	30.5 (33.52)	34.5 (33.97)	32.50 (34.75)
3.	Plastic bin	66.0 (54.33)	63.5 (52.83)	64.75 (53.58)	3.5 (10.52)	4.5 (12.23)	4.0 (11.38)	30.5 (33.51)	32.0 (34.45)	31.25 (33.98)
4.	Gunny bag lined with polythene	65.5 (54.03)	63.0 (52.53)	64.25 (53.23)	3.5 (10.76)	4.5 (12.23)	4.0 (11.50)	31.0 (33.83)	32.5 (34.75)	31.75 (34.29)
5.	Vadai	63.5 (52.83)	65.5 (54.03)	64.50 (53.38)	2.5 (9.05)	3.5 (10.76)	3.0 (9.91)	34.0 (35.67)	31.0 (33.83)	32.50 (34.75)
6.	Earthern pot	64.5 (53.43)	66.0 (54.33)	65.25 (53.88)	3.0 (9.98)	3.0 (9.98)	3.0 (9.98)	32.5 (34.25)	31.0 (33.83)	31.75 (34.04)
7.	Bamboo bin	65.5 (54.03)	64.5 (53.43)	65.0 (53.73)	2.0 (8.13)	3.0 (9.83)	2.5 (8.98)	32.5 (34.25)	32.5 (34.25)	32.5 (34.26)
Means		65.21 (53.84)	63.86 (53.03)		2.93 (9.75)	3.71 (11.05)	(34.21)	31.86 (34.64)	32.43	
		Str.	Fum.	Str.x Fum	Str.	Fum.	Str.xFum	Str.	Fum.	Str.x Fum.
CD 5%		-	-	1.18	-	1.14	-	-	-	-

Note: Str.=Structure; Fum.=Fumigant; Str.x Fum.=Interaction

Values in the paranthesis are angular transformed values.

Table No.XIV: The effect of storage structures and fumigants on percentage germination one and half months after fumigation.

Sl. No.	Storage structures	Percentage of Normal seedlings			Percentage of Abnormal seedlings			Percentage of Dead and Diseased		
		EDB	ED/CT	Means	EDB	ED/CT	Means	EDB	ED/CT	Means
1.	Metal bin	63.5 (52.63)	62.0 (51.44)	62.75 (52.38)	2.5 (9.05)	3.5 (10.76)	3.0 (9.90)	34.0 (35.66)	34.5 (35.97)	34.25 (35.81)
2.	Plywood bin	63.0 (52.53)	61.5 (51.64)	62.25 (52.09)	3.5 (10.76)	3.5 (10.76)	3.5 (10.76)	33.5 (34.36)	35.0 (36.27)	34.25 (35.81)
3.	Plastic bin	63.5 (52.63)	62.5 (52.23)	63.0 (52.53)	3.5 (10.76)	4.5 (12.23)	4.0 (11.37)	33.0 (35.05)	33.0 (35.06)	33.0 (35.05)
4.	Gunny bag + Polythene	62.5 (52.23)	61.0 (51.35)	61.75 (51.79)	3.5 (10.76)	4.5 (12.23)	4.0 (11.49)	34.0 (35.66)	34.5 (35.97)	34.25 (35.81)
5.	Vadai	60.5 (51.06)	48.0 (49.60)	59.25 (50.33)	2.5 (9.05)	3.5 (10.76)	3.0 (9.90)	37.0 (37.46)	38.5 (38.35)	37.45 (37.90)
6.	Earthern pot	59.5 (50.47)	57.5 (49.31)	58.50 (49.84)	2.5 (9.05)	2.5 (9.05)	2.5 (9.05)	38.0 (38.06)	40.0 (39.23)	39.0 (38.64)
7.	Bamboo bin	58.0 (49.60)	57.0 (49.02)	57.50 (49.31)	2.0 (8.13)	2.5 (9.05)	2.25 (8.59)	40.0 (39.23)	40.5 (39.17)	40.25 (39.20)
	Means	61.5 (51.65)	59.9 (50.72)		2.8 (9.62)	3.5 (10.69)		35.6 (36.64)	36.5 (37.14)	

	Normal: Str.	Normal: Fum.	Normal: Str.x Fum		Abnormal: Str.	Abnormal: Fum.	Abnormal: Str.x Fum	Dead/Diseased: Str.	Dead/Diseased: Fum.	Dead/Diseased: Str.x Fum.
C.D.5%	0.69	0.37	0.97	-	-	-	-	2.32	-	-

Str.=Structure; Fum.=Fumigant; Str.xFum.=Interaction.

Note: Values in the paranthesis are Angular transformed values.

polythene (66.5 to 65.5 per cent) when EDB was used. Same structures, under EDCT accounted for significantly less number of normal seedlings (62.0 to 63.5 per cent).

Conversely Bamboo bin, vadai and earthern pot recorded significantly higher percentage of normal seedlings (65.5 and 66.0) under ED/CT than under EDB (63.5 and 64.5).

Bamboo bin was also found to favour good germination with comparitively higher normal seedlings under both ED/CT and EDB though the difference was insignificant.

4.2.3(b) Abnormal seedlings after 120 hrs of fumigation

No significant difference was noted between structures in respect of abnormal seedlings. Least percentage of abnormal seedlings were recorded from bamboo bin (2.5) and the highest in plastic bin and gunny bag lined with polythene.

Among fumigants, significantly the least percentage of abnormal seedlings were noticed under fumigant EDB (2.93) compared to ED/CT (3.71) in all structures.

The interaction being non-significant, it was observed that the least per cent of abnormal seedlings was noticed in bamboo bin under EDB (2.00) and the highest in plastic bin and gunny bag lined with polythene (4.5) under ED/CT. It was further observed that per cent abnormal seedlings was comparitively lesser in traditional storage structures under both fumigants as against in improved storage structures.

4.2.3(c) Per cent dead and diseased after 120 hrs of fumigation

Storage structures showed no significant difference between them in respect of this parameter. The least percentage of dead and diseased seeds were observed in plastic bin (31.25) and the highest in Metal bin (32.75 per cent).

Fumigants also did not exhibit any significant difference between them but EDB recorded comparatively less dead and diseased seeds (31.86 per cent) than ED/CT (32.43 per cent) in all structures.

The interaction effect was also observed to be insignificant. Again, least percentage of dead and diseased seeds were noticed in plastic bin and plywood bin with EDB (30.5). On the other hand the highest percentage was in plywood bin (34.5) under ED/CT and vadai (34.0 per cent) under EDB.

4.2.3(d) Per cent normal seedlings 1½ months after fumigation

Storage structures exhibited no significant difference among them in respect of per cent normal seedlings. Plastic bin recorded highest percentage (63.00 per cent) of normal seedlings followed by metal bin (62.75 per cent) and plywood bin (62.25 per cent). Gunny bag lined with polythene was significantly inferior to first three structures but significantly superior to bamboo bin, earthern pot and vadai. The percentage of normal seedlings was the least in bamboo bin (57.50 per cent).

In the case of fumigants, storage structures under EDB, recorded significantly higher (61.50) per cent of normal seedlings over ED/CT (59.90).

The interaction effect was significant. All improved storage structures (metal bin and plastic bin 63.5 per cent, plywood bin 63.00 per cent and gunny bag lined with polythene 62.5 per cent) registered significantly higher percentage of normal seedlings compared to traditional structures (vadai 60.50, earthern pot 59.5 and bamboo bin 58.0).

Similar trend was observed in respect of structures under ED/CT in that plastic bin, metal bin, plywood bin and gunny bag lined with polythene with per cent normal seedlings ranging from 62.5 to 61.0 per cent were found significantly superior to vadai, earthern pot and bamboo bin with 58 to 57 per cent normal seedlings. The highest per cent of normal seedlings was obtained in metal bin and plastic bin both under EDB and ED/CT.

4 4.2.3(e) <u>Per cent abnormal seedlings 1½ months after fumigation</u>

The least percentage of abnormal seedlings was observed in bamboo bin (2.25) with the highest per cent noticed in plastic bin and gunny bag lined with polythene (4.0 per cent). Difference between different structures was insignificant.

No significant difference was seen between fumigants. However, structures under EDB recorded a less percentage (2.8 per cent) of abnormal seedlings in comparision with ED/CT (3.5 per cent).

The interaction effect was statistically not significant. Bamboo bin and earthern pot registered the lower percentage (2.0 and 2.5 respectively) of abnormal seedlings using EDB fumigant and under ED/CT (2.5 per cent where as, the highest percentage of (3.5) was seen under EDB in gunny bag lined with polythene and plastic bin and under ED/CT (4.5 per cent).

4.2.3(f) <u>Per cent dead and diseased 1½ months after fumigation</u>

None of the storage structures showed significant differences among them. The lowest percentage of dead and diseased seeds were observed in plastic bin (33.0) followed by metal bin, plywood bin and gunny bag lined with polythene (34.25). The highest percentage of dead and diseased seeds were observed in bamboo bin (40.25) followed by earthern pot (39.0) and vadai (37.45) with no significant differences among them.

Storage structures under EDB registered comparitively less percentage of (35.6 per cent) of dead and diseased seeds than under ED/CT (36.5). However, the differences between the fumigants was found to be non-significant.

The interaction effect was also insignificant. Plastic bin accounted for the least percentage (33.0 per cent) of dead and diseased seeds under EDB and ED/CT and bamboo bin accounted for the highest under EDB (40.0 per cent) and ED/CT (40.5 per cent).

4.2.4 Loss in weight 1½ months after fumigation

The influence of storage structures on the action of fumigant was assessed 1½ months after fumigation. The results of which are furnished in Table-XV.

In the case of storage structures, loss in weight suffered was the least in plastic bin (47.5 g) followed by metal bin (48.75 g). Gunny bag lined with polythene (49.5 g) and plywood bin (50.0 g), the difference being insignificant. Bamboo bin suffered the highest loss in weight of (92.0 g) followed by earthern pot (83.0 g) and vadai (76.5 g), the differences being significant among themselves and over other structures.

TableNo.XV: Less in weight of seeds observed in different storage structures - one and half months after fumigation.

Sl. No.	Storage structure	Weight loss (g)		
		EDB	ED/CT	Means
1.	Metal bin	49.0	48.5	48.75
2.	Plywood bin	50.5	49.5	50.00
3.	Plastic bin	48.5	46.5	4[illegible].5
4.	Gunny bag + polythene	49.5	49.5	49.5
5.	Vadai	80.5	72.5	76.5
6.	Earthern pot	82.0	84.0	93.0
7.	Bamboo bin	90.5	93.5	92.0
	Mean	64.35	63.42	
	<u>Source</u>:	<u>Str.</u>	<u>Fum.</u>	<u>Str.x Fum.</u>
	C.D.5%	3.67	-	5.17

In the case of fumigants, the least loss in weight was observed in structures where in ED/CT (63.42 g) was used as a fumigant compared to the structure where in EDB was used (64.35 g). However, fumigants showed no significant differences. The interaction effect was significant, structures plastic bin followed by metal bin and gunny bag lined with polythene suffered the least loss in weight under ED/CT and EDB in comparison with vadai, earthernpot and bamboo bin which suffered significantly higher loss in weight. Further, it was observed that the first four structure did not show difference statistically amongst themselves both under EDB and ED/CT.

The fumigants EDB and ED/CT were observed to produce significant differences only in structure vadai where in the loss in weight incurred was significantly high under EDB as against ED/CT.

Bamboo bin was been to suffer maximum loss in weight of all structures.

Based on the relative performance in respect of 14 parameter the study revealed plywood bin to emerge as the best storage structure as well as one for fumigation followed by metal bin, plywood bin and gunny bag lined with polythene is revealed by high insect mortality after 120 hrs of fumigation, less time to bring about the death of residual population, showing less beetle population one and half month after fumigation, comparitively less seed damage and higher percentage of normal seedlings.

The performance of traditional storage structures was far inferior compared to the improved structures when they were used as such. Among them, earthern pot has been observed to perform better in respect of all parameters followed by vadai. The performance of bamboo bin was significantly the most inferior to all the other structures under study.

In regards to fumigants, ethylene dibromide was found superior in bringing about higher mortality of pest population, taking less time to cause the death of residual pest population after fumigation and causing negligible injury to germinating seeds as compared to ED/CT which induced less insect mortality in all the structures and accounted for higher per cent of abnormal seedlings.

Relating to interaction between structures and fumigants, plastic bin followed by metal bin, plywood bin and gunny bag lined with polythene under EDB fumigation accounted for high insect mortality, less time to kill the residual beetles population which developed after fumigation, less damage to seeds and higher percentage of normal seedlings (and lower per cent of abnormal seedlings) and less loss in weight of stored seeds.

The efficacy of ED/CT in the above four structure was found to be slightly inferior to EDB. However, ED/CT fared better than EDB in plastic bin followed by plywood bin metal bin and gunny bag lined with polythene in the order.

In the three traditional structures, fumigants action was at a low EDB and among the fumigants ED/CT performance was slightly superior to EDB.

4.3 Effect of seed moisture on growth and development of *S.oryzae*

With a view to determine the optimum seed moisture for the development and survival of *S.oryzae*, an experiment was conducted during February-March and the results obtained in the respect of total developmental period, number of beetles emerging, growth index and per cent seed damage are detailed in Table-XVI.

4.3.1 Total developmental period

Of the ten seed moisture levels tested for their favourability for insect development, a significantly longer period of 36.11 days over all other seed moisture levels was observed at 7.80. With increasing seed moisture level from 7.80 through 9.00 to 11.0 per cent, the developmental period decrease through 33.70 to 33.11 days. The difference noticed between periods was not significant. A significantly shorter developm-

Table No.XVI: Effect of seed moisture on growth and development of *S.oryzae*

Sl. No.	Relative Humidity (%)	Grain moisture Content (%)	Total development period (in days)	No.of beetles emerged	Growth index	Percentage of seed damaged: Adult nibbling	Percentage of seed damaged: Holed
1.	10	3.80	0.00 (0.0025)**	0.00 (0.7071)*	0.00 (0.7071)*	2.00 (1.54)*	0.00 (0.0025**
2.	22	5.00	0.00 (0.0025)	0.00 (0.7071)	0.00 (0.7071)	5.33 (2.37)	0.00 (0.0025)
3.	32	7.00	0.00 (0.0025)	0.00 (0.7071)	0.00 (0.7071)	6.00 (2.50)	0.00 (0.0025)
4.	43	7.80	36.11 (36.93)	1.66 (1.419)	0.0499 (0.7414)	6.00 (2.50)	9.33 (17.53)
5.	51	9.00	33.70 (35.49)	2.33 (1.626)	0.0644 (0.7511)	10.00 (3.11)	7.33 (15.35)
6.	63	11.00	33.11 (35.13)	5.00 (2.3123)	0.1488 (0.8053)	12.66 (3.60)	14.66 (22.45)
7.	75	13.20	(32.04) (34.48)	18.00 (4.4531)	0.5616 (1.0302)	16.66 (4.11)	35.33 (36.46)
8.	86	16.00	30.57 (33.57)	12.33 (3.4580)	0.4029 (0.9498)	18.66 (4.35)	33.33 (35.06)
9.	90	19.40	0.00 (0.0025)	0.00 (0.7071)	0.00 (0.7071)	0.00 (0.70)	0.00 (0.0025)
10.	100	24.20	0.00 (0.0025)	0.00 (0.7071)	0.00 (0.7071)	0.00 (0.70)	0.00 (0.0025)
	F.test		(8933.86)**	(234.681)**	NS	(35.55)**	N.S
	C.D.5%		0.54	0.50	-	0.64	-

Note: * The values mentioned in the paranthesis are square root transformed values.
** The values mentioned in the paranthesis are Angular transformed values

mental period of 32.04 and 30.57 days, which differed significantly among themselves was noted at 13.20 and 16.00 per cent seed moisture. Higher seed moisture was quite unfavourable for insect development as revealed at 19.40 and 24.20 per cent, where no beetle emergence was observed and in addition seeds were severely infected with fungus. Similarly, no beetle emergence was been at 3.80 to 7.00 per cent seed moisture. Further, these found to be very hard and bright.

4.3.2 Beetle emergence

No emergence of beetles was observed at 3.80 to 7.0 per cent seed moisture contents. Significantly the least number of beetles (1.66) were found to emerge at 7.80 per cent. Highest number of beetles (18.00) emerged at 13.20 per cent seed moisture. As the seed moisture content increased from 13.20 per cent to 16.00, the number of beetles emerging 12.33 also declined. Nine and 11.00 per cent seed moisture accounted for 2.33 and 5.00 beetles emergence. Differences between number of beetles emerging at all the seed moisture levels were statistically significant. Seed moisture of 19.40 and 24.20 per cent showed no beetle emerging and such seeds were found severely attacked with fungus.

4.3.3 Growth Index

The highest growth index of 0.5616 was obtained at 13.20 per cent seed moisture as compared to the least value of 0.0499 at 7.88 per cent seed moisture. Nine, 11.0 and 16.00 per cent seed moisture registered the growth index of 0.0644, 0.1488 and 0.4029, respectively. No growth index was obtainable at moisture 3.80 to 7.0 per cent, 19.40 and 24.20 per cent seed moisture as no beetle emergence was noticed.

4.3.4 Seed damage

4.3.4(a) Per cent adult nibbled seeds

Significantly least percentage of adult nibbled seeds (2.0) was observed at 3.80 per cent seed moisture. The highest percentage of damage by adult nibbling (18.66) followed by 16.66 and 12.66 were caused to seeds with 16.0, 13.20 and 11.0 per cent moisture content with difference being insignificant. When seed moisture content increased to 5.0, 7.0, 7.80 and 9.0 per cent, they accounted for injury by adult nibbling ranging from 5.33 to 10.00 with difference between damage being non-significant. At 19.40 and 23.20 seed moisture severe attack at fungus was seen and no beetle developed.

4.3.4(b) Per cent holed seeds

A seed moisture of 3.80 to 7.0 per cent was unfavourable for larval development and subsequent adult emergence and hence recorded no holed seeds. Nine per cent seed moisture accounted for the least percentage of holed seeds (7.33) and the highest percentage of holed seeds (35.33) was noticed at 13.20 per cent seed moisture. Seed moisture of 7.80, 11.00, 16.00 per cent registered 9.33, 14.66 and 33.33 per cent holed seeds respectively, where in the first two did not differ significantly but differed significantly with the latter. At 19.40 and 24.20 per cent seed moisture content severe attack of fungus was noticed and no beetle developed.

Based on four parameters used for assessment of the favourable seed moisture, it was observed that development was not possible at 3.80 to 7.00 per cent seed moisture. The seeds appeared very hard and bright, however, these were damaged by adult nibbling.

Seed moisture of 7.80 to 11.0 supported a longer insect developmental period, least survival value, least growth index value and least per cent damaged seeds.

Inspite of comparitively a little prolonged developmental period, 13.20 per cent grain moisture was found to be the most favourable for growth, development and survival as revealed by the highest survival value, highest growth index value and the highest per cent holed seeds. Insect develoment was inversely related to seed moisture between 11.0 and 16.0 per cent.

4.4 Evaluation sorghum genotypes for their relative suceptibility to the attack of S.oryzae

Seeds of 17 sorghum genotypes including the few released for cultivation were tested fortheir relative susceptibility to rice weevil infestation. The results are presented in Table-XVII to XIX

4.4.1 Free choice Random distribution technique (Table-XVII)

4.4.1(a) Number of beetles congregating

Of the 17 sorghum genotypes, tested genotypes 148, CS 3541, SB1079, CSH-6, A, B, D, E and F were found to be least susceptible (5.22 to 8.07 congregating beetles) followed by moderately susceptible genotypes exhibited by SB901, CSH-2, CSH-5, SB905, SB461, SB1066, C and CSH-1 (9.33 to 19.29 congregating beetles) none of the sorghum genotypes tested proved highly susceptible for the congregating beetle. Genotype D (4.64 beetles) differed significantly from genotypes CS3541 (8.28 beetles) and F (8.07 beetle). Further, genotype 148 (5.22 beetles) following D, revealed significant differences from genotype CS3541.

Table No.XVII: Relative susceptibility of seventeen sorghum genotypes to the attack of *S.oryzae* (Free choice random distribution technique)

Sl. No.	Varieties	No.of beetles congregating at each variety	No.of beetles emerging on 24th day after enclosing	Percentage of damaged seeds Adult nibbling	Holed seeds	Reduction in 5 g seeds in g.
1.	S.B.901	9.33	11.00	17.50	13.5	0.20
2.	148	5.22	16.00	15.50	14.0	0.43
3.	CS-3541	8.28	19.00	19.00	16.0	0.10
4.	CSH-2	8.86	16.50	13.50	5.5	0.08
5.	CSH-5	9.07	17.50	13.50	10.0	0.35
6.	SB-905	13.93	26.00	17.00	14.5	0.50
7.	SB-461	15.43	25.00	24.0	18.5	0.63
8.	SB-1066	13.79	25.00	21.5	17.5	0.51
9.	SB-1079	6.22	16.00	18.0	13.5	0.07
10.	CSH-6	6.28	23.00	15.5	8.5	0.30
11.	A	6.14	10.00	13.5	7.5	0.31
12.	B	5.10	9.00	12.5	5.5	0.33
13.	C	15.29	9.50	23.0	18.0	0.69
14.	D	4.64	8.50	12.5	10.0	0.39
15.	E	7.14	17.50	11.5	7.5	0.04
16.	CSH-1	19.29	29.00	40.5	26.0	0.88
17.	F	8.07	19.50	17.0	12.5	0.41
Source:						
	CD 5%	3.02	8.98	6.02	2.86	-

4.4.1(b) <u>Number of beetles emerging on 24th day</u>

Saving SB905, SB461, SB1066, CSH-1 and CSH-6 which were moderately susceptible, the remaining genotypes were found to be least susceptible by accounting comparitively less beetle emergence. None of the varieties came under highly susceptible group. Genotype D (8.5 nos) was the least susceptible of all with very minimal number of beetles emerging on the 24th day followed by C (9.5 nos) and A (10.10 nos) genotypes. Genotype D differed significantly in respect of number of beetles emerged from genotype F (19.5 nos), CS3541 (19.0 nos), CSH-5 and E (17.50 nos). While C and A revealed significant differences over genotype F and CS-3541. Moderately susceptible genotypes showed no significant differences among themselves.

4.4.1(c) <u>Per cent adult nibbled seeds</u>:

All genotypes excepting CSH-1 exhibited least susceptibility to adult nibbling, CSH-1 was found to be moderately susceptible with 40.5 per cent nibbled seeds. Among the least susceptibility category of genotypes, genotype E recorded the least (11.5) per cent nibbled seeds followed by B and D (12.5 per cent), CSH-2, CSH-5 and A (13.5 per cent), 148 and CSH-6 (15.5 per cent) SB905 and F (17.00 per cent). The only genotype CSH-1 (40.5 per cent) falling under moderately susceptible group differed significantly from all the remaining genotypes under least susceptible group.

4.4.1(d) Per cent holed seeds

Ten out of 17 genotypes tested fell under least susceptible category. The ten included CSH-2 and B (5.5 per cent), A and E (7.5 per cent), CSH-6 (8.5 per cent), CSH-5 and D (10.0 per cent), F (12.5 per cent) and SB1079 and SB901 (13.5 per cent). Rest of the genotypes were observed to be moderately susceptible with per cent holed seeds ranging from 14 per cent in genotype 148 to 126.0 per cent in CSH-1. None of the genotypes were found highly susceptible.

Among the least and moderately susceptible genotype category, CSH-2 and B suffered the least damage of 5.5 per cent while CSH-1 suffered the highest damage of 26 per cent holed seeds and was differed from all others from the point of view of susceptibility.

4.4.1(e) Reduction in weight

The genotypes CSH-1, C, SB-461, SB-1066, SB-905 and 148 suffered higher loss in weight of seeds (0.88 to 0.48 g) weighing originally 5 g and hence categorised as highly susceptible. The least susceptible genotypes included A, CSH-6, SB-901, CS3541, CSH-2, SB1079 and E which suffered comparitively minimal loss (0.31 to 0.04 g). Falling under the moderately susceptible group were the genotypes F, D, CSH-5 and B all of which accounted for a loss in weight ranging from 0.41 to 0.33 g. In all the groups viz., least, highly and moderately susceptible groups, the genotypes did not show any significant differences either within the group or between the group.

Study on the evaluation of 17 genotypes for their relative susceptibility to the attack of S.orygae under free choice testing conditions showed about 12 genotypes to be least susceptible, having proved to be so, in respect of all five parameters (E, A and SB1079), 4 parameters (B, D, CSH-2, CSH-6, SB-901, CS-3541 and F) and three parameters (CSH-5, 148).

Four genotypes were observed to be moderately susceptible having proved so in respect of four parameters (CSH-1), 3 parameters (SB-1066, SB-905 and SB-461).

Genotype 'C' appeared to be least susceptible (2 parameters) and moderately susceptible (2 parameters).

4.4.2 No choice confound test (Table-XVIII)

4.4.2(a) Number of beetles emerging

All the seventeen genotypes under testin were found moderately susceptible as indicated by the number of beetles

Table No.XVIII: Relative susceptibility of seventeen sorghum genotypes to the attack of S.oryzae (No choice confound test).

Sl. No.	Varieties	No.of beetles emerging from 5 g	Wt.of 5 beetles emerged	Total development period (in days)	Percentage of damaged seeds		Reduction in 5 g
					Adult nibbling	Holed seeds	
1.	SB-901	10.00	2.66	35.43	15.00	10.66	0.20
2.	148	10.00	2.33	35.24	15.66	14.33	0.13
3.	OS-3541	6.66	2.00	37.45	7.00	4.66	0.25
4.	CSH-2	7.00	2.66	36.05	6.33	5.00	0.27
5.	CSH-5	8.00	2.33	35.15	8.00	5.66	0.13
6.	SB-905	11.00	3.00	35.32	16.00	14.66	0.32
7.	SB-461	10.00	3.00	35.44	16.00	11.33	0.35
8.	SB-1066	13.33	3.00	32.74	20.00	15.66	0.34
9.	SB-1079	6.66	2.33	38.05	6.00	6.00	0.21
10.	CSH-6	5.00	2.33	38.71	3.00	1.66	0.20
11.	A	9.00	2.66	33.59	12.66	9.00	0.05
12.	B	6.66	2.66	37.71	7.00	6.00	0.10
13.	C	13.00	3.00	32.92	19.00	16.00	0.32
14.	D	6.66	2.33	37.62	6.00	4.66	0.18
15.	E	8.33	2.66	35.05	7.00	4.66	0.15
16.	CSH-1	19.00	4.00	29.32	34.00	24.33	0.50
17.	F	9.66	2.66	35.43	6.33	3.33	0.10
	Source:						
	C.D.5%	-	0.80	1.21	3.52	3.80	-

emerging which ranged from 5 to 19. The genotype CSH-6 accounted for the least number of beetles (5.0 numbers) emerging, as against the highest number of beetle emergence (19.00) supported by the genotype CSH-1. The difference noticed between genotypes were not significant.

4.4.2(b) Weight of five beetles after emergence

Six genotypes namely CS-3541, 148, CSH-5, SB-1079, CSH-6 and D were observed to be the least susceptible as revealed by weight of five beetles that emerged from each of the above genotypes. In this category the weight of five beetles ranged from a minimum of 2.00 mg (genotype CS-3541) to 2.33 mg (all other genotypes). Six genotypes SB-901, CSH-2, A, B, E and F were noted to be moderately susceptible with five beetles weight of 2.66 mg. Highly susceptible category of genotypes constituted by SB-905, SB-461, SB-1066, C and CSH-1 with weight (5 beetles) fluctuating from 3 to 4 mg.

Genotypes of the least susceptible and moderately susceptible categories revealed no statistical differences among themselves within the category or between the categories. CSH-1 (4 mg) however showed significant differences from the other genotypes in the highly susceptible category as well as other two categories.

4.4.2(c) Total developmental period

Baring the genotype CSH-1 (29.32 days) falling under the highly susceptible category all others exhibited moderately developmental period ranging from 32.74 days in SB1066 to 88.05 days in CSH-6. Genotypes SB1066 with 32.74 days and C with 32.92 days of developmental period did not differ significantly among themselves but did so from all other genotypes.

4.4.2(d) Per cent adult nibbled seeds

All the seventeen genotypes involved in testing for their reaction suffered minimum damage (least susceptibility) with CSH-6 recording the lowest percentage of adult nibbled seeds (3.0) and CSH-1 the highest (34.0). CSH-1 with 34.0 per cent nibbled suffered significantly highest adult nibbling injury compared to all other genotypes. There found no genotype either the most susceptible or moderately susceptible through this parameter.

4.4.2(e) Per cent holed seeds

Though this is most reliable parameter it was observed that all the 17 genotypes fell under least susceptible category. Among the genotypes CSH-6 exhibited the least percentage of holed seeds (1.66) as opposed to CSH-1 on the other extreme recording the highest (24.33 per cent). Incidentally it was noted that CSH-1 was distinct from all other genotypes.

Genotypes F, E, D, CS.3541, CSH-2 and CSH-5 with holed seeds ranging from 3.33 to 5.66 per cent, genotypes SB1079, B and A with 6-9 per cent holed seeds, genotypes SB901, SB461 and 148, with 10.66 to 14.33 per cent holed seeds and SB905, SB1066 and C with 14.66 to 16.0 per cent holed seeds were all on par in respective grouping.

4.4.2(f) Reduction in weight

Of the 17 genotypes under study, 16 genotypes with reduction in weight ranging from 0.05 g to 0.35 g out of original 5 g of seeds were found to be least susceptible. The only remaining genotype (CSH-1) with a weight reduction of 0.5 g was moderately susceptible. The genotypes did not exhibit any significant differences between them.

Under confined testing conditions 10 genotypes were proved as least susceptible, based on four paramters (CSH-6, D, CS-3541, CSH-5, SB1079 and 148), three parameters (SB905, SB461, C and SB1066).

Six genotypes (SB901, CSH-2, A, B, E and F) proved to be least as well as moderately susceptible based on 3 parameters each. However, when genotypes reaction in respect of the most reliable parameters is taken into consideration, they were also observed to be least susceptible.

CSH-1 of all genotypes was found to be highly susceptible to S.oryzae attack.

On consideration of results of both testing situation, the genotypes D, CSH-6, SB079, CS3541, CSH-5 and 148 emerged(x(x) as least susceptible genotypes to S.oryzae. No common genotypes were found either as moderately susceptible or as highly susceptible. But, the genotypes CSH-1, SB-905, SB-461 and SB-1066 were found to be highly susceptible for one reliable parameter.

Table No.XIX: Grouping of Sorghum genotypes based on their relative standing in different parameters.

Character	Least susceptible Genotypes $\bar{x}$ - 0	Highly susceptible genotypes $\bar{x}$ - 0	Moderately susceptible genotypes $\bar{x}$ - 0 to $\bar{x}$ + 0
<u>**Free choice random distribution technique**</u>			
I. <u>**Number of beetles congregating at each variety:**</u> $\bar{x}$ = 17.52 ; 0 = 17.98	148, CS-3541, SB-1079, CSH-6, A, B, D, E, F.	-	SB-901, CSH-2, CSH-5, SB-905, SB-461, SB-1066 C, CSH-1
No. of beetles emerging after 24 days of enclosing. $\bar{x}$ = 17.52 ; 0 = 37.80	SB-901, 148, CSH-3541, CSH-2 CSH-5, SB-1079, A, B, C, D E, F.	-	SB-905, SB-461, SB-1066 CSH-1, CSH-6
Percentage of damaged seeds: i) Adult nibbling: $\bar{x}$ = 17.97 ; 0 = 44.63	SB-901, 148, CS-3541, CSH-2 CSH-5, SB-905, SB-461, SB-1066, SB-1079, CSH-6, A, B C, D, E, F.	-	CSH-1
ii) Holed seeds: $\bar{x}$ = 12.85 ; 0 = 26.67	SB-901, CSH-2, CSH-5, SB-1079 CSH-6, A, B, D, E, F.	-	148, CS-3541, SB-905, SB-461, SB-1066, C, CSH-1.
reduction in 5 g seeds $\bar{x}$ = 0.37 ; 0 = 0.05	E, SB-1079, CSH-2, CS-3541, SB-901, CSH-6, A	CSH-1, C, SB-461 SB-1066, SB-905 148	B, D, CSH-5, F
II. <u>**Number choice confound test:**</u>			
No. of beetles emerging from 5 g seeds. $\bar{x}$ = 9.40 ; 0 = 10.75	-	-	All are moderately susceptible

...contd

Table No.XIX (Contd..)

Character	Least susceptible genotypes $\bar{x}$ - 0	Highly susceptible genotypes $\bar{x}$ - 0	Moderately susceptible genotypes $\bar{x}$ -0 to $\bar{x}$ +0
Wt. of five beetles emerged $\bar{x}$ = 2.68 ; 0 = 0.20	148, CS-3541, CSH-5, SB-1079 CSH-6, D	SB-905, SB-461 SB-1066, C, CSH-1	SB-901, CSH-2, A, B, E, F
Total developmental period $\bar{x}$ = 35.48 ; 0 = 4.89	-	CSH-1	Except CSH-1 all other genotypes
Percentage of damaged seeds-			
i) Adult nibbling $\bar{x}$ = 12.05 ; 0 = 56.45	All genotypes	-	-
ii) Holed seeds $\bar{x}$ = 8.68 ; 0 = 33.90	All genotypes	-	-
Reduction in 5 g $\bar{x}$ = 0.51 ; 0 = 0.09	SB-901, 148, CS-3541, CSH-2 CSH-5, SB-905, SB-461, SB-1066, SB-1079, CSH-6, A, B, C, D, E, F.	-	CSH-1

DISCUSSION

CHAPTER V

DISCUSSION

5.1 Evaluation of storage structures for their relative efficacy in checking insect infestation

Seven storage structures both of conventional and improved types were evaluated for their relative efficacy in protecting seed from insect infestations, and their influence on the action of two commonly used fumigants. Effect of seed moisture on the development and survival as well as relative susceptibility of 17 sorghum genotypes to *S. oryzae* was investigated. The results of these studies are discussed in thefollowing pages (Table-III to VIII).

Of the structures tested, metal bin emerged out to be the best of all by its performance in registering the least number of living and highest number of dead beetles which is in agreement with Srivastava *et al.*,(1973) who noted least population count in metal bin and gunny bag over other structures and Bertrand (1941) who observed higher mortality of beetles in metal bin after 9 months of storage. An additional advantage noted in metal bin was that it had no cracks and crevices which enabled the beetles to breed and multiply at faster rate (Ramasivan *et al.*, 1968).

The percentage of seed damage, adult nibbling and holed seeds was the least which conforms to the findings of the

Ozburn *et al.*(1960). Ramasivan *et al.* (1966) reported that grains stored over 2 to 6 years in metal bin sustained less insect damage (16 per cent) compared to the Thekkas (35 per cent), cement tanks (100 per cent) and other receptacles (69-82 percent) and Srivastava *et al.* (1973) found metal bin with higher percentage of grain and less weevilled seeds over other structures used by villagers.

Least seed damage logically resulted is least loss in weight of seeds stored in metal bin which agrees with the report of comparitively less quantative loss of 2.03 per cent in metal bin as compared with that of 2.25 per cent noted in bag storage (Ramasivan *et al.*, 1966). The findings of Srivastava *et al.*,(1973) in the course of a case study on storage practices followed by villagers that seeds stored in metal drum suffered the least compared to all other structure prevailing in those villages and that of Doharey *et al.* (1975) stands testimony to the present revealation.

Lesser the percentage of weevilled (holed) grains more is the percentage of germination, was revealed in the studies of Yadav *et al.* (1968) working on the extent of relationship between damage and germination of jowar (PJ 4K) infested by *S.oryzae*. He reported that increased damage by developing grub resulted in decreased germination. In the present study metal bin accounted for higher percentage of normal seedlings and lower percentage of both abnormal and, dead and diseased seeds. These findings are in confirmity with reservation such as insignificant fall in viability of seed in long run of storage in metal bin (Osbum et al., 1960). Commercial seed lot of sweet sorghum variety Sugar drip stored in metal bin, in retaining above 70 per cent germination after prolonged storage period of 27 months compared to that of close mesh, jute bags over 20 months (Peel, 1962) and aluminium silo's superiority over concrete bins in recording higher percentage of germination (Sarid et al., 1965).

Metal bin topped, was fallowed by plywood bin, plastic bin and gunny bag lined with polythene which are all considered to be improved types with difference in respect of most of the parameters between them being insignificant.

Plywood bin was found next best to metal bin by virtue of the least percentage of adult nibbled seeds, second in causing comparatively lesser percentage of holed seeds, abnormal, dead and diseased seeds and higher percentage of normal seedlings. It stood third in harbouring live and dead beetles which could be understood by the work of Krishnamurthy and Majumder (1978) who reported that plywood bin accounted for less kernel damage and no loss in viability even after one year of storage. According to them the structures had good qualities such as high degree of gas worthiness, fairly high amount of carbon-dioxide accumulation. However, the disadvantage was with its durability.

Third in the order of releative performance, was plastic bin. Its position was justified because of its standing second in harbouring live and dead beetles and causing least loss in weight, and third in favouring higher percentage of normal seedlings, lesser percentage of abnormal seedlings and dead and diseased seeds and in recording minimum seed damage. This revealation are best explained in the earlier investigations of Krishnamurthys and Majumder (1978) on comparitive evaluation of storage bins namely plywood bin, ferrocement and HMHD (high moleculer, high density polythelene) bins where in they claimed plastic bin to possess the same good qualities of plywood bin as stated in an earlier paragraph with the only disadvantage being that of its durability.

Of the improved structures, gunny bag lined with polythene ran ed the last in its relative performance by virtue of standing first in respect of live and dead beetles, third in recording loss in weight and fourth in accounting for higher percentage of normal seedlings, lowest percentage of abnormals and, dead and diseased seeds. Disadvantages noted with the gunny bag and polythene were, the permeable nature to the moisture and vapour in the former and rapid susceptibility to wear and tear in the latter. Hence, when both were interlined and used for seed storage, the performance was almost comparable to any good structure which is elucidated in the findings of Peel (1962) who claimed commercial seed lots of sorghum variegy sugar drip stored in wearhouse in jute bag lined with polythene and in close mesh jute bags favoured higher germination (above 70 per cent) for 24 months (former) and 20 months (latter) respectively.

The present study also clearly established that seeds stored in metal bin prolonged the developmental period of insect pest as compared to seeds stored in gunny bag lined with polythene. This clearly indicates the unsuitability of seeds for the insect to infest breed and multiply.

The temperature and relative humidity over the study period did not vary appreciably (27.0 to 31.6°C and 53 to 74 per cent RH) irrespective of ambient temperature and relative humidity. The seed moisture varied little thus revealing the structures to fairly withstand for fluctuations in external environmental conditions.

On the contrary, conventional storage structures in use in the rural areas, whose replicas were tested in the study, were observed to be significantly inferior to earlier discussed structures in respect of all parameters. Of the three conventional structures, vadai revealed to be the best followed by earthern pot and bamboo bin.

Vadai and earthern pot both accounted for higher number of live beetles and lesser dead beetles. The porous nature of the container made them permeable to the ambient atmosphere thereby allowing oxygen inside and Co_2 to the outer atmosphere. The microenvironment thus developed inside, because of Co_2 not accumulating was found to be favourable for insect growth and multiplication, a similar view being held by Vayssiere (1948). As a consequence, conventional structures showed comparitively the higher percentage of damage due to adult nibbling and developing grubs. These results confirm to the findings of Ramasivan et al.(1968) that mud pots showed higher percentage (69 to 82) of seed damage compared to the (16 per cent) in metal bin. Higher seed damage resulted in greater loss in weight with the higher percentage of holed seeds, the percentage of normal seedlings obtained was also low as claimed earlier by Yadav et al. (1968), who found that increased damage by developing grubs of S.oryzae resulted in decreased germination of jowar & seeds. The per cent dead and diseased seeds were more because of injury, has been confirmed earlier through the findings of Hurd (1921) in case of wheat seeds where in ruptured (Seed coat injury) seeds were often invaded by moulds and invasion was more rapid when the rupture was over endosperm.

The bamboo bin proving to be the most inferior of all structures, tested, in the study by harbouring highest number of live beetles (and least dead beetles), which was possible due to the favourable atmosphere prevailing within storage structure because of the porous nature of the structure. Besides, 'cracks and crevices' inside, provided scope for further development and multiplication, this observation being subscribed to earlier by Ramasivan et al.(1968) who found storage structures with cracks and crevices to harbour higher insect population and damage. Parvathappa et al.(1972) also, in conformation had recorded more number of beetles and high percentage kernel damage in bamboo bin as compared to gunny bag. That the S.oryzae penetrated through the plastered wall (Ramasivan et al., 1966) was confirmed in the present investigation where in it penetrated through cowdung and red earth slurry, loss in weight was the highest in bamboo bin (Girish et al., 1974) was also confirmed in the present study. Bamboo bin because of all these, recorded, the least percentage of normal seedlings as reported in the earlier findings of Pingale (1953) where germination fell from 90 per cent to 10 per cent.

In respect of total developmental period, it was the shortest in bamboo bin indicating the most favourable environment prevailing in that structure as compared to earthern pot and vadai.

In conclusion, it may be stated that among the improved storage structures, metal bin was the best followed by plywood bin, plastic bin and gunny bag lined with polythene. All the conventional storage structures were found inferior to above four structures, when they were used as such. Of the three rural structures, vadai proved to be relatively better than earthern pot and bomboo bin, which incidentally was the most inferior of all structures tested in the study. The three structures being economically viable with the farmers at large in the rural areas, their continued use is inevitable for storing seeds and grains. Their physical traits have to be improved in such a manner, as to make them as far as possible air tight and moisture proof, according to Giles (1965) who also had the view of successful control of insect infestation in mud granaries treated with bitumen or any painting material which would seal the pores, which will go a long way in keeping insect and their activity bang as well as damage to grain low or nil.

5.2 Relative influence of storage structures on the action of fumigants

Storage structures with their structural difference, one apt to influence the action of fumigants. An investigations on this aspects has provided certain information which is quite useful in fumigation (Table IX to XV).

5. 5.2.1 Effect of storage structure

The relative efficacy of structures as already been discussed in the preceeding pages but the relative positions occupied by them based on their influence on the action of fumigant was different. Plastic bin occupied the top position followed by metal bin, plywood bin and gunny bag lined with polythene with the difference being insignificant between them in respect of all fourteen parameters. The superiority of metal bin was ruled out for its gas-worthiness because of leakage of fumigant through gaps found at joints or metal sealings as compared to plastic bins which is in confirmation of the findings of Thiem and Bogs (1975) who in their investigation on the control of store pests in aluminium silo, with phosphine found considerable loss of gas especially through seals at segment rings, manholes and inlet portions. The plastic bin manfuctured with single moulding, had no joints and therefore there was no leakage of gases.

In regards to conventional structures the relative positions established earlier was not altered when fumigants were administered.

5.2.2 Effect of fumigants

Among the two fumigants, EDB accounted for higher mortality over ED/CT, as reported by Punj and Girish (1967) who claimed that of the three fumigants EDB was most toxic to *T.granarium* followed by carbondisulphide and ED/CT. The time taken by EDB for causing death of the residual population of beetles was less compared to ED/CT as revealed in the studies of Khare *et al.* (1966), according to whom EDB fumigation gave 91 and 98 per cent kill of the caged insects while, disinfesting the mill. After incubation mortality rose up to 100 per cent, thus indicating the delayed action of EDB on the surviving insects. The present investigation revealed that one and half months after fumigation, reinfestation by beetles found increasing was with ED/CT and conversely beetles were few which is well demonstrated in the work of Cornes and Oyeniran (1968) where in fumigation with ED/CT against *T.castaneum* and *S.oryzae* recorded reinfestation one month later and after a damageable population build up was seen, 2 months hence.

Because of comparatively high toxicity of EDB to *S.oryzae* it registered less percentage of nibbled seeds (22.71 and 23.42) over 120 hours of fumigation and one and half months after fumigation, respectively and encountered significantly least percentage of holed seeds (8.42) which finds support in the work of Punj and Girish (1967).

The effect of fumigants on the per cent seed germination, EDB proved to be better over ED/CT by way of favouring the higher percentage of normal seedlings, least percentage of abnormal seedlings and lesser percentage of dead and diseased seeds after 120 hours of fumigation, which agrees with the observations of Girish et al. (1972) who found germinability of jowar wheat and other crop seeds with different moisture contents under EDB fumigation at the varied dosage remain unaffected, while Clifford (1958) observed the reduced seedling growth in case of seeds of maise varieties fumigated with ED/CT at different doses. Similar trend was observed even one and half month after fumigation, when seed germination test revealing higher percentage of normal seedlings, lower percentage of abnormal seedlings and, dead and diseased seeds in the case of EDB over ED/CT. Further seeds in all structures under EDB significantly less loss in comparison to ED/CT.

6.2.3 Interaction effect of structures and fumigants

Irrespective of fumigants used, the improved structures namely plastic bin, metal bin, plywood bin and gunny bag lined with polythene in that order accounted for effective checking of S.oryzae infestation as compared to conventional structures, vadai, earthern pot and bamboo bin.

Plastic bin combined well in providing effective control of S.oryzae with fumigant EDB and followed by metal bin, plywood bin and gunny bag lined with polythene with the difference between these being insignificant.

Plastic bin under the influence of EDB registered comparitively higher number of dead beetles after 120 hrs of fumigation, this occupying fourth position in causing mortality which was reasoned by Krishnamurthy and Majumder (1978) who in evaluating the storage bins, reported that plastic (high molecular, high density- HMHD) bins had high degree of gas worthiness and fairly high amount of Co_2 accumulation. The depleation of oxygen and accumulation of Co_2 might have increased the toxicity of EDB (Bond et al., 1967) to the larvae and pupae with the result, one and half month after fumigation, the reinfestation was found to be quite low thus occupying second position for this parameter. With high beetle mortality and least reinfestation per cent, adult nibbled seeds (13.5) and per cent holed seeds (4.5) were also observed to be less. Consequently, germination was seen to be of high order with higher percentage of normal seedlings, lower percentage of abnormal, dead and diseased seeds, the observations agreeing with those of Girish et al. (1972).

Metal bin in combination with EDB was observed to fall in line with that of plastic bin with higher beetle mortality which is also agreed to, in the findings of Lindgren et al.

(1954) who investigating 10 fumigants for their relative effectiveness against S.oryzae and other store pests in metal chamber found EDB to cause complete mortality of S.oryzae The fumigant took least number of days to kill the residual beetles population, the observations confirming to the findings of Lindgren et al. (1954) on relative effectiveness of 10 fumigants where in after fumigation with EDB in aluminium silo, the insects were seen dieing in different dates. Reinfestation observed one and half months after fumigation was quite low, the findings agree with those of Girish et al. (1972) who, in their investigation with ED/CT and EDB in kothis, kuthlas and tin drums found efficient control of latent infestation of S.oryzae and R.dominica to a maximum extent in tin drums with EDB as compared to other structures with infestation being less. The per cent adult nibbled (15.5) and holed seeds (5.5) were also less and consequently the per cent normal seedlings obtained were high and per cent abnormals, dead and diseased were low.

Plywood bin under EDB has given a good account of itself in causing high mortality which was perhaps due to high degree of gas worthiness and capacity to accumulate Co_2 as reported by Krishnamurthy and Majumder (1978), concentration of Co_2 accumulation contributing to the increased toxicity of EDB as already been emphasised by Bond et al. (1967) and Shayesteh (1975) who reported phostoxin in air tight wooden box to cause higher mortality of *S.granarius* and *T.confusum*. Ethylene dibromide acted against the developing stages of insects (Punj and Girish, 1969) thus resulting in reduced reinfestation and as a consequence damage of all kinds was also low with the result the percentage of normal seedlings were more and percentage of abnormal, dead and diseased were low.

Gunny bag lined with polythene occupied fourth position under EDB recording higher mortality, as reported by Pingale (1955) and Cornes *et al*. (1968), the later findings complete the mortality of *S.oryzae* due to EDB in gunny bags under tarpuline which was later supported by Shayesteh's(1975) observation of complete mortality of *S.granarius* under similar conditions. The structure in conjunction with EDB took shorter duration to bring about the death of residual beetle population. The reinfestation, a month and a half after fumigation was the least, these observations received support from Punj and Girish (1969) and Lallan Rai (1964) who noted similar situation under EDB fumigation in sacked wheat under Rubberised gas proof. The last mentioned author noted *S.oryzae* emergence at the rate of 2 beetles per kg of wheat. High beetle mortality and low reinfestation accounted for low per cent seed damage (15.5 adult nibbled and 10.0 holed) hence the loss in weight (49.5 g) noticed was very less, and as a result highest percentage of normal seedlings and lower percentage of dead and diseased were seen.

The aforesaid four structures under the influence of ED/CT occupied positions from 5th to 8th which was as follows, plastic bin followed by plywood bin, metal bin and gunny bag lined with polythene. The interaction effect between these structures was insignificant both under EDB and ED/CT.

Conventional structures provided control of insect infestation both under EDB and ED/CT which was significantly far inferior to other improved structures. Among the rural structures, vadai proved to be better in respect of all parameters followed by earthern pot and bamboo bin under both EDB and ED/CT fumigation. The first two accounted for lesser mortality, which may be explained due to porous nature of the structure resulting in failure to hold the fumigant effectively inside the structure and the number of beetles killed was less while the time taken for the death of residual population comparatively longer. Consequently, reinfestation by rice weevil was considerably high and so also the seed damage which was quite high. With higher percentage of seed damage, loss sustained by seeds under ED/CT in the above two structure was heavy. The per cent normal seedlings obtained was appreciably low, the observations agree with that of Yadav _et al._ (1968), who established a correlation between damage and germination of jowar infested by _S.oryzae_, claimed that increased damage resulted in decreased germination percentage. The per cent dead and diseased seeds was high which may be due to more insect injury. This view found support in the findings of Hurd (1921) who claimed ruptured wheat seeds suffer mould infection. Invasion was more rapid when rupture was over endosperm than on embryo.

Bamboo bin came up with least performance under both EDB and ED/CT. Inspite of Bamboo bin being plastered, inside and outside, with cowdung and red earth, beetles were seen penetrating through walls, similar observation having been made earlier by Ramasivan et al. (1966). The bamboo bin wall possessed pores even after covering walls with red earth and cowdung. Beetle mortality was the least and time taken to kill the residual beetle population was long, which was due to the fumigant vapours not being confined and heavy air movement from inside to outside with the highest number of live beetles, the per cent damage sustained by this structure was also the highest and as a consequence the loss in weight suffered was also high. The per cent normal seedlings was low because high per cent holed seed (Yadav et al., 1968). The percentage of dead and diseased was the highest in bamboo bin under both fumigants as reported earlier by Hurd (1921).

In brief, improved structures proved to be significantly superior with plastic bin leading other three structures. It was followed by metal bin, plywood bin, and gunny bag lined with polythene conventional structures, on the other hand faced badly with vadai among them performing well over other two.

Ethylene dibromide proved to be appreciably a better fumigant over ethylene dichloride and carbon-tetrachloride as evidenced by the formers capability in inflicting mortality and not affecting seed germination in all storage structure where they were administered. EDB fumigation in plastic bin followed by metal bin, plywood bin and gunny bag lined with polythene provided appreciable control of S.oryzae as compared to ED/CT when fumigated in those structures. Both these structures were seen to provide significantly lesser control of insects in the conventional storage structures.

5.3 Seed moisture

Effect of seed moisture on the growth and development of S.oryzae was investigated which revealed an inverse relationship between moisture and development of S.oryzae.

In the present study, a seed moisture of 7.80 per cent registered a development period of 36.11 days which was shortened with increase in seed moisture upto 16.00 per cent. The latter accounted for 30.57, the shortest period and perhaps the optimal. Similar observations were made by Thyagarajan (1980) in case of R.dominica and Karan Singh et al., (1974) in the case of S.oryzae. Beyond 16.00 per cent, at 19.40 and 24.20 seed moisture no beetle emergence was seen and further seeds were attacked by fungus.

Similarly, seed moisture of 3.80 to 7.0 per cent did not favour beetle development as indicated by no emergence which is in agreement with the findings of Howe (1965) who found the minimum RH to be 60.00 per cent and with increase in moisture content, the number of beetles emerging were also more. The least and the highest number of beetle emergence were noticed at 7.80 and 13.20 seed moisture, respectively and further increase in seed moisture to 16.00 per cent resulted in decrease number of beetles emergence. Thus clearly establishing optimal seed moisture at 13.20 and the optimal range at 13.20 to 16.00 per cent. The above findings are in confirmity with the observations of Karan Singh et al. (1973) who in their study observed increased beetle emergence at 75 per cent RH, the least at 60 per cent RH with fungal attack at 90 per cent and concluded that 13.20 per cent seed moisture as the optimal favourable for rice weevil development which was further confirmed in their subsequent investigations (Karan Singh et al., 1974; Karan Singh et al., 1975).

The data on growth index also emphasised the present findings that 13.20 per cent seed moisture was the most favourable level for growth and development of rice weevil and further increase in seed moisture as indicated at 16.00 per cent, resulted in growth index value being decreased thus pointing out the unfavourable nature of seed moisture beyond 13.20 per cent.

Thyagarajan (1980) was of the same opinion in the case of R.dominica.

Rice weevils were able to nibble the seeds even at 3.80 per cent seed moisture and increasing per cent nibbled seeds. Chaterjee (1953) also obtained similar result of seed damage of 12.80, 18.11 and 30.2 per cent at 2, 8 and 12 per cent seed moisture respectively. The per cent holed seeds also tended to increase with increase in seed moisture, the least being noticed at 7.80 per cent. The present revealation is in confirmation with the observation of Krishnamurthy et al.(1976) who reported increased percentage of damage (38.00, 55.00 and 69.0 per cent) with increase in moisture content (low, medium and high seed moisture) in stored seeds.

The present investigation has conclusively established that the seed moisture abofe 13.20 upto 16.0 (75 to 86.0 RH) favoured the growth and development S.oryzae. The most optimal level being 13.20 per cent which is on par with the findings of Pingale andGirish (1967) who reviewing the effect of seed moisture on store pests claimed 14.0 per cent as the optimum seed moisture with the lowest being at 60 per cent RH which permitted insect development. The most optimum seed moisture of 13.20 per cent in this study accounted for the shortest developmental period, highest number of beetle emergence, highest growth index and highest per cent adult nibble and holed seeds.

4.4 Relative susceptibility of sorghum genotypes to rice weevil infestation

The possibility of evolving genotypes unfavourable for development and multiplication of seed insect depends upon detection of less susceptible or resistant ones and factors responsible for it. With this objective in view the present study involving seventeen sorghum genotypes was carriedout to determine least moderately and highly susceptible genotypes to S.oryzae attack.

Evaluation of genotypes was made under two testing situations namely the free choice random distribution technique where beetle had access to seeds of their choice and no choice confound technique where beetles were left with no choice except to accept seeds given to them using mean and standard deviation, the genotypes were grouped into least, moderate and highly susceptible categories under both testing situation. No genotype was found to be completely resistant to the attack of rice weevil which may be explained by the findings of Davey (1965) and Khokhar and Gupta (1974) who attributed the resistance to weevil attack possibly due to grain size, protein content and hardness of the seed.

The present evaluation under both the testing situations. Established six genotypes D followed by CSH-6, SB1079, CS-3541, CSH-5 and 148 in that order, as least susceptible. These genotypes were noted to favour fairly longer developmental period of the insect which is in agreement with longer developmental periods that Rout *et al.* (1976) observed in least susceptible varieties of rice. Further, the same workers observed that the least susceptible genotypes produced largest number of adults, which was confirmed in the present study. The number of beetles emerged was minimum in these genotypes which agrees with the results of Dang and Pant (1965), Chahal and Labh Sing (1975) and Doraiswamy *et al.* (1976) that least susceptible genotypes gave rise to lesser number of beetles. Since these genotypes recorded less number of beetles, they also counted for less damage by adult and developing grub, which is also observed in the work of Puttarudrappa *et al.* (1971), where in least susceptible recorded comparitively lesser damage. With beetles not relishing the feeding on these genotypes, seeds suffered less loss in weight as reported by Widstrom *et al* (1972).

No genotype was identifiable as moderately susceptible under both the testing situation. The two techniques gave confused revealation with regards to moderately susceptible genotypes.

Similarly, both the testing situations did not point out any genotype which could be categorised as highly susceptible, perhaps physical characteristics, like, colour, texture, shape etc., and biochemical composition of seeds were such as to discourage the attack by and subsequent development of beetles that no genotypes were seen to be susceptible. However, this has to be investigated, further. Comparitively genotypes CSH-1, of all genotypes tested was found to be highly susceptible to S. oryzae, attack as proved by its reaction in respect of two parameters, CSH-1, hence accounted for shorter developmental period, highest number of beetles emerging, highest weight of five beetles, highest seed damage, and loss in seed weight, among all 17 genotypes tested. Findings of Krishnamurthy et al. (1976) who found CSH-1 as more susceptible than CSH-5 and CSH-2 (included in the present study also) proves the above convictions beyond doubt.

SUMMARY

CHAPTER VI

SUMMARY

A study conducted to evaluate seven storage structures, four of them of improved and three conventional types for their relative efficacy in checking insect infestation on stored seeds, true replicas (models) of these structures were filled with CSH-1 jowar seeds and rice weevil (50 beetles) were released. The experiment, which replicated thrice lasted for a period of five months. Seed samples were drawn from each structure every month and analysed and the entire quantity analysed at the end of the study. The investigations have established the supermacy of metal bin over all those followed by plywood bin, plastic bin and gunny bag lined with polythene among the improved structures besides establishing conclusively the superiority of these improved structures over the conventional structures in respect of protecting seeds from insect infestation. Among conventional structures vadai scored over earthern pot marginally and bamboo bin which was incidentally, the structure that gave little protection to seeds stored in it from insect infestation.

The relative influence of seven storage structures on the action of fumigants was also investigated, structures filled with 3 kgs of jowar seeds, received 250 insects each two fumigants namely EDB and ED/CT were used for fumigation of seeds in each structure. The study was replicated twice. EDB proved to be marginally a better fumigant over ED/CT in causing high mortality, taking less time to cause the death of residual beetle population, suppressing reinfestation, registering minimal seed damage, minimal loss in seed weight and finally accounting for higher percentage of normal seedlings and less percentage of abnormal and dead and diseased seeds.

The interaction effect between fumigant improved structure and fumigant conventional structure was significant in that fumigation in improved structure gave significantly effective control of insect infestation and consequently seed protection over fumigation in conventional structures. The latter, as proved by the present investigation, are far inferior for the purpose of fumigation.

Studies on seed moisture levels for rice weevil infestation growth and development revealed that no development was possible at low moisture levels such as 3.80 to 7.00 per cent and beyond, at 7.80 to 11.0 per cent. The insect development become rapid with further increase in seed moisture, with the optimal range of 13.20 to 16.0 per cent seed moisture. Above 16.0 per cent seed moisture insect did not develop as indicated by non-emergence of beetle, besides the seeds were infected by fungus.

Studies on the relative susceptibility of seventeen sorghum genotypes under two testing situations namely free choice random distribution technique and no choice confound testing showed genotype D followed by CSH-6, SB1079, CS3541, CSH-5 and 148 to be least susceptible to rice weevil attack. None of the genotypes were identifiable under moderately and highly susceptible categories. However, CSH-1 of all the 17 genotypes tested, proved to be highly susceptible in respect of 2 distinct reliable parameters and in others too.

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