# BIOLOGY AND MANAGEMENT OF RICE WEEVIL, *Sitophilus oryzae* L. IN POP SORGHUM

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# I. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a premier crop of the semi arid tropics and a major staple food in several parts of the world. It is a dry land crop grown in *kharif* and *rabi* seasons for the utility as food, feed, forage and industrial raw material. However, it is considered less economical and the production is relegated to marginal lands and less fertile soils with reduced input use. Sorghum grains are consumed in different forms in India namely, unleavened bread, boiled rice like products. Popped sorghum is a popular traditional snack food in central and south India which has market potential. Popping improves quality by reducing antinutrients, increasing the grain protein, carbohydrate digestibility and soluble dietary fibre. Popped sorghum is considered to be superior to popped corn as they are tender, have less hull and do not clog the space between the teeth and cause less noice when eaten. Besides, the popped sorghum grains have been found to have as much flavour and is as nutrious as popcorn (Subramanian, 1956).

It is well established fact that lot of efforts should be put for the production of “every single grain” but this is of no use if the produced seeds are not saved, which recalls the proverb “a grain saved is a grain equally produced”. This adage depends mainly on how best we protect the quality of grains during storage. Loss of grains stored as seed, the future food of our country is to the tune of 7-8 per cent accounting to major share of economic loss worth Rs. 600-700 crores. Scientists are equally putting their efforts and attempting to find ways and means to reduce losses in storage due to store pest.

Among the several insects attacking stored grains, *Sitophilus oryzae* L. has got economic importance. It is the most destructive insect pest of the stored raw cereal grains in the world (Champ and Dyte, 1976). *Sitophilus oryzae* causes substantial losses to stored grain amounting 18.30 per cent (Adams, 1976). This species has a relatively short developmental period and high populations can easily be built up (Aitken, 1975). Thus, unless control measures are taken, heavy infestations may take place. Additionally, the kernel damage caused by *S. oryzae* larvae, enables other species, the external feeders, which are not capable of infesting sound grain, so increase the damage rapidly.

Prevention of losses in stored products due to insects is of paramount importance. For this, study of the life history habits and habitats is necessary to have thorough understanding of the situation favourable to the pest and to know the vulnerable stages in life history which would be taken advantage for the effective management of pests.

Although, agricultural chemicals stand “Miracle Weapons” in the frontline of defense, stored grains are not free from problems. Sole reliance on an array of chemicals has led to several problems of residual hazards. Several technologies are available with utilization of local technologies and the use of locally available inert or raw materials in practices are meagre. Recently lot of work is being carried out on indigenous practices for protecting field crop pests, such work on storage is very less and not in much practice. The rural techniques of storage remains remote if not scientifically used widely by farming community. Further, it is high time to protect such methodologies and their documentation and giving wide publicity is the need of the hour in the present trend of livelihood to keep pace with our future generation to tackle the problems of storage. Moreover government of India is increasing its attention for establishing national and international buffer stocks of food stuff to guard against irregularities in production due to vagaries of climate, thus creating circumstances in which storage losses can be potentially lower.

There has been little emphasis in breeding for grain resistance to insect pests of stored grain products. In the countries where storage facilities are inadequate, stored grain resistance might be used either alone or along with other protective methods. Apart from this different plant products and inert materials have been used as surface barrier against storage pests to prevent cross infestation.

Since, the pop-sorghum grains are not consumed directly and immediately, they are stored for long time, popped and sold as snacks food throughout the year. There is no information on the incidence, biology and management of *S. oryzae* on pop sorghum. Keeping the above facts in view, investigations were carried out with the following objectives.

1. To study the biology of rice weevil *S. oryzae* on pop sorghum
2. Screening of varieties of pop sorghum in comparison with grain sorghum against *S. oryzae*
3. Ecofriendly approaches for the management of rice weevil

# II. REVIEW OF LITERATURE

The literature pertaining to the biology of rice weevil *Sitophilus oryzae* (L.), screening of pop sorghum genotypes for their resistance to the rice weevil and management of rice weevil with plant products and inert materials has been reviewed and presented below.

## 2.1 BIOLOGY OF THE RICE WEEVIL *S. oryzae*

The perusal of literature revealed that there is no work on pop sorghum. Hence, an attempt has been made to collect the information pertaining to rice weevil on grain or seed sorghum, other cereals and pulses.

### 2.1.1 Egg

Wille (1923) observed six to nine days of egg stage in case of *calandra oryzae* (L.) on husked rice during summer, whereas Okuni (1924) observed three to four days of incubation period under normal condition.

Newman (1927) reported three to five days of egg stage from Australia. Wenholz (1927) reported that egg stage on an average occupied three days under warm moist conditions. The eggs of *S. oryzae* laid on maize hatched in five to six days after oviposition (Anonymous, 1933). The egg period of rice weevil occupied on an average of 4.41 days (Anonymous, 1934). Treiman (1937) reared rice weevil in laboratory on unpolished rice at 27 to 28$^{0}$C and 90 to 95 per cent relative humidity. According to him, the egg period occupied 6 to 7 days. Lefevre (1953) recorded on an average of 2.65 days of incubation period in laboratory. According to Lopez-Cristobal (1953) the egg period lasted for 5 to 10 days whereas Lin (1958) recorded 3 to 10 days of incubation period in Formosa and the hatchability of egg of *S. oryzae* was influenced by the female age (Anand Prakash, 1980).

Bheemanna (1986) recorded incubation period of 5 to 8 days on CSH-5 sorghum cultivar.

Bhuiyah *et al.* (1990) observed 5 to 6 days of incubation period of rice weevil on maize at 23 to 30$^{0}$C and 79 to 87 per cent relative humidity. Barbuiya *et al.* (2002) reported incubation of 5 to 7 days on rice. Yevoor (2003) observed incubation period of 5 days on maize grains at 14 to 34$^{0}$C temperature and 55 to 88 per cent relative humidity.

Sattigi (1982) carried out detailed work on biology of *S. oryzae* on sorghum. According to him the freshly laid eggs were white and oval shaped and became pink and opaque prior to hatching. The incubation period ranged from five to nine days and length and breadth of egg measured on an average of 0.46 mm and 0.11 mm, respectively.

Bheemanna (1986) reported that eggs were laid singly inside the scooped grains. Generally only one egg was found inside the grain. Egg measured 0.341 mm to 0.0379 mm in length and 0.151 mm to 0.189 mm in width.

### 2.1.2 Larva

Wille (1923) reported that each grain containing single grub of *S. oryzae* and total larval period ranged from 12 to 17 days during summer whereas it varied from 21 to 24 days with four moults according to Okuni (1924). Newman (1927) recorded 20 to 30 days of larval period of rice weevil and Wenholz (1927) observed three weeks of larval stage on maize. Different instars were recognised by the width of the head capsule (Nakayama, 1931). Larval period of 30 and 23.22 days were recorded on maize (Anonymous, 1933 and 1934). Treiman (1937) recorded upto four larvae in a grain which occupied 18 to 20 days to complete larval stage in rice. According to Lopez-Cristobal (1953) the larval stage ranged from 10 to 30 days.

Lin (1958) in his study on biology of *S. oryzae* on stored rice in Formosa recorded the larval period of 15 to 29 days with an average of 19.20 days. Further, he also opined that the development of larva was better on rice, wheat and barley without husk as compared to the seeds of pea, tur, sorghum and maize.

According to Sattigi (1982) the larval period ranged from 23 to 33 days with an average of 28 days during February to March, 1982. There were three moults and four instars on CSH-1 genotypes. Bheemanna (1986) reported larval period of 25-34 days on CSH-5 sorghum hybrid.

Urrelo and Wright (1989) observed four instars of *Sitophilus zeamais* (M.) on maize at 70 per cent relative humidity and temperature of $27^0$C.

The larval period ranged from 16 to 20 days on maize grain at 23 to $35^0$C and 79 to 87 per cent relative humidity (Bhuiyah *et al.*, 1990).

Rice weevil *S. oryzae* when reared on maize grains the developmental period from egg to pupation was longer than on rice as studied by Pittendrigh *et al.* (1997).

Yevoor (2003) reported larval period of 27.25 days on maize grains at temperature of 14 to $34^0$C and 55 to 88 per cent relative humidity.

### 2.1.3 Pupa

Wille (1923) noticed 7 to 11 days of pupal period but, Okuni (1924) and Wenholz (1927) recorded 5 to 20 days and 3 to 4 days, respectively.

Pupal stage lasted for 5 to 12 days with an average of 5.25 days (Anonymous, 1933 and 1934).

Treiman (1937) reported 5 to 7 days of pupal period when *S. oryzae* was reared on unpolished rice. The laboratory temperature and relative humidity were 27 to $28^0$C and 96 to 95 per cent, respectively.

Lopez-Cristobal (1953) opined 6 to 16 days pupal period of *S. oryzae*. Lin (1958) observed 1 to 2 and 3 to 13 days of pre-pupal and pupal period on stored rice, respectively.

The pupa resembled adult in all respects. Pupal period occupied six to nine days with an average of eight days and pre-puapl period occupied one to two days (Sattigi, 1982).

Pupal period ranged from 8 to 11 days on CSH-5 sorghum genotypes (Bheemanna, 1986), while 8 to 9 days was recorded on maize by Bhuiyah *et al.* (1990).

Yevoor (2003) reported pupal period of 8 to 9 days on maize at temperature of 14 to $34^0$C and 55 to 88 per cent relative humidity.

### 2.1.4 Adult longevity and total life cycle

Wille (1923) observed 45 days in summer, five months in cool weather of autumn and winter for completion of one generation whereas Okuni (1924) reported eight generations of *S. oryzae* in a year and the adult lived on an average for 160 days. According to Newman (1927) the adult lived for 12 months and had seven to eight generations per year as the life cycle was completed in 30 days in summer.

The life cycle was completed in about a month or may be prolonged for several month under favourable conditions (Wenholz, 1927). Nakayama (1931) recorded three to four generations in a year in Korea.

The total life cycle of *S. oryzae* on sorghum grain (11.80 – 12.33% moisture) averaged almost 54 days and there were six to seven overlapping generations per year. Male survived for 12 to 122 days with an average of 70.2 days and females for 51 to 122 days with an average of 83.9 days. The emerged male and female were approximately equal in number and they survived for a maximum of 19 days when enclosed without food (Lefevre, 1953). According to Lopez-Cristobal (1953) the adult survived for 15 to 30 days with food.

Lin (1958) reported eight generations per year in Formosa. The adult males survived for 12 to 130 days and 1 to 139 days, respectively.

The adult male and female lived for 16 to 172 and 14 to 196 days, respectively. In the absence of food the adult female lived for 9 to 17 days and male for 7 to 13 days as per the report placed on records by Sattigi (1982).

Bheemanna (1986) observed adult longevity ranging from 14 to 165 and 7 to 11 days with and without food, respectively.

Bhuiyah *et al.* (1990) reported that adult longevity in male and female was 114 to 115 and 119 to 120 days, respectively when a day old adults were released into 2 kg sacks of maize.

Yevoor (2003) observed that female lived for 115.76 days, male lived for 97.42 days with food. Female lived for 9.50 days, male lived for 7.32 days without food.

## 2.2 SCREENING OF POP SORGHUM GENOTYPES IN COMPARISON WITH GRAIN SORGHUM AGAINST RICE WEEVIL

The persual of literature revealed that there is no work on this aspect.Hence an attempt has been made to collect the information on grain sorghum and other cereals.

Samuel and Chattergi (1953) reported that among the 24 varieties screened against *S. oryzae* the variety JS-20 proved to be highly resistant. Whereas the variety Imperial Saomer was highly susceptible to the pest.

Russell (1966) on the reaction of four varieties to rice weevil reported a short adult life with increasing hardness of grain and further opined that colour, size, endosperm character and tannin content played important role in the extent of weevil damage.

Preliminary studies made by Doraiswamy (1971) revealed that the varieties CO-4, CO-18 and CO-19 were found resistant. K-3, CO-11, CO-20 and K-2 were recorded to be susceptible and varieties K-5, Swarna and CSH-1 were highly susceptible.

Puttarudrappa *et al.* (1971) screened nine varieties of sorghum against rice weevil at Dharwad. After 84 days it was found that in the different varieties 17.96 to 31.34 percentage of the seeds were damaged and the population averaged to 7.20 to 21.23 insects per bottle. The variety M 35-1 showed least per cent infestation of 11.96 as compared to 19.90 to 31.34 infestation in IS-3691, CSH-1, CSH-2, C7-1195 and Nandyal. Both the hybrids CSH-1 and CSH-2 were equally susceptible to *S. oryzae* that 31.34 infestation was in case of Nandyal and CSH-1, but the multiplication of insect population was less. This may be attributed to the mortality of the insects during storage or due to the characteristics like colour of the grain, size, hardness, endosperm characters and tannin content.

Kishore *et al.* (1975) reported that percentage of damaged grains due to rice weevil after 45 days varied from 6.50 (CSH-5) to 21.17 (CSV-4).

Krishnamurthy *et al.* (1976) studied the differential resistance to sorghum genotypes to *S. oryzae*. The grains of five hybrids and a local genotype of sorghum were compared for resistance. According to him CSH-5 was fairly resistant to the pest and M 35-1 was infested by a larger number of weevils.

The performance of 39 sorghum lines were studied by Ramalho *et al.* (1977). There were no significant differences in number of adult weevils emerging from different sorghum. But, they differed significantly in the development period as well as in the weight of insects. There was no correlation between resistance, tannin content and hardness

Murthy and Aftab Ahmed (1978) reported that varieties 302, 604, Swarana were found susceptible while Y-75 proved resistant against rice weevil.

Borikar and Tayde (1979) carried out screening studies against rice weevil and reported that hybrids CSSH-8R, CSH-1 and CSH-5 and the varieties 168 and 370 were less susceptible to attack by *S. oryzae* than the local varieties R-16 and 604.

Chundurwar and Karanjikar (1979) from Parbhani Maharashtra observed the relative susceptibility of eight sorghum cultivars to rice weevil. His observations revealed that the hybrids SPH-1, CSH-6 and CSH-1 were significantly less damaged than rest of the cultivars tested. SPH-1 and CSH-6 were least susceptible as compared to rest of the cultivars. The variety SPH-61 relatively had less incidence of rice weevil followed by CSH-6K, CSV-5, CSH-8R, CSV-4, SPH-1 and CSH-5 (Borikar, 1980).

Patel *et al.* (1980) studied the ovipositional preference of rice weevil to nine sorghum varieties and four hybrids. Observations on the ovipositional preference were recorded after one week of the release of fifty pair of adults. Egg plugs on the kernels were counted after staining with acid fuchsion. Data revealed that kernels of CSH-8R received the minimum (3.25) number of egg plugs followed by CSH-6 (5.25), CSV-4 (5.25), CSV-1 (6.50), CSH-1 (7.50), CSV-3 (7.75) and CSV-6 (8.00). Dathe *et al.* (1981) reported none of the hybrids tested was found resistant to pest though CSH-5 was less susceptible as compared to CSH-1 and CSH-6.

Kurdikeri *et al.* (1993) reported that initial germination of 97.12 per cent in maize hybrid Deccan 103 was brought down to 39.50 per cent, after six months of storage due to rice weevil infestation.

Bheemanna *et al.* (1994) studied the relative susceptibility of some sorghum genotypes to rice weevil and reported that the population build up was lowest on DMS-6 (10.33 weevils), highest on CSH-1 (360.33), CSH-1 recorded (13.10 g), DMS-652 recorded lowest grain weight loss (2.35 g).

Balakai (1998) reported that Bhogapur local, IS-2205, SPV-462 and SPV-924 recorded the least grain loss ranging from 7.1 to 7.4 per cent and proved moderately resistant, CSH-5 were most susceptible.

Reddy *et al.* (2002) evaluated thirty five grain sorghum genotypes representing 6 variable groups for the orientation, colonization and ovipositional response of the rice weevil, *Sitophilus oryzae* (L.). Greater levels of oviposition were noticed in 2077B, DJ-6514 and IS11758 in free choice tests and 22198, M148-138, P-721 and Nizamabad (M) in no choice tests. To the contrary, M-35-1, Swati and Lakadi showed greater susceptibility for oviposition. Significantly less damage to seed observed on 2219A/B, 116B, IS9487, IS 11758, CSV 8R (M) and local yellow.

## 2.3 ECOFRIENDLY APPROACHES FOR THE MANAGEMENT OF RICE WEEVIL IN POP SORGHUM

### 2.3.1 Sweet flag rhizome (*Acorus calamus*) powder

Jilani (1984) reported that *A. calamus* as good grain protectant against *S. oryzae* and *Rhizopertha*.

Panesu *et al.* (1983) reported that the dried and ground rhizome of sweet flag used at 50 g per kg of wheat against *S. oryzae* reduced the damage of stored seeds to 5.4 per cent compared to untreated control.

Sweet flag significantly reduced the seed infestation and F1 progeny production of *S. oryzae* in wheat when used at 0.5 per cent as reported by Tiwari (1993).

Kalasagond (1998) found that sweet flag rhizome powder at 0.6 per cent caused cent per cent mortality of *S. oryzae* and complete protectant upto 240 days. Sweet flag powder @ 5 per cent was found to be most effective grain protectant even upto 45 days after treatment resulting in 100 per cent mortality. It reduced to 97.5 per cent at 90 days treatment (Rama Rao and Sarangi, 1998).

Biradar (2000) studied the mortality of *S. oryzae* consequent to the impregnation of gunny bags with botanicals. Sweet flag rhizome extract @ 5 per cent v/v at 30 days after storage offered 100 per cent mortality. Among different treatments tested sweet flag rhizome extract protected upto 90 days of storage.

Sunilkumar (2003) studied that sweet flag was highly protective upto 180 days against *S. oryzae* @ 10 per cent dosage showing less than one per cent seed damage in sorghum.

Yevoor (2003) studied that sweet flag powder @ 2 per cent caused zero per cent grain damage and weight loss and cent per cent adult mortality of *S. oryzae* upto 60 days after storage in sorghum against *S. oryzae*.

### 2.3.2 Turmeric (*Curcuma longa* Rose)

Panikar and Vijayalakshmi (1998) reported efficacy of natural plant products like neem leaf powder, turmeric powder, eupatorium powder and citronella leaf powder against *Sitophilus oryzae*. Turmeric powder was found to be lest effective.

### 2.3.3 Neem leaf powder (*Azadirachta indica* A. Juss)

Jilani and Su (1983) indicated the repellent activity of neem leaf powder to *S. granarius* and *R. dominica* on wheat seeds. It was reported that the average number of *R. dominica* adult emergence was 3.08, 5.16 and 20.16 with neem leaf powder used at 2.0 and 1.0 per cent and untreated control, respectively. This repellent activity of neem leaf powder was supported by Banarjee and Nigam (1985).

Valsamma and Patel (1992) tried the neem leaf powder (10%) against pulse beetle, *C. analis* on green gram and reported that at 30 and 60 days after treatment, the seed damage was 4.3 and 4.8 per cent as against 9.7 and 22.8 in untreated control.

The neem leaf powder used at five per cent (w/w) to protect greengram against pulse beetle *C. analis* revealed 7.5 per cent adult mortality after three days of release when compared to 100 per cent mortality in the untreated control (Juneja and Patel, 1994).

Sharvale and Borikar (1998) evaluated the neem leaf powder against *C. chinensis* in chickpea and observed that the adult mortality after 48 hours of release was 1.25 per cent with a weight loss of 10.78 per cent after 20 days.

Rajapakse *et al.* (1998) evaluated the neem leaf powder at 2.5 , 5.0, 7.0 and 10 per cent against *C. maculatus* infesting cowpea. Mean mortality after two DAT was 0.3, 0.25, 0.2, 0.3 and at four DAT mean mortality was 3.10, 3.50, 3.25 and 3.0 per cent, respectively.

Sunilkumar (2003) studied that neem leaf powder at 1 per cent dosage was not effective in protecting the sorghum grains after 30 days after storage against *S. oryzae*.

### 2.3.4 Custard apple seed powder (*Anona squamosa* L.)

The custard apple seed extract possess more olfactory repellency against normal susceptible strain of *S. oryzae* and *T. castanum* as compared to saopnut (Quadri, 1973).

Luca (1979) observed the antifeedent effect of custard when mixed at 0.5 to 2.0 parts per 100 parts and also prevented build up of bruchid population.A mean survival of *C. chinensis* with 56.66 and 26.00 per cent after three days of release and 10.66 and zero per cent after seventh day of release at one and 2 g/100 g of seeds respectively as reported by Ali *et al.* 1981), the survival in the untreated control at corresponding period was 86.66 and 45.00 per cent. There was no egg laying observed as compared to 380 eggs in the untreated control. There was no adult emergence of second generation and consequently no seed damage was noticed but in the control cent per cent seed damage was noticed with 54 adults.

Mishra *et al* (1992) found that wheat grains can be protected from the attack of *S. oryzae* by mixing custard apple seed powder at 5 per cent for 75 days.

Kalasagonda (1998) noticed the adult mortality of *S. oryzae* at 60, 120, 180 and 240 DAT with 56.66, 50.00, 45.00, 36.66; 66.66, 63.33, 55.00, 50.00; 73.33, 66.66, 61.66, 53.33 and 80.00, 71.66, 68.33, 63.33 per cent at 0.8, 1.0, 1.2 and 1.4 per cent custard apple seed powder in wheat seeds respectively as against 0.00, 6.00, 6.66 and 5.00 in untreated control. Number of F1 adult emergence and weight loss of wheat seeds when treated with 0.8, 1.0, 1.5 and 1.4 per cent custard apple seed powder recorded 278, 211.33, 145.66, 94.00 adults with 12.06, 10.73, 8.73, 3.93, per cent weight loss as against 476.66 adults and 19.36 per cent weight loss in the untreated control.

Custard apple seed powder at 5 per cent in rice and wheat grains showed cent per cent mortality of *S. oryzae* at 7 days after beetle release and recorded zero per cent weight loss 90 days after storage (Sivasrinivasu, 2001).

Sunil Kumar (2003) concluded that custard seed powder at 1 per cent was effective in controlling *S. oryzae* on sorghum grains upto 90 days after storage.

Yevoor (2003) opined that custard apple seed powder @ 0.2 per cent was highly effective and showed cent per cent upto 60 DAT and zero per cent grain damage and weight loss upto 90 DAT.

### 2.3.5 Tulsi leaf dust

Banarjee and Nigam (1985) observed repellent effect in leaves of tulsi (*Ocimum basilicum* L.) against stored grain pests.

Shivanna *et al* (1994) reported the per cent weight loss due to first generation pulse beetle was maximum in untreated check 17.89 per cent and on par with 1.5 g (15.08%). Lohra and Singhvi (1998) reported the repellency power of tulsi at the rate of 1.0, 2.5 and 5.0 ml/100 g sorghum seeds against *T. confusum*.

### 2.3.6 Lakke leaf powder (*Vitex negundo*)

Mishra *et al.* (1992) showed that *Vitex negundo* leaf powder @ 5 per cent in wheat grains caused 80.00 per cent mortality of *S. oryzae* at 30 days after treatment. Per cent damaged grains, weight loss and population build up during 90 days of storage were 19.7, 12.7 and 2.90, respectively. Leaf powder extract of *V. negundo* at 5 per cent resulted in 96.34 per cent mortality of *S. oryzae* at 30 days after treatment and then onwards effectiveness gradually reduced as reported by Biradar (2000).

Sunilkumar (2003) observed that there was 7 to 18 per cent seed damage in sorghum seeds treated with *Vitex negundo* @ 1 per cent from 30 to 90 days after treatments.

Yevoor (2003) recorded 72.5 per cent mortality of rice weevil in maize grains at 30 and 60 DAT, respectively. However, its toxicity decreased after 120 DAT.

### 2.3.7 Kalonite clay

Besides the use of inert dusts such as calcium oxide, gypsum, kaolinite and attapulgite as diluents or carriers in the formulation of pesticides. These so called inert materials also exhibit insecticidal property when used alone. High cost of processing these days probably limits commercial use. However, extensive deposits of attapulgite clays in Andhra Pradesh and Rajasthan are almost pure. Thus, it would be worth while to explore the possibility of using such materials in managing the stored grain pests.

Alexander *et al.* (1944) was the first to report that inert dusts remove the insect epicuticular lipid layer either by absorption depending on physical nature of the dust particle. Their mode of action on various pests was studied by Wigglesworth (1944).

Krishnamurthy *et al.* (1965) stated that more than length and diameter of the inert dusts more is the insecticidal activity. Desiccation power of inner dust to insects was more in kaolinite clay than in mountmorillonite clay (Ebling, 1971).

Swamiappan *et al.* (1976) observed that acid activated clay treatment caused cent per cent adult mortality of many of the stored grain pests within 24 hours after treatment. Attapulgite based clay dusts have good insecticidal property causing 90.00 per cent mortality in *Corcyra cephalonica, T. castaneum* and *S. oryzae* within 48 hours after treatment (Verma *et al.*, 1976).

Yevoor (2003) opined that kaolinite @ 10 per cent caused upto 90 per cent mortality of adult at 28 days after release and less per cent grain damage and weight loss upto 90 DAS.

### 2.3.8 Neem seed kernel powder (NSKP)

Mixing of kernel powder at one to two parts of seed protected wheat seeds from *S. oryzae* for at least 269 days (Jotwani and Sircar, 1965). Deshpande (1967) investigated that neem seed powder at two per cent was effective in protecting jowar grains against *S. oryzae*. Seed powder at 1.00 per cent and 2.00 per cent reduced oviposition of adult rice weevil (Girish and Jain, 1974).

Ketkar (1976) reported that seed powder at 0.5 per cent of grain reduced *S. oryzae* population. Chander and Ahmed (1983) reported that neem leaf powder at 5 per cent (w/w) protected the wheat seeds against *S. oryzae* infestation for three months.

Mishra *et al.* (1992) reported that seed powder at 0.5 per cent (w/w) retained its effect for longer duration causing 100, 96.70, 83.30 per cent audlt weevil mortality at 30, 60 and 75 days after treatment. Neem seed powder at 0.5, 1.00 and 2.5 g per kg of maize seeds recorded cent per cent mortality within five days after treatment and protected seeds for six months without affecting the seed viability. Neem seed kernel powder at 2 per cent (w/w) was found effective in protecting maize seeds against *S. oryzae* for two weeks (Sharma, 1995).

Kalasagond (1998) noticed the mortality of *S. oryzae* at 60, 120, 180 and 240 days after treatment with 0.8, 1.0, 1.2 and 1.4 per cent neem seed powder in wheat grains were 25.00, 8.33, 8.33 and 6.66 per cent, 43.33, 26.66, 25.00 and 8.33 per cent, 51.66, 41.66, 35.00 and 10.00 per cent, 61.66, 53.33, 43.33 and 26.66 per cent, respectively as against 0.00, 0.00. 6.66 and 5.00 in untreated control.

Rama Rao and Sarangi (1998) reported neem seed powder (5%) as a effective grain protectant against *S. oryzae* with 87.70 per cent mortality which reduced to 82.50 per cent from 30.00 to 90.00 days after treatment. Neem seed kernel powder @ 4 per cent when mixed with maize grains, effectively protected the grains for 5 months against *S. oryzae* attack (Sharma, 1999). Neem seed powder @ 5 per cent caused cent per cent mortality of rice at 7 days after beetle release and weight loss was nil during 90 days of storage as per the observations placed on records by Sivasrinivas (2001).

Mahanti (2002) reported that neem seed powder at the rate of 2 g per kg of maize seed caused 100 per cent mortality of *S. oryzae* at 10 days after beetle release.

Sunilkumar (2003) reported that neem seed powder @ 1 per cent showed less per cent of seed damage of 5 to 10 per cent from 30 to 60 days after storage.

Yevoor (2003) recorded zero per cent grain damage and weight loss 90 DAS and cent per cent mortality 60 DAS.

### 2.3.9 Sand

Application of sand in India is an age old practice to protect stored grains from insect attack (Pruthi and Singh, 1950). Sand later from 0.75 to 1.25 cm protected the redgram and bengalgram seeds from *C. chinensis* attach and prevented oviposition, adult emergence and damage to seeds (Haracharan Singh, 1966 and Choudhary and Pathak, 1989). Sand at 30 per cent effectively prevented the infestation by *S. zeamais* and *S. cerealellela* in maize (Golob *et al*., 1982).

The mortality of adults of *C. chinensis* at 24, 48 and 72 HAR was recorded to be 10.00, 13.33, 20.00 per cent, 13.33, 33.33, 26.66 per cent and 20.00, 26.66, 33.33 per cent at 20, 30, 50 per cent sand in red gram seeds as against no mortality in control by Kittur (1990). Further, mean number of eggs laid, adult emergence and per cent weight loss at 20, 30 and 50 per cent were 213.30, 151.66, 69.60, 175.00, 120.67, 150.00 and 6.54, 4.19, 0.96 per cent, respectively as compared to 214.33, 194.83 and 6.37 per cent in control.

### 2.3.10 Saw dust

Chahal and Judge (1988) studied saw dust as physical barrier against khapra beetle *Trogoderma granarium* (E.) in wheat grains. An 8 cm layer of saw dust over wheat grains prevented the attack of beetle. When saw dust was mixed with wheat grains, the reduction in the pest population was related to the ratio of saw dust to wheat grains with greatest reduction being obtained at ratio of 4:5.

Yevoor (2003) reported that saw dust @ 10 per cent was not effective in controlling rice weevil damage to maize grains showing more grain damage (70%), weight loss (50%) and 10 per cent adult mortality upto 180 DAT.

### 2.3.11 Ash (cow dung)

Pawar (1980) reported that 1.25 cm layer of cow dung ash at the top was effective in protecting seeds from *C. chinensis* in tanks and barrel. Further, mixing with 30 per cent wood ash was also effective against *S. oryzae* and *S. cerealella* in maize. Studies made by Ofuya (1986) indicated that wood ash was the most effective in reducing the damage by *C. maculatus* in cowpea seeds and observed that the adult emergence was noticed after 95 days of treatment.

Kittur (1990) found that cow dung ash to be good in controlling *C. chinensis* activities in redgram seeds. The mortality of beetles at 24, 48 and 72 hours after treatment (HAR) was 10, 10, 20 per cent, 43.33, 46.66, 80.00 per cent and 100.00, 100.00, 100.00 per cent when used at 15, 20 and 30 per cent, respectively wherein no mortality was observed in untreated control. Further, mean number of eggs laid, adult emergence and per cent weight loss when used at 15, 20 and 30 per cent were 137.67, 0.0, 0.00; 37.33, 0.00, 0.00 and 2.11, 0.00, 0.00 per cent, respectively as against 214.33, 194.83 and 6.37 per cent in untreated control. The minimum ratio of 3 parts to 4 parts of cowpea seeds prevented population growth of *C. maculatus* and 3 cm layer of ash on top of stored seeds prevented infestation by adults (Wolfson *et al.*, 1991).

Apuli and Villet (1996) tested wood ash against *C. maculatus* in cowpea. The damage to seeds ranged from 63 per cent in the ash free control to 1.3 per cent in seeds treated with 30 per cent ash. The number of progeny similarly ranged from 148 in the untreated control to 2.5 in 30 per cent ash treatment.

Kalasagond (1998) evaluated the inert dusts, ash (30 cm top layer) and activated kaolin (1.2%) were found to be highly effective which caused cent per cent adult mortality of *S. oryzae* and *R. dominica*. This was followed by 30 per cent ash admixture which was found to be moderately effective further preventing F1 progeny and grain weight loss.

Sivasrinivasu (2001) found cent per cent mortality of rice weevil at 28 days after storage in sorghum treated with 30 per cent ash and observed no weight loss for 90 days of storage period.

Yevoor (2003) reported that ash was not effective to maize grains which showed less than 50 per cent adult mortality, 30 DAT and zero per cent adult mortality at 150 and 180 DAT.

# III. MATERIAL AND METHODS

Studies on the biology of *Sitophilus oryzae* (L.) on pop sorghum variety Talakal-6, evaluation of plant products and inert materials, screening of pop sorghum genotypes against *S. oryzae* were conducted during 2005-06 in the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad, Karnataka state. Materials used and the technique employed during the course of investigation for conducting experiment are presented here.

## 3.1 BIOLOGY OF RICE WEEVIL *Sitophilus oryzae* (L.)

Studies on the biology of the rice weevil, *S. oryzae* was carried out under laboratory condition when the maximum and minimum temperature was $39.5^0$C and $11.7^0$C respectively. The maximum and minimum relative humidity were 86 and 51 per cent respectively during the course of investigations (Appendix-I).

### 3.1.1 Maintenance of stock culture

Stock culture of the rice weevil was initiated by collecting the adult weevils from the infested sorghum grains from university farm store house. The culture was further maintained in glass bottle of two litre capacity containing the pop sorghum grains. The mouth of the container was covered with a muslin cloth. Fresh grains were provided periodically for the development of beetles. The culture so maintained was used throughout the period of investigations.

### 3.1.2 Pure culture

Pure culture of the beetles was developed by infesting insect free pop sorghum grains with freshly emerged single mating pair. The culture was maintained in the glass bottle of 1 l capacity on insect free pop sorghum grains. Mouth of the such container was covered with muslin cloth. The culture was used to study the biology of the beetle pest.

### 3.1.3 Egg stage

Thirty rice weevils were enclosed with 50 g pop sorghum grains in each bottle and these bottles were kept in ambient conditions. Damaged grains were replaced every morning with uninfested grains. Grains containing eggs were separated out by examining under microscope and were used for further study.

### 3.1.4 Incubation period

Pop sorghum grains with rice weevil eggs so obtained were maintained in a glass vials for incubation. Daily twenty grains from the day of oviposition to egg hatching were dissected to determine the incubation period.

### 3.1.5 Larval period

On hatching the larvae of rice weevil were allowed to feed individually inside the grains in specimen tube of 7.5 cm x 2.5 cm size having 5 gram pop sorghum grains. Five grains per day were dissected out to see the different stages of the larvae. The dissection of grains was made upto the pupal stage. The period between egg hatching and pupation was observed as larval period.

### 3.1.6 Pupal period

The pupal period of the pests was studied by observing the same larvae for pupation inside the grains. This was maintained and the observations were made till the adult emergence. The period between formation of pupae till the adult emergence was noted as pupal period.

### 3.1.7 Ovipositional studies

A pair of emerged weevils were collected in specimen tube (7.5 x 2.5 cm) and such ten specimen tubes were maintained. The weevils were allowed to mate. Mating period, premating period were recorded.

### 3.1.8 Adult longevity

The ability of the adults of *S. oryzae* to live in the presence or absence of food was determined by enclosing male and female adults obtained from the culture separately. Ten such vials were maintained for each of the male and female with and without food.

## 3.2 SCREENING OF POP SORGHUM GENOTYPES IN COMPARISON WITH GRAIN SORGHUM GENOTYPES AGAINST RICE WEEVIL

Three pop sorghum genotypes and three genotypes of grain sorghum were collected and evaluated to know their reaction to the rice weevil, *S. oryzae* under laboratory condition. Freshly harvested grains of *kharif* and *rabi* seasons were secured from Main Agricultural Research Station, College of Agriculture, Dharwad. The genotypes included were Talakal – 6, Mugad local, Shiggaon local, DSV-3, CSH-14 and CSH-16.

Sound, unaffected grains of each genotypes were dried in hot air oven for six hours at $42^{0}$C in order to eliminate the infestation by store grain pests. The moisture content of grains was 10.7 $\pm$ 2 per cent.

Grains of each variety weighing 100 g were kept in plastic bottle of 500 ml capacity. Ten pairs of five days old weevils were introduced in each bottle and tops were kept covered with muslin cloth and tightly fixed with rubber band. These were kept in four replications for observations upto 180 days. For every month, each bottle was examined periodically to note the loss of weight of grains, percentage of damaged grains, per cent germination and population build up, per cent popping. The data were subjected to statistical analysis by performing angular transformation.

### 3.2.1 Germination test

Seed germination was carried out employing rolled paper towel test, described by International Rules for Seed testing (ISTA) (Anon., 1996). Germination was observed at monthly interval for six months.

### 3.2.2 Estimation of weight loss

For loss estimation, 100 g of seeds were taken into plastic bottle of 500 g capacity, ten pairs of adults were released into the plastic bottle, open top of the plastic bottle was covered with muslin cloth and fastened with rubber band. Each treatment was replicated four times. Observation on seed damage and weight was recorded. Weight loss was worked out by using the formula (Adams and Schulton, 1978).

$$\text{Per cent weight loss} = \frac{(UND) - (DNU)}{U\,(ND + NU)} \times 100$$

Where,

U - Weight of uninfested grains (g)

NU - Number of uninfested grains

D - Weight of infested grains (g)

ND - Number of infested grains

## 3.3 ECOFRIENDLY APPROACHES FOR THE MANAGEMENT OF RICE WEEVIL IN POP SORGHUM

Various botanicals (Plate 1) were evaluated for their bioefficacy against rice weevil *S. oryzae* in pop sorghum. The following botanicals were included in the present study.

### 3.3.1 Rhizomes

Rhizomes of sweet flag *Acorus calamus* L., turmeric *Curcuma longa* L. were procured from local market and made into bits and shade dried for a week then ground into powder.


Plate 1 : Different plant products used for management of rice weevil *S. oryzae*


Plate 2 : Different inert materials used for management of rice weevil *S. oryzae*

**Plate 1: Different plant products used for management of rice weevil S. oryzae**

**Plate 2: Different inert materials used for management of rice weevil S. oryzae**

**Table 1: List of botanicals used for evaluation against *S. oryzae***

| Common name | Scientific name | Part | Dosage (%) |
|---|---|---|---|
| 1. Lakke | *Vitex negundo* L. | Leaves | 5 |
| 2. Kharanja/honge | *Pongamia glabra* L. | Leaves | 5 |
| 3. Sweet flag | *Acorus calamus* L. | Rhizome | 1 |
| 4. Tulsi | *Oscimum basilicum* L. | Leaves | 5 |
| 5. Custard apple | *Annona squamosa* L. | Seeds | 5 |
| 6. Adasali | *Adathoda vesica* L. | Leaves | 5 |
| 7. Neem | *Azadirachta indica* A. Juss | Leaves | 5 |
| 8. Neem | *Azadirachta indica* A. Juss | Seeds | 5 |
| 9. Pwriwinkle | *Vinca rosea* L. | Leaves | 5 |
| 10. Turmeric | *Curcuma longa* L. | Rhizome | 5 |

**Table 2 : List of inert materials used for evaluation against *S. oryzae***

| Name | Dosage in per cent (w/w) |
|---|---|
| 1. Kaolinite clay | 10 |
| 2. Cow dung ash | 30 |
| 3. Sawdust | 10 |
| 4. Sand | 10 |
| 5. Bentonite | 10 |

### 3.3.2 Leaves

The leaves of *Vitex negundo* L. and *Vinca rosea* L.*, Adathoda vesica* L.*, Pongamia glabra* L., *Azadirachta indica* and A. Jus, *Oscimum basilicum* L., were collected and shade dried for a week then ground into powder.

### 3.3.3 Seeds

Seeds of *A. indica* and *Annona squamosa* L., were collected and made into powder using a grinder.

### 3.3.4 Preparation of inert materials

Dry cowdung pallets were collected from the farm house and burnt to get the ash. Sawdust was collected from the carpenters house. Kaolinite clay and Bentonite clay were obtained from the Soil Science Department of UAS, Dharwad (Plate 2).

Each of the grain protectant at the desired dosage was thoroughly mixed with 100 g of uninfested seeds of Talakal-6 variety in a plastic bottle of 250 g capacity. Freshly, emerged weevils were drawn from the stock culture bottle and released at the rate of 10 pairs of adults per bottle. Bottles were covered with muslin cloth and fastened with rubber band. Each treatment was replicated 3 times. Observations on adult mortality at 7, 14, 21, 30 days after storage, seed damage and weight loss and population buildup and adult mortality were recorded at monthly interval for 6 months. Per cent mortality was recorded on the basis of number of dead and live insects. Per cent weight loss was calculated by using the aforesaid formula (Adamas and Schulton, 1978).

### 3.3.5 Jute bag treatment

Small jute bags that could hold 250 g of pop sorghum grains were prepared from new full sized bag by cutting it into required size. 100 g of grains of pop sorghum variety Talakal-6 were treated with plant products and inert materials at below mentioned dosage and filled inside the jute bags, 10 pair of adults weevil were released and bags were tied. The observations which are mentioned above were recorded on 30, 60, 90, 120, 150 and 180 DAS.

### 3.3.6 Popping quality of treated sorghum samples

Grains were put in a hot pan temperature 220 $^{0}$C and covered with a cloth and stirred continuously and continued popping till the popping sound of grains stopped. Popped grains were then removed from the hot pan and after cooling weight of popped and unpopped grains were noted and the following quality parameters were used to assess the popping quality (Yenagi *et al.,* 2005).

3.3.6.1 Popping quality

3.3.6.1.1 Popping yield (%)

$$\text{Popping yield (\%)} = \frac{\text{Total weight of popped grains}}{\text{Total weight of grain (popped grain + unpopped grain)}} \times 100$$

3.3.6.1.2 Volume expansion ratio

Expansion ratio is the ratio of popped volume (ml) to that of volume as ml raw kernels (ml) and expressed as ml.

$$\text{Volume expansion ratio} = \frac{\text{Total popped volume}}{\text{Volume of raw kernels}} \times 100$$

### 3.3.7 Organoleptic evaluation of popped sorghum of treated samples

Organoleptic evaluation of popped sorghum treated with different ecofriendly materials which have yielded more than 70 per cent popping was done for appearance, colour, texture, taste, aroma and overall acceptability by scoring method of Swaminathan (1995). Code number were given to samples of sorghum treated sweet flag powder, custard seed powder, neem seed kernel powder, kaolinite, bentonite and malathion. Samples were evaluated by panel of ten judges (Appendix II), for the acceptability of the treated sample. The mean score was obtained for all the characters and he data were statistically analyzed.

# IV. EXPREIMENTAL RESULTS

Results of the investigations on the rice weevil *Sitophilus oryzae* (Linn.) with reference to its biology, reaction of genotypes, and bioefficacy of grain protectants in pop sorghum carried out during 2005-06 at the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad are given as here under.

## 4.1 BIOLOGY OF RICE WEEVIL *Sitophilus oryzae* (L.) ON POP SORGHUM GRAINS

Biology of the *S. oryzae* on pop sorghum grains having 10.7 per cent moisture content under laboratory condition at temperature and relative humidity ranging from 11.7 $^{0}$C to 39.5 $^{0}$C and 51 to 86 per cent, respectively was carried out. The results along with description of brief biology of various developmental stages are presented as follows.

### 4.1.1 Egg

Eggs were laid inside the cavity on the pop sorghum grains. The eggs were oval in shape with one end pointed and other end rounded. Freshly laid eggs were translucent and white and became opaque before hatching (Table 3).

### 4.1.2 Larva

Three moults and four instars were observed under laboratory conditions, grub development took place inside the grain. Grub was apodous, short, stout, yellowish white brown coloured head (Plate 3). There were 13 segments with nine pairs of spiracles, one pair was on thorasic region and the rest were on abdominal segments. Body was covered with small setae (Table 4). First instar measured 0.29 mm to 0.31 mm length, second instar 0.41 mm to 0.49 mm, third instar 0.88 m to 10.1 mm, fourth instar 1.35 to 1.50 mm. Grub period ranged from 21 to 30 days with a mean of 25.8 $\pm$ 3.70 days.

### 4.1.3 Pupa

Pupa was white to yellowish white, exerete with clearly visible head thorax and abdomen (Plate 4). Pupa measured 3.41 mm to 3.46 mm. pupal period occupied 7-8 days with an average of 7.4 + 0.55 days. Pupation took place in larval tunnel inside pupal case.

### 4.1.4 Total life cycle

The total life cycle from egg to adult occupied 35 to 46 days with an average of 40.2 $\pm$ 4.69 days.

### 4.1.5 Adult

Newly emerged adults were reddish brown which gradually turned to black in due course of time. Adults were elongate sub-cylindrical with four orange coloured patches on elytra (Plate 5). Externally both male and female look alike but on closer observation, the rostrum of the male was comparatively thick, closely punctured roughs curved, while in female it was elongate, slender smooth, shining slightly curved and sparsely punctured. Head was prolonged into snout at the tip of which mouth parts are situated.

Antennae were short and geniculate type. Adults measured 3.5 to 4.00 mm in length.

### 4.1.6 Pre mating periods

The pre mating period observed during present study ranged from 4 to 6 days with an average of 5.2 $\pm$ 0.83 days.

### 4.1.7 Mating period

The mating of the weevil was observed during day time from 9.00 am to 6.00 pm. Hot sunshine seems to favour mating. The mating period ranged from 30 to 67 minutes with an average of 51.2 $\pm$ 14.02 minutes.

### 4.1.8 Adults longevity

With food, adult females survived for 81 to 104 days with an average of 95.80 $\pm$ 9.04 days but males survived for 57 to 61 days with an average of 59.2 $\pm$ 1.64 days. Without food adult female survived for only 9 to 12 days with an average of 10.6$\pm$1.14 days. While, males survived for 5 to 7 days with an average of 5.6 $\pm$ 0.89 days.

**Table 3: Biology of the rice weevil, *Sitophilus oryzae* L. on pop sorghum**

| Sl. No. | Particulars | Mean (days) | Standard deviation (SD$\pm$) | Range (days) |
|---|---|---|---|---|
| 1. | Grub period | 25.8 | 3.70 | 21-30 |
| 2. | Pupal period | 7.4 | 0.55 | 7-8 |
| 3. | Adult longevity | | | |
| | **I. Male** | | | |
| | a. With food | 59.2 | 1.64 | 57-61 |
| | b. Without food | 5.6 | 0.89 | 5-7 |
| | **II. Female** | | | |
| | a. With food | 95.8 | 9.04 | 81-104 |
| | b. Without food | 10.6 | 1.14 | 9-12 |
| 4. | Premating period | 5.2 | 0.83 | 4-6 |
| 5. | Mating period (min) | 51.2 | 14.02 | 30-67 |
| 6. | Total life cycle | 40.2 | 4.69 | 35-46 |

**Plate 3 : Different larval instars of rice weevil *S. oryzae***

Plate 3: Different larval instars of rice weevil S. oryzae

**Plate 4 : Pupae of rice weevil *S. oryzae***

Plate 4: Pupae of rice weevil S. oryzae

**Plate 5 : Adult female and male of rice weevil *S. oryzae***

Plate 5: Adult female and male of rice weevil S. aryzae

**Table 4: Measurement of different stages of *S. oryzae***

| Stages | Body length (mm) | |
|---|---|---|
| | Range (mm) | Average (mm) |
| **1. Grub** | | |
| First instar | 0.29-0.32 | 0.30 |
| Second instar | 0.41-0.49 | 0.45 |
| Third instar | 0.88-1.10 | 0.95 |
| Fourth instar | 1.35-1.50 | 1.43 |
| **2. Pupa** | 3.41-3.46 | 3.44 |
| **3. Adult** | | |
| a. Male | 3.0-3.50 | 3.25 |
| b. Female | 3.5-4.00 | 3.75 |

## 4.2 SCREENING OF POP SORGHUM GENOTYPES IN COMPARISON WITH GRAIN SORGHUM AGAINST RICE WEEVIL, *S. Oryzae*

Three pop sorghum varieties along with two popular hybrids and one variety were screened to know their reaction to *S. oryzae* at different days of storage. The observations on per cent grain damage, weight loss, germination percentage, adult emergence, per cent popping, were taken into consideration to decide the susceptibility of pop sorghum genotypes to *S. oryzae*. Results on these parameters are presented in the table 5 to 10.

### 4.2.1 Per cent grains damage

#### 4.2.1.1 30 DAS

At 30 days after storage, grain sorghum variety DSV-3 recorded significantly minimum of 30.7 per cent grains damage (Table 5) followed by grain sorghum hybrid CSH-16 (43.90), CSH-14 (56.80) and Mugad local (50.60). Significantly maximum per cent of damaged grains were noticed in Shiggaon local (82.50) and Talakal-6 (67.60).

#### 4.2.1.2 60 DAS

At 60 days after storage, maximum of 88.40 per cent damaged grains were observed in Shiggaon local followed by Talakal-6 (75.70). This was followed by CSH-14 (64.20) which was on par with Mugad local (57.80). Significantly minimum of 33.10 per cent damaged grains were noticed in DSV-3 followed by CSH-16 (51.10).

**Table 5 : Screening of pop sorghum varieties in comparison with grain sorghum varieties against rice weevil damage**

| Genotypes | Per cent grain damage | | | | | | |
|---|---|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **150 DAS** | **180 DAS** | **Mean** |
| Talakal-6 | 67.60b (55.35) | 75.70b (60.48) | 80.10b (63.52) | 82.70b (65.44) | 84.50b (66.78) | 86.70b (68.58) | 79.55b |
| Mugad local | 50.60c (45.37) | 57.80cd (49.47) | 61.30d (51.53) | 63.40c (52.79) | 64.60c (53.50) | 71.00c (57.39) | 61.45d |
| Shiggaon local | 82.50a (65.30) | 88.40a (70.11) | 92.70a (74.32) | 95.90a (78.30) | 97.40a (80.79) | 99.36a (85.57) | 92.71a |
| CSH-16 | 43.90d (41.15) | 51.10d (45.64) | 56.70d (48.82) | 59.70c (50.65) | 67.30c (55.28) | 70.90c (57.39) | 58.26e |
| CSH-14 | 56.80c (48. 90) | 64.20c (53.28) | 72.70d (58.49) | 78.50b (62.40) | 82.90b (65.58) | 86.00b (68.09) | 73.51c |
| DSV-3 | 30.70e (33.66) | 33.10e (35.12) | 38.50e (38.343) | 44.00d (41.54) | 49.30d (44.69) | 55.60d (48.21) | 41.86f |
| CD (1%) | 3.555 | 3.875 | 3.872 | 3.458 | 4.388 | 3.751 | 0.316 |
| SE m± | 0.853 | 0.929 | 0.929 | 0.829 | 1.053 | 0.900 | 0.075 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

**Table 6: Weight loss of different genotypes of pop sorghum and grain sorghum due to *S. oryzae* infestation**

| Genotypes | Per cent weight loss | | | | | | |
|---|---|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **150 DAS** | **180 DAS** | **Mean** |
| Talakal-6 | 4.60b (12.59) | 6.20b (14.40) | 8.30b (16.76) | 10.50b (18.94) | 12.30b (20.50) | 16.50b (24.08) | 9.73b |
| Mugad local | 2.80d (9.58) | 3.80d (11.31) | 5.20d (13.24) | 7.30d (15.72) | 9.40d (17.88) | 10.40d (18.91) | 6.48d |
| Shiggaon local | 6.60a (14.89) | 7.90a (16.29) | 9.90a (18.34) | 12.20a (20.47) | 15.30a (23.02) | 19.30a (26.03) | 11.86a |
| CSH-16 | 2.00e (8.13) | 3.40e (10.67) | 4.9e (12.72) | 6.30e (14.51) | 7.90e (16.35) | 10.10d (18.56) | 5.76e |
| CSH-14 | 3.20c (10.35) | 5.40c (13.45) | 7.50c (15.89) | 9.40c (17.84) | 11.20c (19.46) | 14.30c (22.19) | 8.50c |
| DSV-3 | 0.63f (4.55) | 1.70f (7.51) | 2.20f (8.54) | 3.40f (10.55) | 4.50f (12.32) | 5.80e (13.92) | 3.03f |
| CD (1%) | 0.39 | 0.16 | 0.41 | 0.31 | 0.51 | 0.38 | 0.28 |
| SE m± | 0.09 | 0.06 | 0.10 | 0.10 | 0.21 | 0.09 | 0.07 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

4.2.1.3 90 DAS

At 90 DAS, per cent damage was higher (92.70) in Shiggaon local followed by Talakal-6 (80.10). Significantly minimum per cent of damaged grains damaged was observed in DSV-3 (38.50) which was followed by CSH-16 (56.70) and it was on par with Mugad local (61.30).

4.2.1.4 120 DAS

At 120 days after storage significantly maximum percentage of damaged grains was recorded in (Table 5) Shinggaon local (95.90) followed by Talakal-6 (82.70). The minimum of 44.00 per cent grains damage was observed in DSV-3 followed by CSH-16 (59.70) which was on par with Mugad local (63.40).

4.2.1.5 150 DAS

At 150 days after storage significantly maximum per cent of grain damage was (Table 5) recorded in Shiggaon local (97.4) followed by Talakal-6 (84.50). Minimum grain damage was observed in DSV-3 (49.30) followed by CSH-16 (67.30) and Mugad local (64.60).

4.2.1.6 180 DAS

Maximum per cent of grain damage was observed in Shiggaon local (99.36) followed by Talakal-6 (86.70). Least grain damage was seen in DSV-3 (55.60) followed by CSH-16 (70.90) and Mugad local (71.00).

### 4.2.2 Per cent weight loss due to *S. oryzae* infestation in different pop and grains sorghum genotypes

4.2.2.1 30 DAS

Among different varieties/hybrids of both pop and grain sorghum were screened against *S. oryzae*, Shiggaon local was highly preferred as it had indicated maximum weight loss of 6.60 per cent (Table 6). In the decreasing order of preference to rice weevil, the entries found to be susceptible were Talakal-6 (4.60), CSH-14 (3.20), Mugad local (2.80), CSH-16 (2.00) and DSV-3 (0.63).

4.2.2.2 60 DAS

Out of six varieties/hybrids screened, the entry DSV-3 was found to be highly resistant to rice weevil. Among three pop sorghum varieties Mugad local (3.8%) was least preferred over other entries by registering highest resistance.

4.2.2.3 90 DAS

Maximum weight loss was recorded in Shiggaon local (9.90) followed by Talakal-6 (8.30), minimum was observed in DSV-3 (2.20) followed by CSH-16 (4.90).

4.2.2.4 120 DAS

Minimum weight loss was noticed in DSV-3 (3.40) followed by CSH-16 (6.30) and Mugad local (7.30), while maximum was observed in Shiggaon local (12.20) followed by Talakal-6 (10.50) and CSH-14 (9.40).

4.2.2.5 150 DAS

Significantly maximum per cent of weight loss was observed in Shiggaon local (15.30) followed by Talakal-6 (12.30). While minimum was observed in DSV-3 (4.50) followed by CSH-16 (7.90).

4.2.2.6 180 DAS

Shiggaon local registered maximum weight loss of 19.30 per cent observed when it was stored for six months. The minimum weight loss of 5.80 was recoded in DSV-3 variety. However, Mugad local and CSH-16 were found to be on par with each other.

## 4.2.3 Population buildup

### 4.2.3.1 30 DAS

Significantly higher number of adults were emerged (Table 7) in Shiggaon local (79.29) followed by Talakal-6 (74.46) while less number of adults were observed in DSV-3 (14.29) followed by CSH-16 (27.30) and CSH-14 (38.22) at 30 days after storage when ten pairs of weevils were released at the beginning of storage.

### 4.2.3.2 60 DAS

The population build up was significantly more in Shiggaon local (85.61) after 60 days of storage which was on par with Talakal-6 (85.24) and Mugad local (77.82). Whereas, it was less in DSV-3 (19.75) followed by CSH-16 (41.94) which was on par with CSH-14 (47.66).

### 4.2.3.3 90 DAS

Population of live insects was minimum in DSV-3 (23.41) followed by CSH-16 (55.15) and CSH-14 (53.22). While, maximum was n Shiggaon local (88.42) which was on par with Talakal-6 (89.94) and Mugad local (80.05).

### 4.2.3.4 120 DAS

Emergence of adults was significantly higher in Shiggaon local (101.7) followed by Talakal-6 (98.10) which was on par with CSH-14 (92.23) and Mugad local (90.51). Minimum adult emergence was seen in DSV-3 (26.74) followed by CSH-16 (60.65).

### 4.2.3.5 150 DAS

Population buildup was minimum in DSV-3 (29.75) followed by CSH-16 (64.30), while maximum was observed in Shiggaon local (122.26) followed by Talakal-6 (113.34).

### 4.2.3.6 180 DAS

More number of live adults were recorded in Shiggaon local (142.78) followed by Talakal-6 (125.83) while it was least loss in DSV-3 (39.82) followed by Mugad local (109.54), which was on par with CSH-16 (112.28) and CSH-14 (114.6).

## 4.2.4 Per cent seed germination due to *S. oryzae* infestation in pop/grain sorghum

### 4.2.4.1 30 DAS

At 30 days after storage (Table 8) DSV-3 maintained maximum germination per cent (88.00) followed by CSH-16 (74.00). While minimum was observed in Shiggaon local (45.00) followed by Talakal-6 (60.00).

### 4.2.4.2 60 DAS

Minimum germination per cent was recorded at 60 DAS in Shiggaon local (40.10) followed by Talakal-6 (58.80) and CSH-14 (61.00) whereas maximum was observed in DSV-3 (80.00) followed by CSH-16 (70.00) and Mugad local (66.30).

### 4.2.4.3 90 DAS

Significantly maximum seed viability was recorded in DSV-3 (78.80) followed by CSH-16 (67.00) and Mugad local (64.30), while minimum was recorded in Shiggaon local (38.90) followed by Talakal-6 (53) and CSH-14 (58.70).

### 4.2.4.4 120 DAS

Minimum seed germination noticed in Shiggaon local (35.30) followed by Talakal-6 (50.60) while maximum was recorded in DSV-3 (74.60) followed by CSH-16 (65.60).

### 4.2.4.5 150 DAS

DSV-3 retained maximum seed viability (70.60) followed by CHS-16 (62.30), Shiggaon local (32.30) recorded minimum seed germination followed by Talakal-6 (48.40).

### 4.2.4.6 180 DAS

Significantly less seed germination was observed in Shiggaon local (30.30) followed by Talakal-6 (44.30), while maximum was recorded in DSV-3 (69.00) followed by CSH-16 (59.80).

**Table 7 : Population buildup of *S. oryzae* in different genotypes of pop sorghum and grain sorghum**

| Genotypes | Population buildup | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| Talakal-6 | 74.46b (8.66) | 85.24a (9.27) | 89.94a (9.52) | 98.10ab (9.93) | 113.34ab (10.67) | 125.83b (11.25) | 97.81a |
| Mugad local | 56.17c (7.53) | 77.82a (8.86) | 80.50a (9.00) | 90.51b (9.54) | 102.31c (10.14) | 109.54c (10.49) | 86.14b |
| Shiggaon local | 79.29a (8.93) | 85.61a (9.28) | 88.42a (9.44) | 101.70a (10.11) | 122.26a (11.09) | 142.78a (11.98) | 103.34a |
| CSH-16 | 27.30e (5.27) | 41.94b (6.52) | 55.15b (7.46) | 60.65c (7.83) | 64.30d (8.06) | 112.28c (10.62) | 60.27d |
| CSH-14 | 38.22d (6.22) | 47.66b (6.94) | 53.22b (7.33) | 92.23b (9.63) | 109.54bc (10.50) | 114.6c (10.74) | 75.91c |
| DSV-3 | 14.29f (3.85) | 19.75c (4.51) | 23.41c (4. 90) | 26.74d (5.22) | 29.75e (5.50) | 39.82d (6.36) | 25.62e |
| CD (1%) | 0.20 | 0.46 | 0.54 | 0.41 | 0.46 | 0.42 | 6.36 |
| SE m± | 0.05 | 0.11 | 0.13 | 0.10 | 0.11 | 0.10 | 1.53 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in parenthesis are √x + 0.5 transformed values

**Table 8: Per cent germination in different pop and grain sorghum genotypes due to *S. oryzae* infestation**

| Genotypes | Pre cent germination | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| Talakal-6 | 60.00e (51.00) | 58.80e (50.07) | 53.00e (47.70) | 50.60e (45.31) | 48.40d (44.07) | 44.30e (41.73) | 52.51e |
| Mugad local | 68.40c (55.80) | 66.30c (54.50) | 64.30c (53.31) | 60.30c (50.92) | 56.10c (48.51) | 55.20c (47.97) | 61.76c |
| Shiggaon local | 45.00f (42.13) | 40.10f (39.27) | 38.90f (38.58) | 35.30f (36.45) | 32.30e (34.60) | 30.30f (33.41) | 37.15f |
| CSH-16 | 74.00b (59.33) | 70.00b (56.79) | 67.00b (54.95) | 65.60b (54.12) | 62.30b (52.11) | 59.80b (50.66) | 66.45b |
| CSH-14 | 64.90d (53.67) | 61.00d (51.35) | 58.70d (50.05) | 55.40d (48.11) | 48.40d (44.07) | 48.30d (44.02) | 56.11d |
| DSV-3 | 88.00a (69.73) | 80.00a (63.44) | 78.80a (62.59) | 74.60a (59.76) | 70.60a (57.15) | 69.00a (56.16) | 78.93a |
| CD (1%) | 0.87 | 0.67 | 1.35 | 1.02 | 0.92 | 1.98 | 3.17 |
| SEm$\pm$ | 0.22 | 0.17 | 0.35 | 0.26 | 0.24 | 0.51 | 0.76 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value



**Plate 6: Popping in healthy and infested grains due to rice weevil S. oryzae damage**

### 4.2.5 Popping yield (%) at 6 months after storage

Significantly maximum per cent of popping (Table 9 and Plate 6) was recorded in Mugad local (85.40) followed by CSH-14 (69.40) and Shiggaon local (65.90) which was on par with DSV-3 (65.10). Minimum per cent popping was observed in Talakal-6 (43.00) followed by CSH-16 (53.10).

### 4.2.6 Volume expansion ratio (180 DAS)

Significantly higher volume expansion ratio (Table 9) was observed in Mugad local (1:12.51) which did not differ from CSH-16 (1:12.10) followed by Talakal-6 (1:10.87) and Shiggaon local (1:10.17).

**Table 9 : Per cent popping in pop and grain sorghum genotypes due to *S. oryzae* infestation**

| Genotypes | Popping yield (%) | Volume expansion ratio |
|---|---|---|
| CSH-16 | 53.10 d | 1:12.10a |
| CSH-14 | 69.40b | 1:4.92e |
| Talakal-6 | 43.00e | 1:10.87b |
| Mugad local | 85.40a | 1:12.51a |
| Shiggaon local | 65.90c | 1:10.17c |
| DSV-3 | 65.10c | 1:9.09d |
| CD (1%) | 0.4663 | 0.4167 |
| SEm± | 0.121 | 0.107 |

Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

## 4.3 ECOFRIENDLY APPROACHES FOR THE MANAGEMENT OF RICE WEEVIL IN POP SORGHUM

### 4.3.1 Per cent adult mortality in plastic jars treated with grain protectants

#### 4.3.1.1 7 DAS

Cent per cent mortality was recorded in grains treated with sweet flag powder neem seed kernel powder, custard seed powder and malathion (5%), followed by (Table 10) kaolinite (93.3) and bentonite (88.33), while zero percent of adult mortality was recorded in untreated check (0.00) followed by sawdust (6.10) and ash (10.00).

#### 4.3.1.2 14 DAS

Cent per cent mortality was observed in seeds treated with sweet flag powder, neem seed kernel powder, custard seed power and malathion (5%) followed by kaolinite (90.3) bentionite (88.33) lakke leaf powder (73.3) and neem leaf powder (63.3), while zero per cent mortality was recorded in untreated check followed by sawdust (6.10) and ash (13.3).

#### 4.3.1.3 21 DAS

Significantly hundred per cent dead adults were observed in sweet flag powder, neem seed kernel powder, custard apple seed powder and malathion (5%) treatments. The next best treatments were kaolinite (96.60) and Bentonite (90) followed by lakke leaf powder (73.3) and neem leaf powder (63.3) which was on par with honge (60). Zero per cent adult mortality was recorded in untreated check followed by saw dusts (10) and ash (13.3)

#### 4.3.1.4 30 DAS

Cent per cent mortality was recorded in treatment sweet flag powder, neem seed kernel powder, custard seed powder, kaolinite and malathion (5%) followed by bentonite (93.3) lakke leaf powder (73.3), neem leaf powder (70) and honge leaf powder (63.3). No mortality was observed in untreated check (0.0) followed by sawdust (13.3) and ash (16.6).

#### 4.3.1.5 60 DAS

Zero per cent adult mortality was seen in untreated check followed by sawdust (13.3) and ash (16.6), while cent per cent mortality was recorded in treatments sweet flag powder, neem seed kernel powder, custard seed powder, kaolinite, malathion followed by bentonite (93.3) lakke leaf hopper (76.6), neem leaf powder (70) and honge leaf powder (63.3).

#### 4.3.1.6 90 DAS

Significantly cent per cent of dead adults were noticed in sweet flag, neem seed, custard seed powder, kaolinite, bentonite, malathion (5%) treatments followed by lakke leaf powder (76.6) and neem leaf powder (73.3). Whereas, in sawdust treatment least per cent mortality of 16.6 was observed. There was no mortality in untreated check.

#### 4.3.1.7 120 DAS

The similar trend existed at above storage period wherein no mortality was observed in untreated check. The cent per cent adult mortality was observed in grains treated with sweet flag powder and malathion (5%) followed by neem seed kernel powder (93.3) and custard seed powder (90) which was on par with kaolinite (90) and bentonite (90). The next best treatments were lakke leaf powder (80), neem leaf powder (76.67) and honge leaf powder (70.00).

#### 4.3.1.8 150 DAS

Again sweet flag powder emerged as best treatment wherein cent per cent mortality was observed. Then followed by malathion (96.6) and custard seed powder (90) which was on par with neem seed powder (90), kaolinite (90) and bentonite (90). While least effective treatments were observed to be sawdust (16.6) and ash (20) as against no mortality in untreated check.

#### 4.3.1.9 180 DAS

Similar observations were recorded even after six months of storage. The best treatment in the order of efficacy were sweet flag (100%), malathion (90.00), neem seed kernel powder (90.00), custard seed powder (90.0), kaolinite (90.00), Bentonite (86.60), honge leaf powder (76.60), lakke leaf powder (70.00), neem leaf powder (66.60), periwinkle leaf powder (50.00), Adasal (30.00), tulsi (30.00), turmeric (26.60) sawdust (20.00), ash (16.60) and untreated control (0.00).

**Table 10 : Efficacy of grain protectants against *S. oryzae* at different periods of storage in plastic jars**

| Treatments | Per cent mortality | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **7 DAS** | **14 DAS** | **21 DAS** | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **150 DAS** | **180 DAS** | **Mean** |
| $T_1$ – Honge leaf powder | 40.0g (39.23) | 56.6f (48.79) | 60.0e (50.77) | 63.3e (52.12) | 63.3e (56.12) | 63.3b (52.12) | 70.0e (56.79) | 70.0d (56.71) | 66.6d (54.70) | 62.93f |
| $T_2$ – Adasal leaf powder | 23.3i (28.86) | 30.0g (33.21) | 33.3g f(35.24) | 33.3h (35.24) | 36.6f (37.23) | 36.6f (37.23) | 33.30g (35.24) | 33.3h (35.24) | 30.0g (33.21) | 49.40h |
| $T_3$ – Periwinkle leaf powder | 50.0f (45.00) | 56.6f (48.79) | 56.6f (48.79) | 56.6f (48.79) | 60.0e (50.77) | 60.0d (50.77) | 60.0f (50.77) | 56.6f (48.79) | 50.0f (45.00) | 56.63g |
| $T_4$ – Neem leaf powder | 56.6e (48.79) | 63.3e (52.12) | 63.3e (52.12) | 70.0d (56.79) | 70.0d (56.79) | 73.3c (58.89) | 70.0e (56.70) | 70.0e (56.79) | 66.6d (54.70) | 67.74e |
| $T_5$ – Lakke leaf powder | 70.0d (56.79) | 73.3d (58.89) | 73.3d (58.89) | 73.3c (58.89) | 76.6c (61.07) | 76.6b (61.67) | 73.3d (58.89) | 73.3d (58.89) | 70.0e (56.79) | 74.04d |
| $T_6$ – Sweet flag | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.00a |
| $T_7$ – Neem seed powder | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 93.3b (75.00) | 90.0c (71.56) | 90.0b (71.56) | 98.51a |
| $T_8$ – Tulsi leaf powder | 20.0j (26.56) | 23.3i (28.86) | 23.3i (28.86) | 26.6j (31.11) | 26.6i (31.11) | 30.0h (33.21) | 30.0h (33.21) | 30.3i (33.21) | 30.0g (33.21) | 27.01j |
| $T_9$ – Custard seed powder | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 90.0c (71.56) | 90.0c (71.56) | 90.0b (71.56) | 96.66ab |
| $T_{10}$ – Turmeric | 23.3i (28.86) | 26.6h (31.11) | 26.6h (31.11) | 30.0i (33.21) | 30.0h (33.21) | 33.3g (35.24) | 33.3g (35.24) | 30.0i (33.21) | 26.6h (31.05) | 28.85j |
| $T_{11}$ – Kaolinite | 93.3b (75.00) | 90.0b (71.56) | 96.6b (79.37) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 90.0c (71.56) | 90.0c (71.56) | 90.0b (71.56) | 94.43bc |
| $T_{12}$ – Bentonite | 88.3c (70.00) | 88.3c (70.00) | 90.0c (71.56) | 93.3b (75.00) | 93.3b (75.00) | 100.0a (90.00) | 90.0c (71.56) | 90.0c (71.56) | 86.6c (68.53) | 91.09c |
| $T_{13}$ – Ash (cow dung) | 10.0k (18.44) | 13.3k (21.40) | 13.3h (21.39) | 16.6k (24.04) | 16.6j (24.04) | 20.0i (26.56) | 23.3j (28.86) | 20.0i (26.56) | 16.6j (24.04) | 16.63k |
| $T_{14}$ – Sand | 33.3h (35.24) | 33.3h (35.24) | 33.3g (35.24) | 36.6g (37.25) | 33.3g (35.24) | 40.0e (39.23) | 43.3i (41.15) | 40.0g (39.23) | 33.3g (35.24) | 36.23i |
| $T_{15}$ – Saw dust | 6.6 l (14.89) | 6.6l (14.89) | 10.0j (18.44) | 13.3l (21.39) | 13.3k (21.39) | 16.6j (24.04) | 20.0k (26.56) | 16.6j (24.04) | 20.0i (26.56) | 13.66k |
| $T_{16}$ – Malathion | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 100.0a (90.00) | 96.6b (79.37) | 90.0b (71.56) | 98.51a |
| $T_{17}$ – Untreated control | 0.0 m (0.00) | 0.0m (0.00) | 0.0 k (0.00) | 0.0m (0.00) | 0.0l (0.00) | 0.0k (0.00) | 0.0m (0.00) | 0.0l (0.00) | 0.0k (0.00) | 0.00l |
| CD (1%) | 1.54 | 1.48 | 1.39 | 1.79 | 1.84 | 1.85 | 1.88 | 1.52 | 2.03 | 3.39 |
| SEm± | 0.40 | 0.38 | 0.36 | 0.46 | 0.47 | 0.48 | 0.49 | 0.39 | 0.52 | 0.88 |

DAS – Days after storage

Means followed by the same letter do not differ significantly by DMRT (P=0.01)

Figures in the parenthesis are arc sine transformed value

### 4.3.2 Grain damage due to *S. oryzae* infestation in plastic jars

#### 4.3.2.1 30 DAS

Significantly maximum per cent of grain damage was recorded in untreated check (64.00) followed by ash (53.30) and sawdust (49.3), while no grain damage (Table 11) was noticed in treatments sweet flag powder, neem seed powder, custard seed powder, kaolinite, bentonite, malathion followed by neem leaf powder (16.6) and lakke leaf powder (17.6)

#### 4.3.2.2 60 DAS

Higher per cent of grain damage was noticed in untreated check (73.3) (Table 11) followed by sawdust (68.00) and ash (67) while, no grain damage observed in treatments sweet flag, neem seed, custard seed powder, kaolinite, bentonite followed by lakke leaf powder (20.3) and neem powder (23.3).

#### 4.3.2.3 90 DAS

Significantly maximum per cent of grain damage was recorded in untreated check (90.30) followed by ash (74.60%) and sawdust (73.00) while, no grain damage was observed in treatments sweet flag, neemseed, custard seed powder, kaolinite followed by malathion (4.00) and bentonite (8.01).

#### 4.3.2.4 120 DAS

Significantly no grain damage was observed in treatments sweetflag neem seed, custard seed powder, kaolinite followed by malathion (6.01) and bentonite (12.00), while maximum was recorded in untreated check (98.5) followed by turmeric (86.60), sawdust(81.6) and ash (81.0).

#### 4.3.2.5 150 DAS

Significantly cent per cent of grain damage was noticed in untreated check followed by turmeric (89.0), sawdust (84.6), ash (83.6) and Tulsi (80), while no grain damage was observed in treatments sweet flag, neem seed, custard seed, kaolnite followed by malathion (6.5) and bentonite (14.00).

#### 4.3.2.6 180 DAS

Among all the treatments, significantly cent per cent of grain damage was recorded in untreated control followed by sawdust (92.3), ash (88.30) and turmeric (87.3). No grain damage was observed in treatments sweet flag, neem seed, custard seed, kaolnite followed by malathion (9.00) and bentonite (18.60).

### 4.3.3 Population buildup in plastic jars due to *S. oryzae* infestation

#### 4.3.3.1 30 DAS

Significantly maximum number of adults were found in untreated check (16.3) followed by sawdust (13) and ash (10) while no adults were emerged in (Table 12) treatments sweet flag powder, neem seed, custard seed powder, kaolinite, malathion followed by bentonite (0.6), neem leaf (1.3) and lakke leaf powder (2.6).

#### 4.3.3.2 60 DAS

Population buildup was maximum in untreated check (28.3) followed by sawdust (24) and ash (21.33), while no adults were emerged in treatments sweet flag, custard seed, neem seed powder, kaolinite and malathion followed by bentonite (0.33) and neem leaf (2).

#### 4.3.3.3 90 DAS

Maximum number of aduls were in untreated check (39) followed by sawdust (38), ash (35) and turmeric (33.3), while no adults were emerged in treatments sweet flag, neem seed, custard seed powder, kaolinite, malathion followed by bentonite (3) and neem leaf powder (7.3).

#### 4.3.3.4 120 DAS

Zero population buildup was noticed in sweet flag, neem seed, custrd seed powder, kaolinite, followed by malathion (7.6) which was on par with bentonite (7.3).

#### 4.3.3.5 150 DAS

**Table 11 : Grain damage due to *S. oryzae* infestation when treated with grain protectants in plastic jars**

| Treatments | Per cent grain damage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| $T_1$ – Honge leaf powder | 25.0h (30.00) | 38.66i (38.41) | 50.0i (45.00) | 62.3h (52.12) | 68.33i (55.12) | 75.0g (60.00) | 53.21e |
| $T_2$ – Adasal leaf powder | 29.0g (35.58) | 44.33h (41.73) | 53.3h (46.89) | 65.0g (53.73) | 71.33h (56.98) | 75.0g (60.00) | 56.32e |
| $T_3$ – Periwinkle leaf powder | 34.6f (36.03) | 50.00g (45.00) | 62.3g (52.12) | 73.6e (59.08) | 78.66f (62.44) | 79.6f (63.15) | 63.12d |
| $T_4$ – Neem leaf powder | 16.6j (24.04) | 23.30j (28.79) | 34.3k (35.85) | 42.0j (40.40) | 50.33k (45.17) | 55.6i (48.22) | 37.06f |
| $T_5$ – Lakke leaf powder | 17.6i (24.80) | 20.3k (26.78) | 36.3j (37.05) | 45.0i (42.13) | 51.66j (45.92) | 56.0h (48.45) | 37.81f |
| $T_6$ – Sweet flag | 0.0k (0.00) | 0.0l (0.00) | 0.0n (0.00) | 0.0m (0.00) | 0.0n (0.00) | 0.0l (0.00) | 0.00i |
| $T_7$ – Neem seed powder | 0.0k (0.00) | 0.0 l (0.00) | 0.0n (0.00) | 0.0m (0.00) | 0.0n (0.00) | 0.0l (0.00) | 0.00i |
| $T_8$ – Tulsi leaf powder | 39.6b (39.00) | 54.60e (47.04) | 63.3f (52.71) | 73.6e (59.08) | 80.0e (63.44) | 85.3d (67.45) | 66.06cd |
| $T_9$ – Custard seed powder | 0.0k (0.00) | 0.0l (0.00) | 0.0n (0.00) | 0.0m (0.00) | 0.0n (0.00) | 0.0l (0.00) | 0.00i |
| $T_{10}$ – Turmeric | 33.3g (35.37) | 51.3f (45.75) | 65.6e (54.09) | 86.6b (68.53) | 89.0b (70.63) | 87.3c (69.12) | 68.85c |
| $T_{11}$ – Kaolinite | 0.0k (0.00) | 0.0l (0.00) | 0.0n (0.00) | 0.0m (0.00) | 0.0n (0.00) | 0.0l (0.00) | 0.00i |
| $T_{12}$ – Bentonite | 0.0k (0.00) | 0.0l (0.00) | 8.0l (16.43) | 12.0k (20.27) | 14.0l (21.97) | 18.6j (25.55) | 8.76g |
| $T_{13}$ – Ash (cow dung) | 53.3b (46.89) | 67.0b (54.94) | 74.6b (5.74) | 81.0d (64.16) | 83.6d (66.11) | 88.3b (70.0) | 74.63b |
| $T_{14}$ – Sand | 37.3e (37.68) | 61.6d (51.71) | 66.3b (54.71) | 73.0f (58.69) | 77.0g (61.34) | 85.0e (67.21) | 66.70cd |
| $T_{15}$ – Saw dust | 49.3c (44.60) | 68.0c (55.55) | 73.0c (58.69) | 81.6c (64.6) | 84.6c (66.89) | 92.3b (73.78) | 74.80b |
| $T_{16}$ – Malathion | 0.0k (0.00) | 0.0l (0.00) | 4.0m (11.54) | 6.0l (14.18) | 6.5m (14.77) | 9.0k (17.46) | 4.25h |
| $T_{17}$ – Untreated control | 64.0a (53.13) | 73.3a (58.24) | 90.3a (71.85) | 98.5a (8.26) | 100.0a (90.00) | 100.0a (90.00) | 87.68a |
| CD (1%) | 0.26 | 0.10 | 0.10 | 0.12 | 0.12 | 0.07 | 3.45 |
| SEm± | 0.07 | 0.03 | 0.26 | 0.03 | 0.03 | 0.02 | 0.89 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

**Table 12: Bioefficacy of grain protectants on the population buildup of *S. oryzae* in pop sorghum**

| Treatments | Population buildup | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| $T_1$ – Honge leaf powder | 3.0h (1.87) | 10.0g (3.24) | 18.6i (4.37) | 45.6b (6.78) | 53.3j (2.41) | 73.33f (8.59) | 33.97g |
| $T_2$ – Adasal leaf powder | 3.6g (2.02 ) | 13.3f (3.71) | 26.6f (5.2) | 50.6c (7.14) | 74.0e (8.63) | 87.66e (9.33) | 42.62f |
| $T_3$ – Periwinkle leaf powder | 5.3h (2.90) | 15.6e (4.01) | 24.0g (4.94) | 52.3b (7.26) | 71.0f (8.45) | 87.0e (9.35) | 42.53f |
| $T_4$ – Neem leaf powder | 1.3j (1.34) | 2.0i (1.58 ) | 7.30k (2.79) | 18.6h (4.37) | 47.0g (6.89) | 71.3f (8.47) | 24.58i |
| $T_5$ – Lakke leaf powder | 2.6i (1.76) | 4.6h (2.20) | 11.6j (3.47) | 24.3g (4.97) | 40.0h (6.36) | 76.3f (8.376) | 26.56h |
| $T_6$ – Sweet flag | 0.0l (0.70) | 0.0k (0.70) | 0.0m (0.70) | 0.0j (0.70) | 0.0k (0.70) | 0.0h (0.70) | 0.00k |
| $T_7$ – Neem seed powder | 0.0l (0.70) | 0.0k (0.70) | 0.0m (0.70) | 0.0j (0.70) | 0.0k (0.70) | 0.0h (0.70) | 0.00k |
| $T_8$ – Tulsi leaf powder | 7.3e (2.79) | 18.6d (4.37) | 29.0e (5.43) | 43.3e (6.61) | 77.3d (8.82) | 90.0e (9.66) | 44.75e |
| $T_9$ – Custard seed powder | 0.0l (0.70) | 0.0k (0.70) | 0.0m (0.70) | 0.0j (0.70) | 0.0k (0.70) | 0.0h (0.70) | 0.00k |
| $T_{10}$ – Turmeric | 9.0b (3.08) | 18.6d (4.37) | 33.3d (5.81) | 52.00b (7.24) | 80.6c (9.05) | 102.0d (10.12) | 49.25c |
| $T_{11}$ – Kaolinite | 0.0l (0.70) | 0.0k (0.70) | 0.0m (0.70) | 0.0j (0.70) | 0.0a (0.70) | 0.0h (0.70) | 0.00k |
| $T_{12}$ – Bentonite | 0.6k (1.04) | 0.33j (0.92) | 3.0l (1.87) | 7.3i (2.79) | 11.0i (3.39) | 15.3g (3.97) | 6.25j |
| $T_{13}$ – Ash (cow dung) | 10.0c (3.24) | 21.33c (4.67) | 35.0c (5.95) | 44.6d (6.71) | 71.3f (8.47) | 87.3e (9.37) | 44.92e |
| $T_{14}$ – Sand | 4.0g (2.12) | 16.0e (4.06) | 22.6h (4.80) | 38.0j (6.20) | 85.6b (9.27) | 112.6c (10.63) | 46.46d |
| $T_{15}$ – Saw dust | 13.0d (3.60) | 24.0b (4.94) | 38.0a (6.20) | 52.0b (7.24) | 92.6a (9.65) | 125.66b (11.23) | 57.5b |
| $T_{16}$ – Malathion | 0.0l (0.70) | 0.0k (0.70) | 0.0m (0.70) | 7.6i (2.84) | 10.3c (3.28) | 16.6g (4.135) | 5.75j |
| $T_{17}$ – Untreated control | 16.3a (4.09) | 28.3a (5.32) | 39.0b (6.04) | 63.0a (7.96) | 93.0a (8.97) | 150.79a (12.30) | 62.39a |
| CD (1%) | 0.10 | 0.06 | 0.05 | 0.07 | 0.09 | 0.25 | 0.67 |
| SEm± | 0.03 | 0.22 | 0.02 | 0.03 | 0.03 | 0.09 | 0.91 |

DAS – Days after storage

Means followed by the same letter do not differ significantly by DMRT (P=0.01)

Figures in parenthesis are $\sqrt{x} + 0.5$ transformed values

Among the different grain protectants used, significantly maximum population buildup (93.00) was recorded in untreated check which was on par with sawdust (92.6) followed by sand (85.6) and tulsi (77.3), while o adults were emerged in treatments sweet flag, neem seed, custard seed powder, kaolinite followed by malathion (10.3) which was on par with bentonite (11.00).

#### 4.3.3.6 180 DAS

Maximum number of adults were emerged in untreated check (150.79) followed by sawdust (125.6), sand (112.6) and turmeric (102), while no adults were emerged in treatments sweet flag, neem seed, custard seed powder followed by bentonite (15.3) which was on par with malathion (16.6).

### 4.3.4 Seed viability due to *S. oryzae* infestation in plastic jars

#### 4.3.4.1 30 DAS

Germination percentage was significantly higher in sweet flag (95) treatments followed by custard seed powder (93.3) and neem seed powder (91.6). Whereas, kaolinite (90) and malathion (90) emerged as next best treatments with respect to seed viability (Table 13).

#### 4.3.4.2 60 DAS

Significantly highest seed viability was recorded in sweet flag (91.6), neem seed powder (90) which was on par with custard seed powder (90) followed by kaolinite (88.3) which was on par with malathion (88.3). significantly lower germination was observed in ash (43.3) followed by untreated check (45) and sand (46.6).

#### 4.3.4.3 90 DAS

Significantly minimum germination was noticed in ash (41.3) which was found on par with untreated check (41.6). Maximum was recorded in treatment sweet flag (90). The next best treatment in the decreasing order of efficacy were custard seed (87.3), neem seed powder (86.6) and kaolinite (85.3). However kaolinite was found on par with malathion (85.6).

#### 4.3.4.4 120 DAS

Seeds maintained maximum viability in grains treated with sweet flag powder (87.3) followed by custard seed powder (86.3) and neem seed powder (85.6), while seeds treated with ash showed minimum germination (39.3) followed by untreated check (40) which was on par with sand (40).

#### 4.3.4.5 150 DAS

Significantly maximum seed viability was noticed in seeds treated with sweet flag powder (86.6) followed by neem seed powder (85) which was on par with custard seed powder (85).

#### 4.3.4.6 180 DAS

Seeds maintained maximum germination when they were treated by sweet flag powder (85) followed by neem seed powder (81.6) which did not differ statistically from custard seed powder (81.6) and malathion (81.6). The minimum germination was observed in untreated check (30) followed by saw dust (32.6) and ash (34).

### 4.3.5 Per cent weight loss due to *S. oryzae* infestation in plastic jars

#### 4.3.5.1 30 DAS

There was no weight loss in the pop sorghum grain due to rice weevil in treatments sweet flag powder, custard seed powder, kaolinite bentonite and malathion. The next best treatments which were least preferred by the weevil were neem seed (0.9), neem leaf powder (2.3) and lakke leaf powder (2.6). The maximum weight loss was (Table 14) observed in untreated control (7.1).

**Table 13: Seed viability due to *S. oryzae* infestation grains treated with grain protectants in plastic jars**

| Treatments | Per cent germination | | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | |
| $T_1$ – Honge leaf powder | 80.6f (63.87) | 75.0e (60.00) | 71.6f (57.80) | 67.0g (54.94) | 63.3g (52.71) | 60.0e (50.77) | 69.58d |
| $T_2$ – Adasal leaf powder | 68.3h (55.73) | 65.0g (53.73) | 63.3h (52.71) | 61.3i (51.53) | 59.0h (50.18) | 58.0f (49.60) | 62.48ef |
| $T_3$ – Periwinkle leaf powder | 61.3h (51.53) | 61.6h (51.71) | 60.0j (50.77) | 54.0l (47.29) | 50.6k (45.34) | 47.6i (43.62) | 55.85g |
| $T_4$ – Neem leaf powder | 66.0k (54.33) | 61.6h (51.71) | 60.0j (50.77) | 56.6k (48.73) | 55.0j (47.87) | 53.6g (47.06) | 58.80fg |
| $T_5$ – Lakke leaf powder | 73.3j (58.89) | 70.6f (57.17) | 66.6g (54.70) | 65.0h (53.73) | 64.3f (53.25) | 60.3e (50.94) | 66.68de |
| $T_6$ – Sweet flag | 95.0a (73.15) | 91.6 a (73.15) | 90.0a (71.56) | 87.3a (69.12) | 86.6a (68.53) | 85.0a (67.21) | 89.25a |
| $T_7$ – Neem seed powder | 91.6c (73.15) | 90.0b (71.56) | 86.6c (68.53) | 85.6c (67.7) | 85.0b (67.21) | 81.6b (64.60) | 86.73abc |
| $T_8$ – Tulsi leaf powder | 51.6l (45.92) | 50.0i (45.00) | 48.0k (43.85) | 45.0m (40.13) | 40.0l (39.23) | 36.3j (37.05) | 45.15h |
| $T_9$ – Custard seed powder | 93.3b (75.00) | 90.0b (71.56) | 87.3b (69.12) | 86.3b (68.28) | 85.0b (67.21) | 81.6b (64.60) | 87.25ab |
| $T_{10}$ – Turmeric | 66.6i (54.70) | 65.0g (53.73) | 61.3i (51.53) | 59.6j (50.53) | 56.3i (48.62) | 52.6h (46.49) | 60.23fg |
| $T_{11}$ – Kaolinite | 90.0b (71.56) | 88.3c (70.00) | 85.3d (67.45) | 83.3e (65.88) | 80.0e (60.44) | 78.0c (62.03) | 84.15bc |
| $T_{12}$ – Bentonite | 88.3e (70.00) | 85.0b (67.21) | 83.3e (65.88) | 81.0f (64.16) | 79.0d (62.72) | 75.3d (60.20) | 81.93c |
| $T_{13}$ – Ash (cow dung) | 48.0b (43.85) | 43.3m (41.15) | 41.3 (39.99) | 39.3op (38.82) | 35.6o (36.63) | 34.0k (35.67) | 40.25i |
| $T_{14}$ – Sand | 49.6n (44.70) | 46.6k (43.11) | 44.3l (41.73) | 40.0o (39.23) | 34.0p (35.67) | 32.6l (34.88) | 41.18hi |
| $T_{15}$ – Saw dust | 51.3m (45.75) | 48.3j (44.03) | 44.0l (41.55) | 42.6n (40.74) | 37.6m (37.82) | 35.6j (36.63) | 43.23hi |
| $T_{16}$ – Malathion | 90.0d (71.56) | 88.3c (70.00) | 85.6b (67.70) | 85.0d (67.21) | 84.3c (66.66) | 81.6b (64.60) | 85.80abc |
| $T_{17}$ – Untreated control | 48.3o (44.03) | 45.0l (42.13) | 41.6m (40.16) | 40.0 (39.23) | 36.0n (36.87) | 30.0m (33.21) | 40.15i |
| CD (1%) | 0.12 | 0.07 | 0.45 | 0.10 | 0.15 | 0.47 | 4.51 |
| SEm± | 0.02 | 0.02 | 0.12 | 0.03 | 0.06 | 0.12 | 1.16 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

**Table 14 : Per cent weight loss due to *S. oryzae* infestation in seeds treated with grain protectants in plastic jars**

| Treatments | Per cent weight loss | | | | | | |
|---|---|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **150 DAS** | **180 DAS** | **Mean** |
| $T_1$ – Honge leaf powder | 3.8g (11.24) | 5.1d (13.05) | 5.9d (14.06) | 7.1cd (15.45) | 8.33b (16.74) | 9.6d (18.05) | 6.63cde |
| $T_2$ – Adasal leaf powder | 4.5e (12.25) | 6.1c (14.3) | 6.8c (15.12) | 7.6c (16.00) | 8.5c (16.95) | 9.6d (18.05) | 7.18c |
| $T_3$ – Periwinkle leaf powder | 4.1f (11.68) | 5.06d (12.92) | 6.0d (14.18) | 6.6de (14.89) | 7.2f (15.56) | 9.2ef (17.66) | 6.36de |
| $T_4$ – Neem leaf powder | 2.3i (8.72) | 3.16f (10.14) | 4.2e (11.83) | 5.2f (13.18) | 6.1h (14.30) | 6.5h (14.77) | 4.57f |
| $T_5$ – Lakke leaf powder | 2.6h (9.28) | 3.73e (11.09) | 4.2e (11.83) | 4.8f (12.66) | 5.8i (13.94) | 6.4h (14.65) | 4.58f |
| $T_6$ – Sweet flag | 0.0l (0.00) | 0.0h (0.00) | 0.0g (0.00) | 0.0h (0.00) | 0.0m (0.00) | 0.0l (0.00) | 0.00h |
| $T_7$ – Neem seed powder | 0.9j (5.44) | 1.1g (6.02) | 1.9f (7.92) | 3.0g (9.98) | 3.6j (10.94) | 4.3i (11.97) | 2.46g |
| $T_8$ – Tulsi leaf powder | 4.2f (11.83) | 5.13d (13.08) | 5.71d (13.81) | 6.4e (14.65) | 7.8e (16.22) | 9.0f (17.46) | 6.37de |
| $T_9$ – Custard seed powder | 0.0l (0 0.0) | 0.0h (0.00) | 0.0g (0.00) | 0.0h (0.00) | 0.0m (0.00) | 0.0l (0.00) | 0.00h |
| $T_{10}$ – Turmeric | 4.5e (12.25) | 5.3d (13.31) | 5.7d (13.81) | 6.5d (14.77) | 7.06g (15.34) | 8.5g (15.95) | 6.26e |
| $T_{11}$ – Kaolinite | 0.0l (0.00) | 0.0h (0.00) | 0.0g (0.00) | 0.0h (0.00) | 0.0 n (0.00) | 0.6k (4.44) | 0.10h |
| $T_{12}$ – Bentonite | 0.0l (0.00) | 0.0h (0.00) | 0.0g (0.00) | 0.0h (0.00) | 0.46l (12.39) | 0.9j (5.44) | 0.22h |
| $T_{13}$ – Ash (cow dung) | 6.0c (14.18) | 7.63b (15.34) | 7.6d (16.0) | 8.5b (16.95) | 9.26b (17.66) | 10.4 c (18.81) | 8.13b |
| $T_{14}$ – Sand | 4.8d (12.66) | 5.8c (13.94) | 6.5c (14.89) | 7.5c (15.89) | 8.3d (16.74) | 9.4de (17.85) | 7.05cd |
| $T_{15}$ – Saw dust | 6.3b (14.54) | 7.26b (15.56) | 8.1b (16.54) | 8.8c (17.26) | 9.2b (17.66) | 10.8b (19.19) | 8.41b |
| $T_{16}$ – Malathion | 0.0l (0.00) | 0.0h (0.00) | 0.0g (0.00) | 0.0h (0.00) | 0.6k (4.44) | 1.0j (5.74) | 0.26h |
| $T_{17}$ – Untreated control | 7.1a (24.35) | 8.5a (16.95) | 9.0a (17.46) | 12.1a (20.2) | 15.7a (23.34) | 18.2a (25.25) | 11.76a |
| CD (1%) | 0.31 | 0.37 | 0.66 | 0.61 | 0.18 | 0.20 | 0.69 |
| SEm$\pm$ | 0.08 | 0.09 | 0.17 | 0.16 | 0.06 | 0.05 | 0.18 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

4.3.5.2 60 DAS

Significantly maximum weight loss was noticed in untreated check (8.5) followed by sawdust (7.26) which was on par with ash (7.63) followed by adasali (6.1) which was on par with sand (5.8), while no weight loss was noticed in treatments sweet flag powder, custard seed powder, kaolinite, bentonite and malathion followed by neem seed (1.1) and neem leaf (3.16).

4.3.5.3 90 DAS

No weight loss was noticed in treatment sweet flag powder, custard seed powder, kaolinite, bentonite, malathion followed by neem seed powder (1.9) and neem leaf powder (4.2) which was on par with lakke leaf powder (4.2), while more weight loss was seen in untreated check (9) followed by sawdust (8.1) which was on par with ash (7.6) followed by sand (6.5) which was on par with adasali (6.8).

4.3.5.4 120 DAS

Significantly no weight loss was seen in sweet flag, custard powder, kaolinite, bentonite, malathion followed by neem seed powder (3.0) and neem leaf powder (5.2) which was on par with lakke leaf powder (4.8). Maximum weight loss was noticed in untreated check (12.1) followed by sawdust (8.8) which was on par with ash (8.5) , followed by sand (7.5) which was on par with adasali (7.6).

4.3.5.5 150 DAS

Among different treatment maximum weight loss was recorded in untreated check (15.7) followed by ash (9.26) which was on par with sawdust (9.2) and adasali (8.5), while no weight loss was observed in sweet flag, custard seed powder, kaolinite followed by bentonite (0.46) and malathion (0.6).

4.3.5.6 180 DAS

Significantly zero per cent weight loss was noticed in sweet flag powder, custard seed powder followed by kaolinite (0.6) and. Bentonite was found (0.9) on par with malathion (1.00) maximum weight loss was recorded in untreated check (18.2) followed by sawdust and ash which recorded 10.8 and 10.4 pre cent weight loss, respectively.

### 4.3.6 Per cent popping due to *S. oryzae* infestation in plastic jars

Significantly higher popping per cent was noticed in seeds treated with sweet flag powder (81.50) followed by custard seed powder (79.60). However, these treatments were found on par with malathion (79.90). kaolinite (77.60) and neem seed powder (78.80) treatments which were next best treatment and found on par with each other (Table 15).

### 4.3.7 Volume expansion ratio

There was no significant difference existed among various treatments with respect to volume expansion ratios (Table 15).

### 4.3.8 Per cent adult mortality in jute bag due to *S. oryzae*

4.3.8.1 30 DAS

Grains in jute bag when treated with sweet flag, neem seed kernel powder, custard seed powder and malathion showed cent per cent mortality followed by kaolinite (92.36), bentonite (85.6). No mortality was found in untreated check while sawdust showed 10 per cent mortality followd by (Table 16) sand (13.3) which was on par with turmeric (13.3).

4.3.8.2 60 DAS

Significantly cent per cent mortality was recorded in sweet flag, neem seed, custard seed powder and malathion followed by kaolinite (90) which was on par with bentonite (90), while no mortality was observed in untreated check and sawdust.

4.3.8.3 90 DAS

Among the different treatment used, absolutely no mortality was recorded in untreated control and sawdust. Sweet flag, neem seed and custard seed powder were emerged as promising botanicals against weevil by recording cent per cent adult morality. Bentonite (85.00) and kaolinite (85.60) were found on par with each other.

**Table 15 : Per cent popping in grains treated with grain protectants in plastic jars due to *S. oryzae* infestation**

| Treatments | Popping yield (%) | Volume expansion ratio |
|---|---|---|
| $T_1$ – Honge leaf powder | 53.30 | 1:11.32 |
| $T_2$ – Adasal leaf powder | 47.40 | 1:11.14 |
| $T_3$ – Periwinkle leaf powder | 50.40 | 1:10.87 |
| $T_4$ – Neem leaf powder | 63.10 | 1:9.90 |
| $T_5$ – Lakke leaf powder | 47.70 | 1:11.25 |
| $T_6$ – Sweet flag | 81.50 | 1:11.13 |
| $T_7$ – Neem seed powder | 79.80 | 1:11.12 |
| $T_8$ – Tulsi leaf powder | 60.10 | 1:10.56 |
| $T_9$ – Custard seed powder | 79.60 | 1:10.78 |
| $T_{10}$ – Turmeric | 77.20 | 1:10.69 |
| $T_{11}$ – Kaolinite | 77.60 | 1:10.79 |
| $T_{12}$ – Bentonite | 74.20 | 1:10.96 |
| $T_{13}$ – Ash (cow dung) | 48.30 | 1:10.62 |
| $T_{14}$ – Sand | 45.60 | 1:10.63 |
| $T_{15}$ – Saw dust | 51.30 | 1:10.60 |
| $T_{16}$ – Malathion | 79.90 | 1:10.91 |
| $T_{17}$ – Untreated control | 49.60 | 1:10.95 |
| CD at 1% | 2.265 | NS |
| SE m$\pm$ | 0.585 | - |

NS – Non-significant

4.3.8.4 120 DAS

Cent per cent death of adults were seen in sweet flag followed by malathion which recorded 93.3 per cent mortality. Both neem seed kernel powder and custard seed powder recorded 91.6 per cent of mortality. No dead adults were recorded in untreated check followed by ash (21.6) and Tulsi (25).

4.3.8.5 150 DAS

Similar trend existed wherein no live adults were recorded in sweet flag followed by neem seed (90) which was on par with custard seed (90) and malathion. No mortality was seen in untreated check and sawdust.

4.3.8.6 180 DAS

Zero per cent mortality was noticed in untreated control and sawdust, followed by ash (16.6), sand (18.3) and tulsi (18.3) which did not differ statistically, while sweet flag again showed hundred per cent mortality followed by neem seed powder (86.6) and custard seed powder (83.3) which were on par with malathion (81.6).

**Table 16 : Evaluation of grain protectants against *S. oryzae* at various days of storage in jutebag**

| Treatments | Per cent adult mortality | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| $T_1$ – Honge leaf powder | 46.6f (43.05) | 50.0e (45.00) | 61.6e (51.71) | 48.3h (44.03) | 40.0g (39.23) | 38.3g (38.23) | 47.47f |
| $T_2$ – Adasal leaf powder | 41.6g (40.16) | 45.0f (42.13) | 50.0g (45.00) | 38.3i (38.23) | 28.3h (32.14) | 21.6i (27.69) | 37.46h |
| $T_3$ – Periwinkle leaf powder | 43.3g (41.15) | 43.3f (41.15) | 56.6f (48.79) | 46.6h (43.05) | 43.3f (41.15) | 26.6h (31.05) | 43.28g |
| $T_4$ – Neem leaf powder | 63.3e (52.12) | 76.6d (61.07) | 76.6d (60.40) | 60.0f (50.77) | 50.0e (45.00) | 41.6fg (40.16) | 61.35e |
| $T_5$ – Lakke leaf powder | 65.0d (53.73) | 80.0c (63.44) | 80.0c (60.40) | 53.3g (46.89) | 48.3e (44.03) | 46.0f (42.71) | 62.10e |
| $T_6$ – Sweet flag | 100.0a (90.0) | 100a (90.0) | 100.0a (0.00) | 100a (0.00) | 100a (90.00) | 100a (90.00) | 100.0a |
| $T_7$ – Neem seed powder | 100.0a (90.0) | 100a (90.0) | 100a (90.0) | 91.6c (73.15) | 90.0b (71.56) | 86.6b (68.53) | 94.70b |
| $T_8$ – Tulsi leaf powder | 16.6h (24.04) | 20.0h (26.56) | 33.3h (35.24) | 25.0k (30.00) | 21.6j (27.69) | 18.3ij (25.33) | 22.46i |
| $T_9$ – Custard seed powder | 100.0a (90.0) | 100a (90.0) | 100a (90.0) | 91.6c (73.15) | 90.0b (71.56) | 83.3c (65.88) | 94.15b |
| $T_{10}$ – Turmeric | 13.3i (21.39) | 16.6i (24.04) | 20.0j (26.56) | 33.3j (75.00) | 21.6j (27.69) | 21.6i (27.69) | 21.06i |
| $T_{11}$ – Kaolinite | 92.3b (73.89) | 90.0b (71.56) | 85.6b (67.78) | 80.0d (63.44) | 73.3c (58.89) | 75.0d (60.00) | 82.70c |
| $T_{12}$ – Bentonite | 85.6c (67.70) | 90.0b (71.56) | 85.0b (67.21) | 73.3e (58.89) | 70.0d (56.79) | 63.3e (52.71) | 77.86d |
| $T_{13}$ – Ash (cow dung) | 17.3h (23.21) | 26.6g (31.05) | 30.0i (33.21) | 21.6l (27.69) | 20.0j (26.56) | 16.6j (24.04) | 22.01i |
| $T_{14}$ – Sand | 13.3i (21.39) | 16.6i (24.09) | 20.0j (26.56) | 30.0k (33.21) | 25.0i (30.00) | 18.3ij (25.33) | 20.53i |
| $T_{15}$ – Saw dust | 10.0j (18.44) | 0.0j (0.00) | 0.0k (0.00) | 0.0m (0.00) | 0.0k (0.00) | 0.0k (0.00) | 1.66j |
| $T_{16}$ – Malathion | 100.0a (90.0) | 100.0a (90.0) | 100a (0.00) | 93.3b (75.00 | 88.3b (70.00) | 81.6c (64.60) | 93.86b |
| $T_{17}$ – Untreated control | 0.0k (0.00) | 0.0j (0.00) | 0.0k (00.0) | 0.0m (0.00) | 0.0k (0.00) | 0.0k (0.00) | 00.00j |
| CD (1%) | 1.54 | 1.66 | 1.55 | 1.65 | 1.67 | 2.56 | 3.87 |
| SEm± | 0.37 | 0.43 | 0.40 | 0.43 | 0.43 | 0.66 | 1.00 |

DAS – Days after storage

Means followed by the same letter do not differ significantly by DMRT (P=0.01)

Figures in the parenthesis are arc sine transformed value

## 4.3.9 Grain damage due *S. oryzae* infestation in jute bag

### 4.3.9.1 30 DAS

The treatments sweet flag, neem seed, custard seed powder, kaolinite and malathion showed zero per cent grain damage (Table 17). Untreated check showed significantly maximum (25.40) per cent of grain damage followed by sawdust (17.90) and sand (14.80).

### 4.3.9.2 60 DAS

The similar trend continued wherein per cent damaged grains were nil in treatments *viz.,* sweet flag powder followed by custard seed powder (1.6), neem seed powder (2.43) and malathion (2.7). This was followed by kaolinite (4.4) and bentonite (6.1). Significantly higher percentage of grain damage was recorded in untreated control (26.80) which was followed by turmeric (23.4) which in turn did not differ significantly from saw dust (20.60).

### 4.3.9.3 90 DAS

Sweet flag powder, neem seed powder, custard seed powder and malathion proved to be more promising treatments by recorded zero per cent grain damage followed by custard apple seed powder (2.3), neem seed kernel powder (3.4), malathion (4.3), kaolinite (5.0) and bentonite (4.6). Turmeric, saw dust showed grain damage about 25.20, 23.30, respectively they did not differ significantly among each other.

The similar trend existed throughout the storage period of about 6 months wherein sweet flag, custard apple seed powder, neem seed kernel powder proved to be most promising botanicals as grain protectants and were found to be on par with malathion treatments.

## 4.3.10 Weight loss due to *S. oryzae* infestation in jute bag

### 4.3.10.1 30 DAS

The per cent weight loss among the different treatments ranged from 0.00 to 11.6. Per cent weight loss was nil in treatments *viz.,* sweet flag powder, neem seed powder, custard seed powder, malathion. Next best treatment (Table 18) was kaolinite (1.3). Significantly higher (11.6) weight loss recorded in untreated control followed by sawdust (10.1).

### 4.3.10.2 60 DAS

Highest weight loss was recorded in untreated control (14.6%) followed by sawdust (12.8%) which was on par with turmeric (12.6%). The effect of other treatments was similar to that at 30 days after storage.

### 4.3.10.3 90 DAS

There was no weight loss in treatments sweet flag powder, neem seed, custard seed powder, malathion. Kaolinite (2.63) and bentonite (2.80) were found to be next best treatments. Significantly higher weight loss was recorded in untreated control (18.10) followed by sawdust (15.06) and ash (12.00).

### 4.3.10.4 120 DAS

Maximum weight loss of 21.1 per cent was recorded in untreated control followed by turmeric (18.3) which did not differ significantly from saw dust (17.8). No weight loss was observed in treatment sweet flag powder, custard seed powder followed by neem seed powder (0.9) and malathion (1.8).

### 4.3.10.5 150 DAS

Significantly highest weight loss observed in untreated control followed by turmeric (20) and sawdust (19.5). Further, the influence of other treatments was similar to that at three months after storage with a marginal increase in the weight loss.

### 4.3.10.6 180 DAS

Grains treated with sweet flag powder showed zero per cent weight loss followed by custard seed powder (2.1) which was on par with neem seed powder (2.2). However, in malathion 3.2 per cent weight loss was recoded as against 24.4 per cent in untreated check. Whereas turmeric and sawdust recorded weight loss of 22 and 20.3 per cent, respectively.

**Table 17 : Efficacy of grain protectants against *S. oryzae* at different period of storage in jutebag**

| Treatments | Per cent grain damage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| $T_1$ – Honge leaf powder | 15.3f (23.03) | 17.8b (24.95) | 20.3e (26.78) | 25.0b (30.00) | 38.6f (38.41) | 50.0e (45.00) | 27.84d |
| $T_2$ – Adasal leaf powder | 16.6de (24.04) | 19.2cd (25.99) | 21.8f (24.83) | 29.0a (35.58) | 44.33e (41.73) | 53.3d (46.89) | 30.70c |
| $T_3$ – Periwinkle leaf powder | 22.6b (28.38) | 24.3b (29.53) | 26.4ab (30.92) | 34.6a (36.03) | 50.0cd (45.00) | 62.3c (52.12) | 36.70b |
| $T_4$ – Neem leaf powder | 15.3f (23.03) | 17.6b (24.80) | 21.0e (27.28) | 23.3b (28.79) | 34.3h (35.85) | 42.0f (40.40) | 25.63e |
| $T_5$ – Lakke leaf powder | 16.0ef (23.58) | 18.4d (25.40) | 21.3de (27.49) | 23.3b (28.79) | 36.3g (37.05) | 45.0g (42.13) | 26.71de |
| $T_6$ – Sweet flag | 0.0l (0.00) | 0.0j (0.00) | 0.0k (0.00) | 0.0f (0.00) | 0.0m (0.00) | 0.0k (0.00) | 0.00j |
| $T_7$ – Neem seed powder | 1.7j (7.43) | 2.43h (8.91) | 3.4i (10.63) | 4.0de (11.54) | 6.1k (14.30) | 8.11j (6.59) | 4.28hi |
| $T_8$ – Tulsi leaf powder | 17.5cd (24.73) | 20.7c (27.06) | 26.1ab (30.72) | 39.6a (398.0) | 54.60b (47.04) | 63.3c (52.71) | 36.96b |
| $T_9$ – Custard seed powder | 1.0k (5.74) | 1.6i (7.27) | 2.3j (8.72) | 36.00e (9.98) | 4.0l (11.54) | 6.50j (15.89) | 3.06i |
| $T_{10}$ – Turmeric | 21.3b (27.44) | 23.4b (29.60) | 25.2bc (30.13) | 33.3a (35.37) | 51.30c (45.75) | 65.5b (54.09) | 36.68b |
| $T_{11}$ – Kaolinite | 3.0i (9.98) | 4.4g (12.11) | 5.0h (12.92) | 6.1cd (14.30) | 8.0j (16.43) | 10.0i (18.44) | 6.08g |
| $T_{12}$ – Bentonite | 5.5h (13.56) | 6.1f (14.3) | 6.9g (15.23) | 8.0c (16.43) | 11.90i (20.18) | 13.0h (21.13) | 8.56f |
| $T_{13}$ – Ash (cow dung) | 13.2g (21.30) | 15.1e (22.87) | 17.5f (24.73) | 20.7b (27.06) | 53.3b (46.89) | 67.0b (54.94) | 31.13c |
| $T_{14}$ – Sand | 14.8f (22.63) | 17.3d (24.58) | 19.6ef (26.28) | 22.6a (28.38) | 37.30fg (37.68) | 51.3e (45.75) | 26.16e |
| $T_{15}$ – Saw dust | 17.9c (25.63) | 20.6c (26.99) | 23.3cd (28.86) | 29.0a (35.58) | 49.30d (44.60) | 54.60b (47.06) | 30.76c |
| $T_{16}$ – Malathion | 1.9j (7.92) | 2.7h (9.46) | 4.3hi (11.97) | 5.50cd (13.56) | 6.1k (14.30) | 8.0j (16.43) | 4.75h |
| $T_{17}$ – Untreated control | 25.4a (30.33) | 26.8a (31.18) | 28.4a (32.20) | 37.3a (37.68) | 64.0a (23.13) | 73.00a (58.69) | 42.48a |
| CD (1%) | 0.94 | 1.39 | 1.42 | 2.96 | 1.08 | 1.13 | 1.22 |
| SEm± | 0.24 | 0.36 | 0.37 | 0.77 | 0.28 | 0.29 | 0.32 |

DAS – Days after storage
Means followed by the same letter do not differ significantly by DMRT (P=0.01)
Figures in the parenthesis are arc sine transformed value

**Table 18: Per cent weight loss due to *S. oryzae* infestation in jutebag treated with grain protectants**

| Treatments | Per cent weight loss | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 180 DAS | Mean |
| $T_1$ – Honge leaf powder | 4.5 f (12.25) | 5.4e (13.44) | 7.3de (15.68) | 9.6de (18.05) | 11.2gh (19.55) | 12.0g (20.27) | 8.33ef |
| $T_2$ – Adasal leaf powder | 5.5e (13.56) | 6.8d (15.12) | 7.76de (16.11) | 10.3d (18.72) | 12.1fg (20.36) | 13.0g (21.13) | 9.24de |
| $T_3$ – Periwinkle leaf powder | 4.6f (12.39) | 7.6d (16.00) | 8.26b (16.64) | 9.2def (17.66) | 13.9e (21.89) | 15.2ef (22.95) | 9.79d |
| $T_4$ – Neem leaf powder | 2.5g (9.10) | 4.11f (11.68) | 6.7e (15.00) | 8.4ef (16.85) | 13.1ef (21.22) | 16.0e (23.58) | 8.46ef |
| $T_5$ – Lakke leaf powder | 3.0g (9.98) | 4.13f (11.68) | 7.1 de (15.45) | 8.3f (16.74) | 12.0fg (20.27) | 14.4f (22.30) | 8.15f |
| $T_6$ – Sweet flag | 0.0j (0.00) | 0.0i (0.00) | 0.0h (0.00) | 0.0j (0.00) | 0.0m (0.00) | 0.0l (0.00) | 0.00i |
| $T_7$ – Neem seed powder | 0.0j (0.00) | 0.0i (0.00) | 0.0h (0.00) | 0.9i (5.44) | 1.8k (7.71) | 2.2k (8.53) | 0.81hi |
| $T_8$ – Tulsi leaf powder | 8.2cd (16.64) | 10.2c (18.63) | 12.5c (20.70) | 14.9c (22.71) | 18.0cd (25.10) | 20.0c (26.56) | 13.96c |
| $T_9$ – Custard seed powder | 0.0j (0.00) | 0.0i (0.00) | 0.0h (0.00) | 0.0j (0.00) | 1.10l (6.02) | 2.1k (8.33) | 0.53hi |
| $T_{10}$ – Turmeric | 7.6b (16.00) | 12.6b (20.79) | 16.6a (24.04) | 18.3b (25.33) | 20.0b (26.56) | 22.0b (27.97) | 16.18b |
| $T_{11}$ – Kaolinite | 1.3 i (6.55) | 1.5h (7.04) | 2.63g (8.13) | 3.8g (11.24) | 5.3i (13.31) | 6.4i (14.65) | 3.38g |
| $T_{12}$ – Bentonite | 1.8h (7.71) | 2.13g (8.33) | 2.8f (9.63) | 4.5g (12.25) | 6.0i (14.18) | 8.2h (16.64) | 4.23g |
| $T_{13}$ – Ash (cow dung) | 9.1bc (17.76) | 10.2c (18.63) | 12.0c (20.27) | 14.2c (22.04) | 14.6d (23.89) | 18.3d (25.33) | 13.36c |
| $T_{14}$ – Sand | 5.03ef (12.92) | 5.6e (13.69) | 7.5de (15.89) | 8.7ef (17.16) | 10.2h (18.63) | 12.3g (20.53) | 8.22ef |
| $T_{15}$ – Saw dust | 10.1b (18.53) | 12.8b (20.96) | 15.0b (22.79) | 17.8b (24.95) | 19.5bc (26.21) | 20.3c (26.78) | 15.92b |
| $T_{16}$ – Malathion | 0.0j (0.00) | 0.0i (0.00) | 1.0h (0.00) | 1.8h (7.71) | 2.5i (9.10) | 3.2j (10.31) | 1.25h |
| $T_{17}$ – Untreated control | 11.6a (19.91) | 14.6a (22.46) | 18.1a (25.10) | 21.1a (27.35) | 22.7a (28.45) | 24.4a (29.60) | 18.75e |
| CD (1%) | 1.13 | 0.98 | 1.16 | 1.18 | 1.34 | 0.95 | 0.96 |
| SEm± | 0.29 | 0.25 | 0.30 | 0.31 | 0.35 | 0.24 | 0.24 |

DAS – Days after storage

Means followed by the same letter do not differ significantly by DMRT (P=0.01)

Figures in the parenthesis are arc sine transformed value

**Table 19 : Population buildup of adults of *S. oryzae* in jutebag treated with grain protectants**

| Treatments | Population buildup | | | | | | |
|---|---|---|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **120 DAS** | **150 DAS** | **180 DAS** | **Mean** |
| $T_1$ – Honge leaf powder | 4.3i (2.19) | 11.3e (3.43) | 15.6cde (4.01) | 26.6g (5.21) | 38.0d (6.20) | 54.0d (7.38) | 24.96f |
| $T_2$ – Adasal leaf powder | 5.0h (2.34) | 8.0h (2.91) | 13.6de (3.75) | 21.6h (4.70) | 40.6d (6.41) | 51.3de (7.19) | 23.35f |
| $T_3$ – Periwinkle leaf powder | 7.0f (2.73) | 11.3e (3.43) | 17.0c (4.18) | 33.6e (5.83) | 53.0c (7.31) | 64.3c (8.04) | 31.03e |
| $T_4$ – Neem leaf powder | 4.3i (2.19) | 8.3h (2.96) | 15.0cde (3.93) | 28.6f (5.40) | 39.6d (6.33) | 50.0de (7.10) | 24.31f |
| $T_5$ – Lakke leaf powder | 6.0g (2.54) | 9.0g (3.08) | 13.3e (3.71) | 22.0h (4.74) | 37.0d (6.12) | 45.0e (6.74) | 22.05f |
| $T_6$ – Sweet flag | 0.0k (0.70) | 0.0k (0.70) | 0.0h (0.70) | 0.0l (0.70) | 0.0j (0.70) | 0.0j (0.70) | 0.00j |
| $T_7$ – Neem seed powder | 0.0k (0.70) | 0.0k (0.70) | 0.0h (0.70) | 3.0k (1.87) | 8.0h (2.91) | 13.3h (3.71) | 4.05i |
| $T_8$ – Tulsi leaf powder | 10.0d (3.24) | 14.0b (3.80) | 22.6b (4.80) | 38.6d (6.25) | 59.6b (7.75) | 68.0c (8.27) | 35.47cd |
| $T_9$ – Custard seed powder | 0.0k (0.70) | 0.0k (0.70) | 0.0h (0.70) | 0.0l (0.70) | 3.3h (1.94) | 6.6i (2.67) | 1.66ij |
| $T_{10}$ – Turmeric | 12.0c (3.5) | 16.3b (4.09) | 24.3b (4.97) | 44.6b (6.86) | 62.6b (7.94) | 75.0b (8.68) | 38.81bc |
| $T_{11}$ – Kaolinite | 0.0k (0.70) | 1.3j (1.34) | 6.0g (2.54) | 10.0j (3.24) | 12.3i (1.54) | 18.6g (4.37) | 8.04h |
| $T_{12}$ – Bentonite | 2.0j (1.58) | 2.3i (1.67) | 8.0f (2.91) | 14.3i (3.84) | 20.0e (4.52) | 30.0f (5.52) | 12.76g |
| $T_{13}$ – Ash (cow dung) | 12.6bc (3.61) | 14.6cd (3.88) | 22.6b (4.80) | 30.0f (5.52) | 53.3c (7.33) | 68.3c (8.29) | 33.57de |
| $T_{14}$ – Sand | 8.3e (2.96) | 10.0f (3.24) | 16.0cd (4.06) | 29.3f (5.46) | 40.3d (6.38) | 55.6d (7.48) | 25.58f |
| $T_{15}$ – Saw dust | 13.3b (3.71) | 15.3c (3.97) | 25.6ab (5.10) | 44.0c (6.67) | 63.3b (7.98) | 78.3ab (8.87) | 39.97ab |
| $T_{16}$ – Malathion | 0.0k (0.70) | 0.0k (0.70) | 0.0h (0.70) | 3.0k (1.87) | 5.33g (2.41) | 9.0i (3.08) | 2.88ij |
| $T_{17}$ – Untreated control | 15.0a (3.93) | 19.3a (4.44) | 28.6a (5.39) | 52.6a (7.28) | 68.3a (8.29) | 85.0a (9.24) | 43.13a |
| CD (1%) | 0.14 | 0.10 | 0.32 | 0.16 | 0.32 | 0.45 | 2.80 |
| SEm$\pm$ | 0.37 | 0.03 | 0.82 | 0.41 | 0.08 | 0.12 | 0.97 |

DAS – Days after storage

Means followed by the same letter do not differ significantly by DMRT (P=0.01)

Figures in parenthesis are $\sqrt{x + 0.5}$ transformed values

## 4.3.11 Emergence of adults in jute bag

### 4.3.11.1 30 DAS

Number of adults emerged was significantly higher in untreated control (15) followed by sawdust (13.3), ash (12.6) and turmeric (12). No beetle activity was seen in treatments with sweet flag powder, neem seed powder, custard apple seed powder, malathion and, kaolinite (Table 19).

### 4.3.11.2 60 DAS

Population buildup was zero in treatments *viz.,* sweetflag powder, custard seed powder, neem seed kernel powder, malathion. The next best treatments were found to be kaolinite (1.3) and bentonite (2.3). Significantly maximum number of adult were recorded in untreated check (19.3) followed by turmeric (16.3) and sawdust (15.3).

### 4.3.11.3 90 DAS

The similar trend was observed at three months after storage wherein treatments sweet flag powder, neem seed powder, custard seed, malathion showed zero population up. Again kaolinite (6) and bentonite (8) was found to be next best treatment. Higher number of adults (28.6) were recorded in untreated check followed by sawdust (25.6) which did not differ statistically from turmeric (24.3).

### 4.3.11.4 120 DAS

Significantly higher number of adults (52.6) were observed in untreated control followed by turmeric (44.66) and sawdust (44.00) population buildup was zero in sweet flag powder, custard seed powder followed by malathion (3.00).

### 4.3.11.5 150 DAS

No adult weevils were emerged in treatment sweet flag powder followed by custard seed powder (3.3). Maximum number of weevil emerged in untreated check (68.30) followed by sawdust (63.3) which was on par with tulsi (59.6).

### 4.3.11.6 180 DAS

The similar observation were made as that of 150 DAS.

## 4.3.12 Per cent popping due to *S. oryzae* infestation in grains stored in jute bag

### 4.3.12.1 180 DAS

Significantly higher per cent of popping was observed in treatment sweet flag powder (82.30) followed by custard seed powder (80.40) which did not differ statistically from malathion (80.80). Minimum per cent of popping (42.40) was recorded in untreated control (Table 20) followed by sand (45.80) and lakke leaf powder (47.30).

### 4.3.12 Volume expansion ratio

Per cent volume expansion ratio did not differ statistically among different treatment at 180 DAS after storage.

### 4.3.13 Organoleptic evaluation of popped sorghum treated with six grain protectants

The popped sorghum treated with custard seed powder recorded maximum (Table 21) score (4.30) which was highly acceptable in appearance followed by Kaolinite (4.02), sweet flag (3.72). However, neem seed kernel powder (3.47) and bentonite (3.30) did not differ significantly.

With respect to colour, malathion was found superior (4.50) followed by kaolinite (4.02), bentonite (3.30) and neem seed kernel powder (3.10).

The score for texture was high in kaolinite (4.90) followed by malathion (4.80), neem seed kernel powder (4.40) and sweetflalg (4.10).

The score for the taste was high in neem seed kernel powder (4.50) followed by custard seed powder (4.30), kaolinite (4.05).

With respect to aroma, highest score was recorded for kaolinite (4.50) followed by neem seed kernel powder (3.80) which was on par with sweet flag (3.70) and malathion was least in the preference.

**Table 20 : Per cent popping in grains treated with grain protectants in jutebag**

| Treatments | Popping yield (%) | Volume expansion ratio |
|---|---|---|
| $T_1$ – Honge leaf powder | 50.40 | 1:10.41 |
| $T_2$ – Adasal leaf powder | 52.80 | 1:10.80 |
| $T_3$ – Periwinkle leaf powder | 50.80 | 1:10.93 |
| $T_4$ – Neem leaf powder | 58.90 | 1:10.58 |
| $T_5$ – Lakke leaf powder | 47.30 | 1:9.95 |
| $T_6$ – Sweet flag | 82.30 | 1:10.26 |
| $T_7$ – Neem seed powder | 78.80 | 1:10.65 |
| $T_8$ – Tulsi leaf powder | 60.60 | 1:11.18 |
| $T_9$ – Custard seed powder | 80.40 | 1:11.13 |
| $T_{10}$ – Turmeric | 54.80 | 1:10.97 |
| $T_{11}$ – Kaolinite | 77.90 | 1:10.63 |
| $T_{12}$ – Bentonite | 73.20 | 1:10.25 |
| $T_{13}$ – Ash (cow dung) | 45.80 | 1:10.94 |
| $T_{14}$ – Sand | 45.50 | 1:11.13 |
| $T_{15}$ – Saw dust | 50.40 | 1:11.12 |
| $T_{16}$ – Malathion | 80.80 | 1:10.84 |
| $T_{17}$ – Untreated control | 42.40 | 1:10.36 |
| CD at 1% | 1.517 | NS |
| SE m± | 0.460 | - |

NS – Non-significant

The overall acceptability score for kaolinite was high (4.50) followed by sweet flag (4.00) which was on par with custard seed powder (3.70) neem seed kernel powder (3.70) and bentonite (3.80).

**Table 21 : Organoleptic evaluation of popped sorghum treated with different grain protectants**

| Sl. No. | Sample | Appearance | Colour | Texture | Taste | Aroma | Overall acceptability |
|---|---|---|---|---|---|---|---|
| 1 | Malathion | 2.99d | 4.50a | 4.80ab | 1.90e | 1.50e | 2.80c |
| 2 | Custard seed | 4.30a | 3.30cd | 3.00d | 4.30ab | 2.90d | 3.70c |
| 3 | Neem seed powder | 3.47c | 3.10d | 4.40bc | 4.50a | 3.80b | 3.70b |
| 4 | Kaolinite | 4.02ab | 4.02b | 4.90a | 4.05b | 4.50a | 4.50a |
| 5 | Sweet flag | 3.72bc | 3.12d | 4.10c | 3.10d | 3.70b | 4.0b |
| 6 | Bentonite | 3.30cd | 3.30c | 2.90d | 3.70c | 3.30c | 3.80b |
| | CD at 5% | 0.44 | 0.39 | 0.43 | 0.30 | 0.23 | 0.34 |
| | SE m$\pm$ | 0.10 | 0.09 | 0.10 | 0.07 | 0.05 | 0.08 |

Means followed by the same letter do not differ significantly by DMRT (P=0.05)

# V. DISCUSSION

Results of the investigation on the rice weevil *Sitophilus oryzae* (Linn.) with reference to biology, varietal resistance and efficacy of grain protectants in pop sorghum grains are discussed in foregoing pages under the light of earlier workers.

## 5.1 BIOLOGY OF RICE WEEVIL ON POP SORGHUM

During present investigation an attempt was made to study the biology of rice weevil *Sitophilus oryzae* (L.) on pop sorghum. The literature on record revealed that absolutely no work has been done on the biology of *S. oryzae* on pop sorghum. Hence the discussion of present findings has been extended to the information published on other cereal crops.

Under laboratory conditions there were three moults with four instars of grub. The larval period occupied 21 to 30 days with an average of 25.8 days. The findings are comparable with Bheemanna (1986) who reported 25 to 34 days of larval period on CSH-5 sorghum genotype with four larval instars (Table 4). Sattigi (1982) also reported similar results. But these findings are in contrary to Bhuiyah *et al.* (1990) who reported 16 to 20 days of larval period on maize grains. The possible reason for variation in duration could be difference in temperature, relative humidity and also change in host during the investigations (Plate 3).

Pupation took place inside the grains. Pupal period varied from 7 to 8 days with an average of 7.4 days (Table 4) at 11.7°C to 39.5°C temperature and 56 to 81 per cent relative humidity. The findings are in conformity with Lopez-Cristobal (1953) who reported 6 to 16 days of pupal period. But Bhuiyah *et al.* (1990) reported 2 to 9 days of pupal period at 23 to 30°C temperature 78 to 87 per cent relative humidity on maize grains. The variation could be due to the difference in temperature, relative humidity and change in the host as well (Plate 4).

Total life cycle from egg to adult took 35 to 46 days with an average of 40.2 days. The findings are in agreement with Howe (1952) who reported 21 to 46 days. But these results do not agree with observation of Bheemanna (1986) who reported 38 to 53 days of total life cycle on sorghum hybrid CSH-5. The difference may be attributed to variation in genotype and different environment condition (Plate 5).

The weevils freely copulated under laboratory condition during day time. The weevils commenced mating 4 to 6 days after emergence with an average of 5.2 days premating period and the mating period lasted for 30-67 minutes with an average of 51.2 minutes (Table 4). The number of workers Bheemanna (1986), Sattigi (1982), Yevoor (2003) have made similar kind of observations.

The adults female longevity with food and without food was 95.80 days (81 to 104 days) and 10.6 days (9 to 12 days) respectively. Similarly, longevity of (Table 4) adult male was 59.2 days (57 to 61 days) and 5.6 days (5 to 7 days), respectively. The present findings draw the support of Bheemanna (1986) who observed adult longevity ranging from 14 to 165 days and 7 to 11 days with and without food, respectively. While, Sattigi (1982) reported adult weevil longevity to be 16 to 172 days with food. The longevity of adult male and female was 14 to 115 and 119 to 120 days, respectively, when one day old adults were released into 2 kg sacks of maize (Bhuiyah *et al.*, 1990) this deviation may be due to change of host.

## 5.2 SCREENING OF POP SORGHUM GENTYPES IN COMPARISON WITH GRAIN SORGHUM AGAINST RICE WEEVIL *S. oryzae* IN STORAGE

Identification of resistant pop sorghum genotypes to save the losses in storage due *S. oryzae* has assumed greater significance. So during present investigations some of genotypes of pop sorghum and grain sorghum were screened for their resistance to *S. oryzae* under laboratory condition.

At 180 days after storage, per cent grain damage was maximum (99.36) in Shiggaon local (Table 5) followed by Talakal-6 (86.70). Grain damage was low in DSV-3 and CSH-14 being 55.60 and 70.90 per cent respectively. In the absence of information on similar studies, it could be reasoned that the host nutrition had played a major role in altering the tolerance capacity of genotypes.

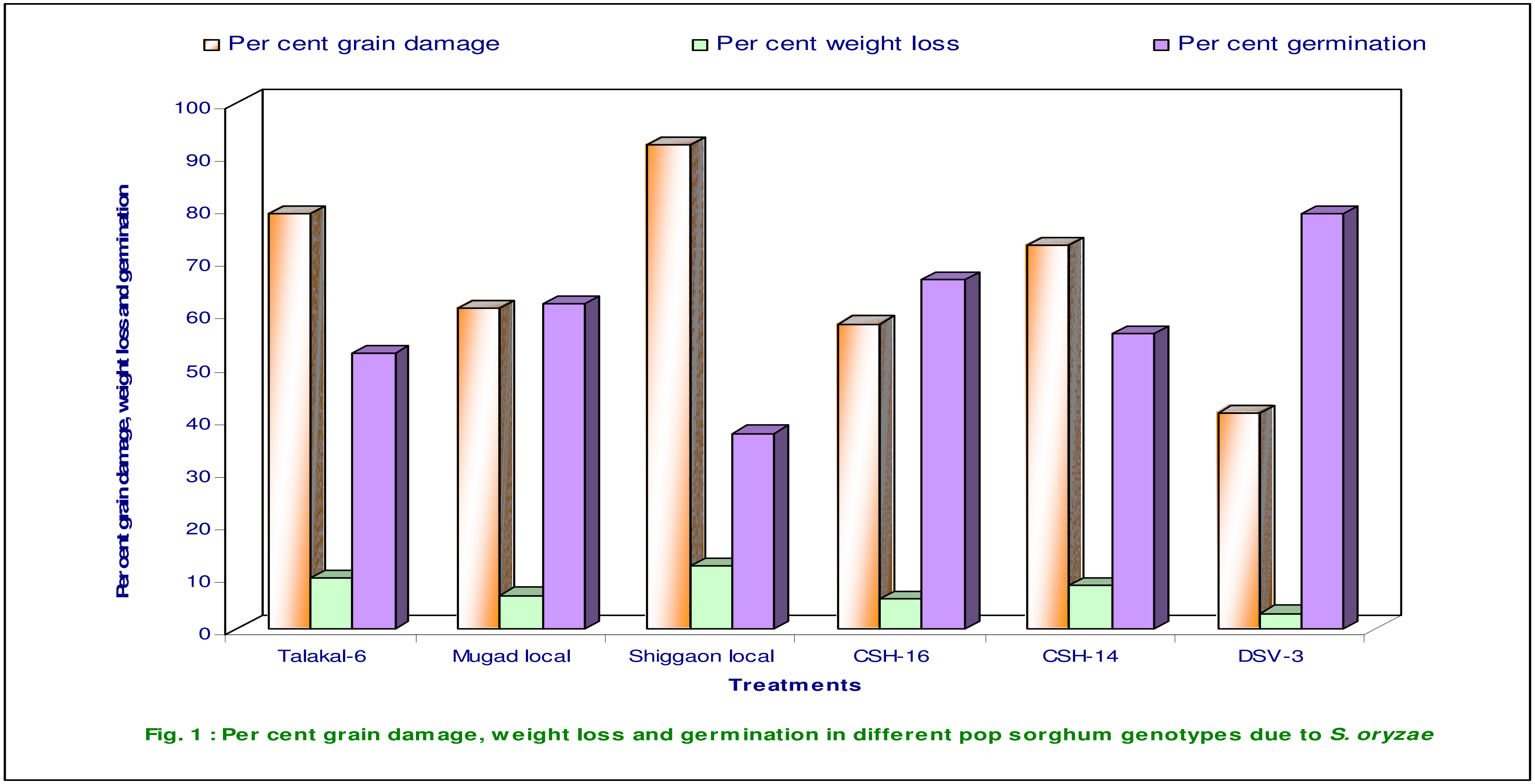


**Fig. 1: Per cent grain damage, weight loss and germination in different pop sorghum genotypes due to S. oryzae infestation**

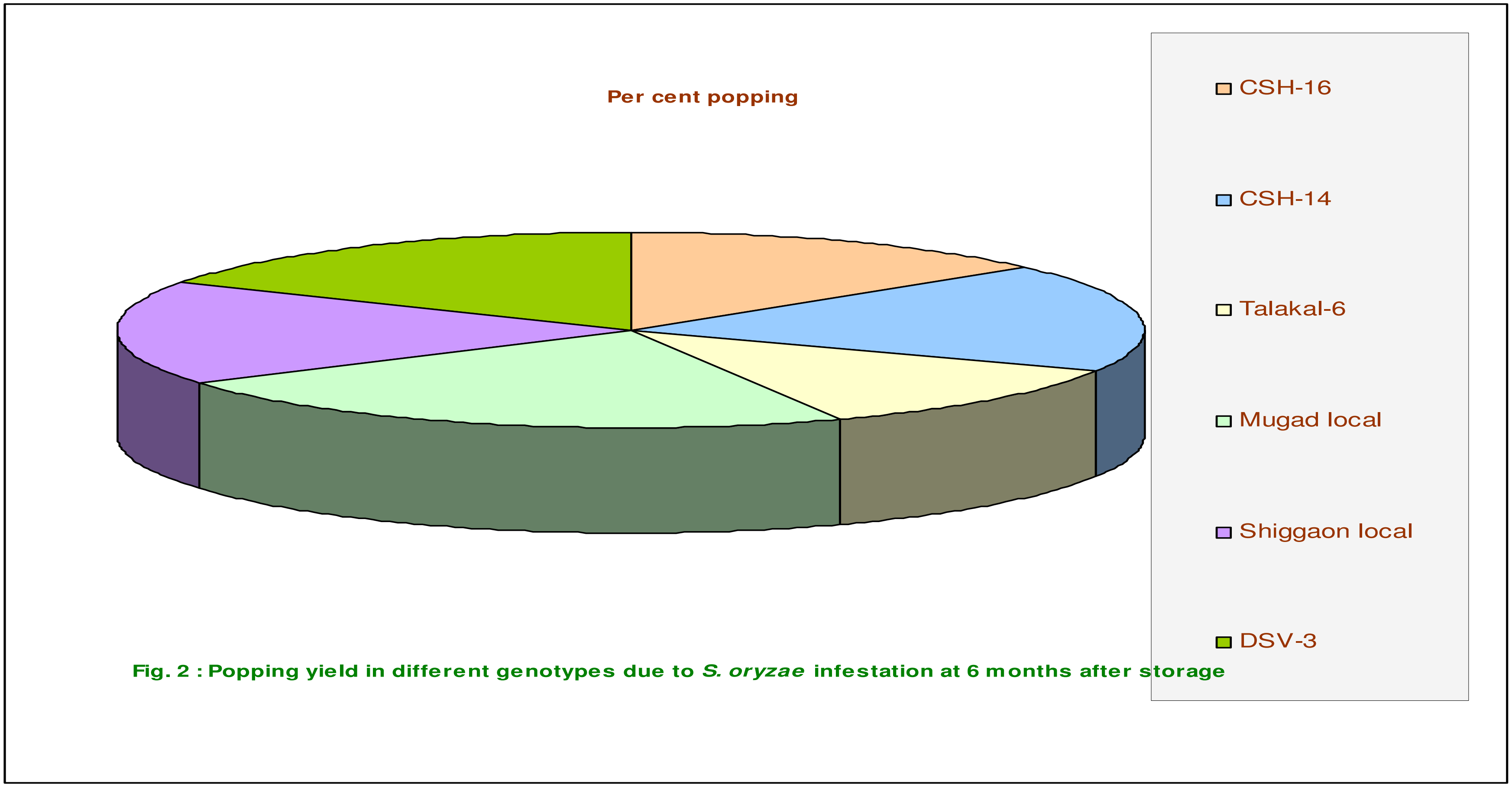


Fig. 2: Popping yield in different genotypes due to S. oryzae infestation at 6 months affer storage

Per cent weight loss among different genotypes due to *S. oryzae* has been presented in Table 6 and per cent weight loss increased with increase in storage period. At 180 days after storage per cent weight loss was more in Shiggaon local and Talakal-6 having 19.30 and 16.50 per cent, respectively. Less per cent of weight loss was noticed in DSV-3 (5.80) and CSH-16 (10.10). The persusal of literature revealed that these results neither can be discussed nor compared as such studies are wanting.

Regarding population buildup, highest progeny were produced on Shiggaon local (142.78) followed by Talakal-6 (125.23), while it was least in DSV-3 (39.82) followed by Mugad local (109.54) at 180 days after storage. Since there is no evidence to make critical discussion on this issue but according to Borikar and Tayde (1979) who reported that hybrids were comparatively had less incidence of rice weevil than the local genotypes. This may be attributed to genotypic character having thick pericarp (Table 7 and Fig. 1).

The damage due to *S. oryzae* affected the viability of genotypes. There was considerable loss in the seed viability (Table 8) at 180 days after storage. DSV-3 recorded maximum germination percentage of 69.00 followed by CSH-16 (59.80). Germination percentage was very poor in Shiggaon local (30.30) followed by Talakal-6 (44.30). Loss of viability could be due to damage caused by *S. oryzae* during storage period. It draws the support of Kurdikeri *et al*. (1993) who reported that initial germination of 97.10 per cent in maize hybrid, Deccan 103 was brought down to 39.50 per cent, after six months of storage due rice weevil infestation.

Per cent popping among different genotypes ranged from 43.00 to 85.40 (Table 9). The per cent popping was maximum in Mugad local (85.40) followed by CSH-14 (69.40). Least per cent popping was observed in Talakal-6 (43.00) followed by CSH-16 (53.10) at 180 days after storage (Fig. 2 and Plate 6).

The apparent variation in popping per cent could be due to infestation of *S. oryzae* in the storage period also difference in physico-chemical properties of the grains. This studies are in agreement with Hadimani *et* al (1995) and Hadimani *et* al (2001).

Maximum volume expansion ratio was recorded in Mugad local (1:12.51) followed by CSH-16 (1:12.10) after six months of storage. While it was least in CSH-14 (1:4.92) followed by DSV-3 (9.09). Again variation may be due to physico chemical properties of grains.

Overall findings of the present investigation on screening of pop genotypes against rice weevil enlightens that, among pop sorghum varieties, Mugad local emerged as the most promising variety relatively resistant to *S. oryzae* when stored for six months. DSV-3 exhibited low per cent damaged grains, weight loss, viability and less population buildup indicating that it is relatively resistant to *S. oryzae* infestation as compared to other varieties.

## 5.3 ECOFRIENDLY APPROACHES FOR THE MANAGEMENT OF RICE WEEVIL IN POP SORGHUM

Awareness of hazards posed by utilization of synthetic pesticides and other drawbacks like residues in the food stuffs, resistance development and environmental hazards *etc.,* has necessitated the need for naturally occurring grain protectants, which may be toxic to specific pest species, but not harmless to man. Since, the pop sorghum grains are not consumed immediately as they are stored for long time and sold as snacks food throughout the year. During the present investigation certain grain protectants have been evaluated for their efficacy against *S. oryzae* and the findings are discussed as here under.

### 5.3.1 Sweet flag powder

Among all the plant products used sweet flag powder afforded maximum protection than any other product. It was found highly effective against *S. oryzae* at 1.00 per cent (Table 10 and Fig. 3) causing cent per cent mortality at seven days after storage. No adult emergence, seed damage and weight loss was recorded even at six months after storage in plastic jars and jute bag. Similar opinion expressed by Sivasrinivasu (2001) who also reported 100 per cent mortality of *S. oryzae* in sorghum grains, treated with 1.00 per cent sweet flag powder. Yevoor (2003) reported that sweet flag powder at 1.00 per cent caused cent per cent adult mortality of *S. oryzae* on maize grains at three months after storage. Sunil kumar (2003) also reported the similar results.

# LEGEND

| Treatments |
|---|
| $T_1$ – Honge leaf powder |
| $T_2$ – Adasal leaf powder |
| $T_3$ – Periwinkle leaf powder |
| $T_4$ – Neem leaf powder |
| $T_5$ – Lakke leaf powder |
| $T_6$ – Sweet flag |
| $T_7$ – Neem seed powder |
| $T_8$ – Tulsi leaf powder |
| $T_9$ – Custard seed powder |
| $T_{10}$ – Turmeric |
| $T_{11}$ – Kaolinite |
| $T_{12}$ – Bentonite |
| $T_{13}$ – Ash (cow dung) |
| $T_{14}$ – Sand |
| $T_{15}$ – Saw dust |
| $T_{16}$ – Malathion |
| $T_{17}$ – Untreated control |

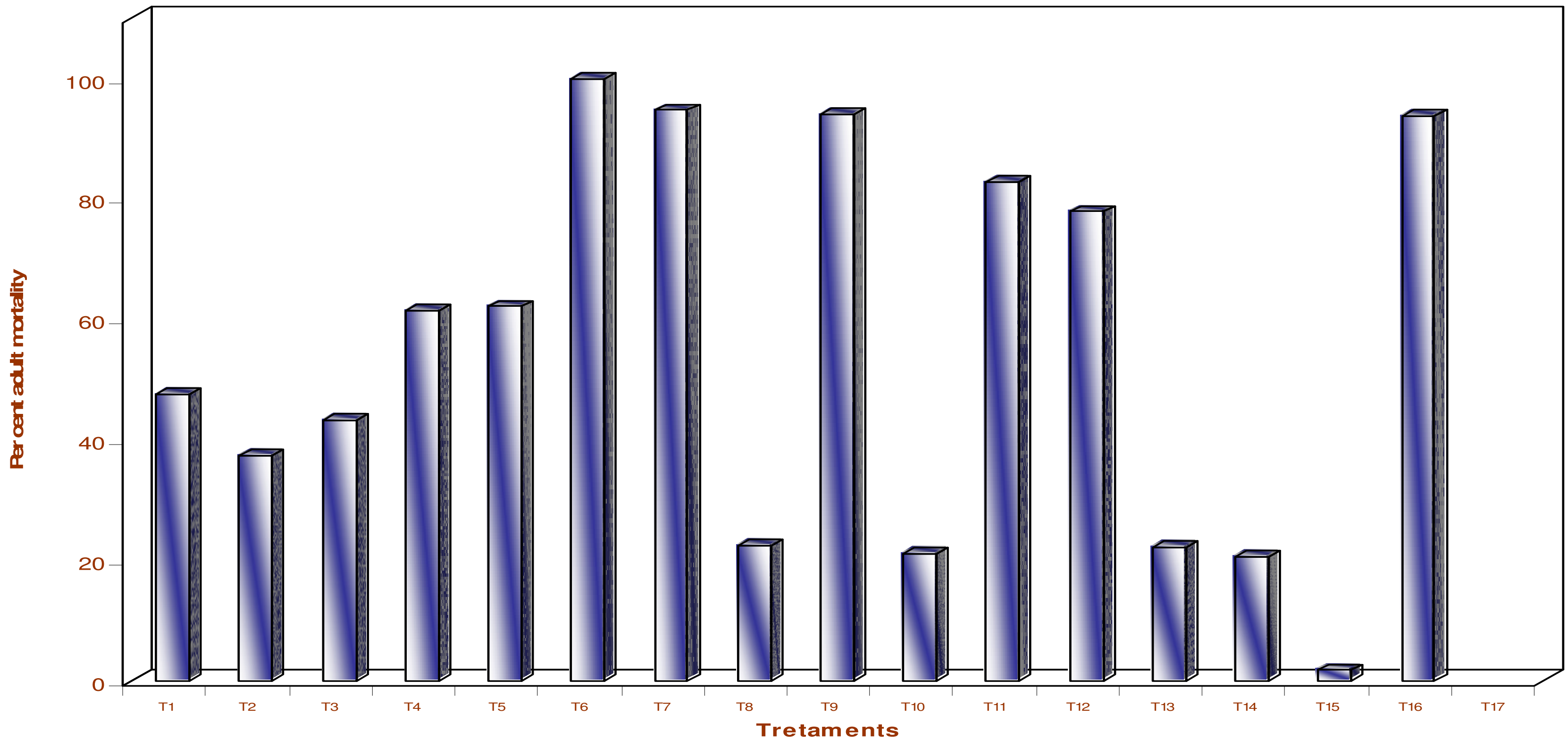


Fig. 3: Bioefficacy of different grain protectants against *S. oryzae* in jute bag

**Fig. 3: Bioefficacy of different grain protectants against S. oryzae in jute bag**

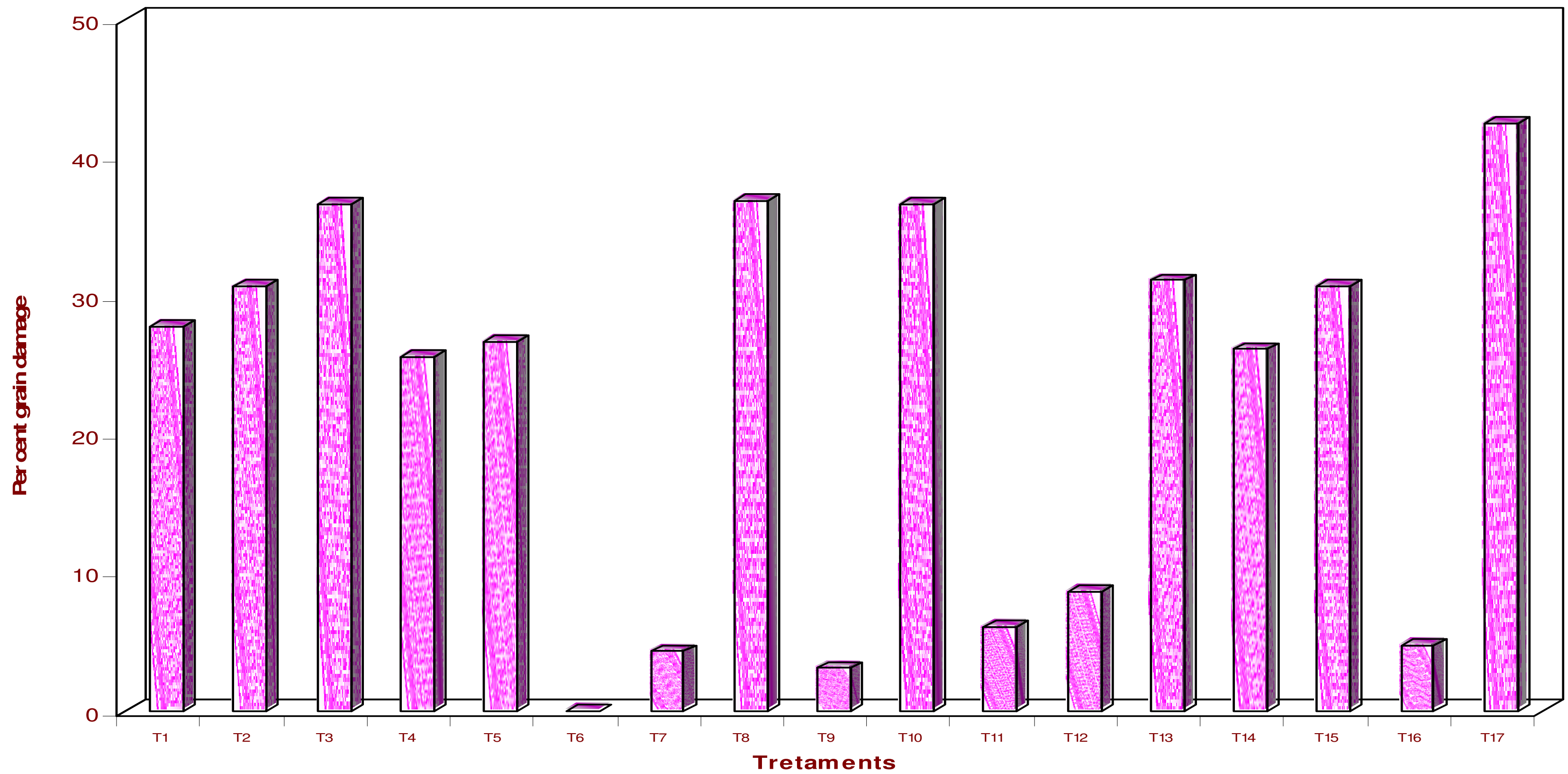


**Fig. 4 : Per cent grain damage in different treatments due to *S. oryzae* infestation in jute bag**

**Fig. 4: per cent grain damage in different treatments due to S. oryzae infestation in jute bag**

### 5.3.2 Custard apple seed powder

Custard apple seed powder was observed to be equally effective as sweet flag powder in controlling the rice weevil at 5 per cent dosage. It was observed to be superior in inflicting mortality, reducing the per cent grain damage, weight loss, adult emergence also maintained seed viability and popping over untreated check.

Custard apple seed powder caused cent per cent mortality at 180 days after storage (Table 10). The mortality per cent recorded by Ali *et al.* (1981) supports the present findings. Though considerable adults emerged in the treated grains, the per cent weight loss was very less in jute bag, this may be due to antifeeding effect of the custard apple seed powder (Luca, 1979). However, complete prevention of damage due to application of custard apple seed powder was observed by Shivanna (1994) and Yevoor (2003) (Fig 4).

### 5.3.3 Neem

#### 5.3.3.1 Seed powder

Neem seed powder at dosage of 5 per cent was found to be equally effective as custard apple, sweet flag powder in controlling the rice weevil throughout the period of experiment. The mortality was cent per cent at 180 days after treatment in plastic jars and 86.6 per cent in jute bag (Table 17) as compared to no mortality in untreated check (Table 11). It also showed zero per cent weight loss, grain damage and no emergence of adults in plastic jars, while in jute bag showed 3.4, 2.2 per cent grain damage and weight loss respectively. These findings are in agreement with Yevoor (2003) who observed cent per cent mortality of adults of rice weevil at three months after storage (Fig. 5).

#### 5.3.3.2 Leaf powder

The neem leaf powder was not found effective in controlling the damage caused by rice weevil in pop sorghum till the termination of experiment. The less effectiveness of neem leaf powder compared to neem seed kernel powder due to less azadirachtin content in leaves.

Although the similar studies have not been made on pop sorghum but similar results were obtained by earlier workers on different storage pests viz., Kittur (1990), Sharvale and Borikar (1998) and Rajapakshe *et al.* (1998).

### 5.3.4 Lakke leaf powder

Lakke leaf powder at 5 per cent dosage was found less effective. Pop sorghum seeds (Var : Talakal-6) when treated with this recorded 70 per cent adult mortality of *S. oryzae* at six months after storage in plastic jars and 46 per cent in jute bag. Per cent grain damage of 56.00 and per cent weight loss of 6.4 was recorded in plastic jars.

Similar opinion expressed by Mishra *et al.* (1992) who reported that lakke leaf powder at 5 per cent caused 73.00 per cent mortality of *S. oryzae* on wheat seeds at 30 days after treatment. Yevoor (2003) also made same observations.

### 5.3.5 Honge leaf powder

Honge leaf powder at 5 per cent dosage recorded 76.6 per cent adult mortality at 180 days after storage. It recorded 75.00 per cent grain damage and 9.6 per cent weight loss. No published supporting evidence could be traced in the literature except for solitary study of Sivanna *et al.* (1994) who reported that Honge is a good disinfestations agent for 12 weeks. It exerted slow action as evidenced from 13 to 20 per cent mortality at 24 hours after release (HAR) and 46 to 90 per cent at 72 against HAR.

### 5.3.6 Periwinkle leaf powder

Periwinkle leaf powder at 5 per cent was found less effective by recording only 50.00 per cent adult mortality at 180 days after storage. It caused 79.6 and 9.2 per cent grain damage and weight loss respectively. These findings are in accordance with Sunil Kumar (2003) who reported 43.00 per cent grain damage and 14.50 per cent weight loss against rice weevil.

# LEGEND

| Treatments |
|---|
| $T_1$ – Honge leaf powder |
| $T_2$ – Adasal leaf powder |
| $T_3$ – Periwinkle leaf powder |
| $T_4$ – Neem leaf powder |
| $T_5$ – Lakke leaf powder |
| $T_6$ – Sweet flag |
| $T_7$ – Neem seed powder |
| $T_8$ – Tulsi leaf powder |
| $T_9$ – Custard seed powder |
| $T_{10}$ – Turmeric |
| $T_{11}$ – Kaolinite |
| $T_{12}$ – Bentonite |
| $T_{13}$ – Ash (cow dung) |
| $T_{14}$ – Sand |
| $T_{15}$ – Saw dust |
| $T_{16}$ – Malathion |
| $T_{17}$ – Untreated control |

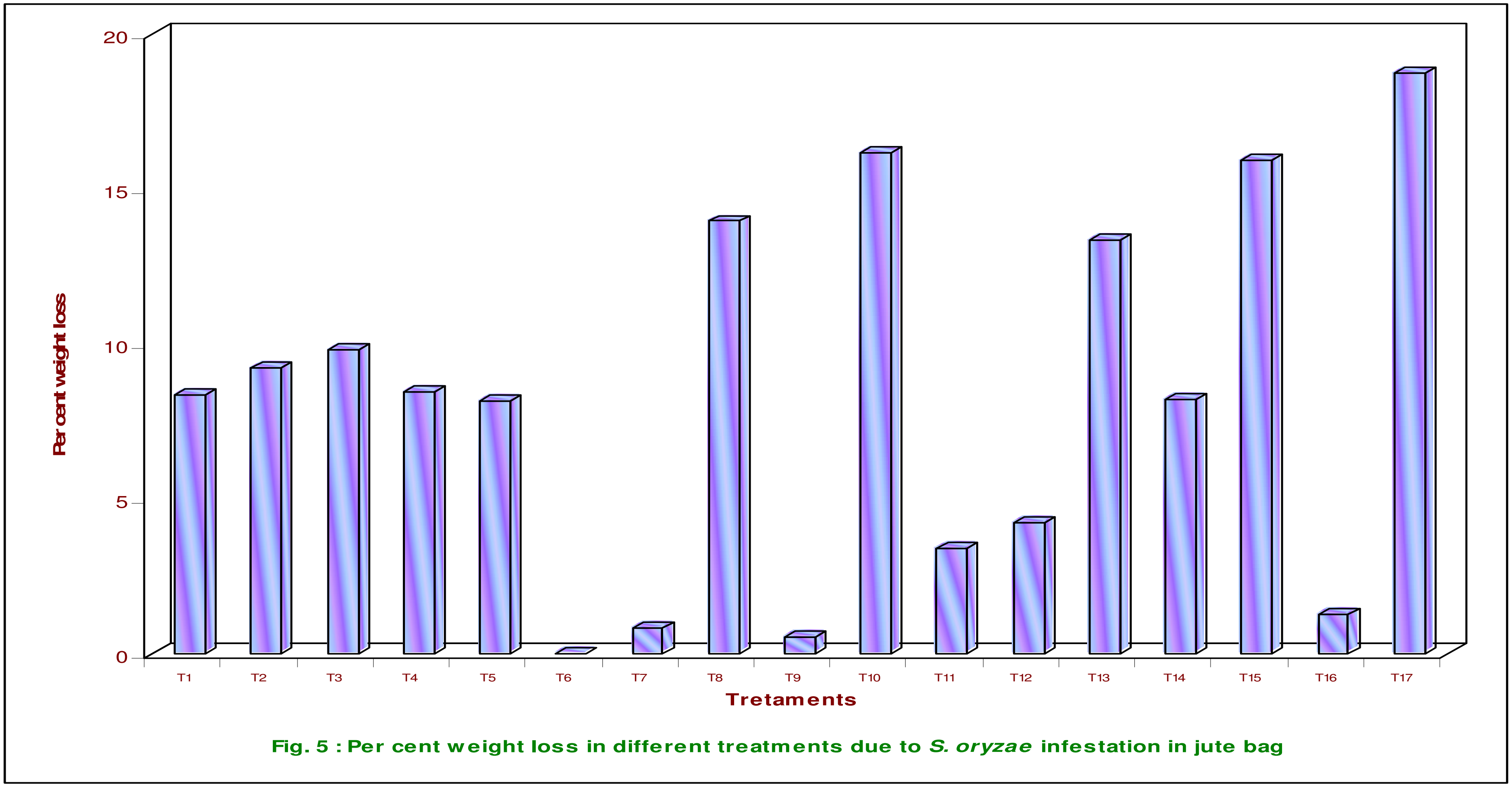


**Fig. 5: Per cent weight loss in different treatments due to S. oryzae infestation in jute bag**

### 5.3.7 Tulsi leaf powder and turmeric powder

Unlike the various plant products discussed so far, tulsi and turmeric powder did not cause any adverse effect on the insects. The beetles behaved and reproduced normally in the treated grains. As a consequential effect of poor performance the grains were subjected to damage therefore per cent grain weight loss was as high as in untreated check. Strikingly different reports are from Banarjee and Nigam (1985) who observed insecticidal effect in tulsi, when tested in extract form. Thus it is implied that active ingredient in the plant product is more effective in liquid form. According to Sunilkumar (2003) turmeric powder is not a good protectant as it caused 57 per cent grain damage and 17 per cent weight loss in sorghum against *S. oryzae*.

### 5.3.8 Kaolinite

Among the inert dusts kaolinite clay was found effective than other tested materials. Pop sorghum grains admixtured with 10.00 per cent caused cent per cent mortality at three months after storage (Table 10). Zero per cent weight loss and grain damage was noticed and also no adult emergence was recorded. Present findings are in perfect agreement with observations of Verma *et al.* (1976) who reported cent per cent mortality within 72 hours after treatment. According to Swamiappan (1978) cause for the mortality is removal of fat molecules from cuticular waxy layer by absorption by clay particles resulting in water loss and subsequent death due to desiccation.

### 5.3.9 Bentonite

Bentonite at 5 per cent dosage was also found effective which caused cent per cent mortality at 90 days after storage (Table 10). It recorded mean grain damage (Table 11) and weight loss (Table 15) of 8.76, 0.22 per cent, respectively and average of 6.25 adults emerged (Table 12) in this treatment. The information on this aspect is lacking totally in the literature. Possibly the cause for this is removal of fat molecules and subsequent death due to desiccation.

### 5.3.10 Cow dung ash

During the present study, ash 30 per cent admixture was found to be ineffective in protecting the grains against *S. oryzae*. It recorded only 16.63 average mortality (Table 10). Due to failure in causing sufficient adult mortality resulted in 74.63 and 8.13 per cent seed damage and weight loss, respectively. These results are in close conformity with Golob *et al.* (1982) who found that ash does not have specific insecticidal effect but may function by reducing the rate of development of the pest and requires high dosage to be effective. Yevoor (2003) results supported the current findings.

### 5.3.11 Sawdust

It was not found effective as it caused average of 13.66 per cent mortality. Present findings are in close relation with Yevoor (2003) who reported zero per cent mortality of *S. oryzae*. It might be due to lack of either abrasiveness or sorptivity of the product.

### 5.3.12 Sand

Sand was tried at 10 per cent dosage as one of the treatments. Adult mortality of 36.23 per cent was noticed in the treatment as compared to no mortality in untreated check. The mortality could be possibly due to mechanical injury caused to beetles during movement. However, the results indicated that sand is not a good protectant. The present findings are not in conformity with Choudhary and Pathak (1989) who reported that sand layer of 2 or 3 cm can be used for the management of bruchids. The variation might be due to stored product and host insect. On the strength of the foregoing discussion it can be concluded that sweet flag powder, custard apple seed powder, neem seed kernel powder, kaolinite, bentonite have strong potentiality in the management of rice weevil in stored pop sorghum.

### 5.3.13 Organoleptic evaluation of popped sorghum treated with grain protectants

With respect to per cent grain damage, per cent popping, overall acceptance, the treatment sweet flag powder was found superior followed by kaolinite and neem seed kernel powder (Table 21). Malathion scored very low score as it was least preferred by experts for its chemical smell. These results neither can be discussed not compared as such studies are wanting.

# VI. SUMMARY

Investigations on rice weevil *Sitophilus oryzae* (Linn) with respect to biology, reaction of genotypes, efficacy of grain protectants carried out under laboratory condition at Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad, during 2005-06 are summarized in this chapter.

Biology of the rice weevil *S. oryzae* on pop sorghum grain variety Talakal-6 under laboratory condition was carried out at a temperature range of 11.7°C to 39.5°C and 51 to 86 per cent relative humidity. Total larval period lasted for 21-30 days with an average of 25.8 ± 3.70 days. The full grown larvae pupated inside the grain and pupal period lasted for 7-8 days with an mean of 7.4 ± 0.54 days. Total life cycle from egg to adult of *S. oryzae* completed in 35-46 days with mean of 40.2 ± 4.69 days. Weevil freely copulated under laboratory condition, commenced mating 4 to 6 days after emergence and mating of weevils lasted for 30-67 minutes with an average of 51.2 minutes.

Adult female longevity with and without food ranged from 81-104 days and 9-12 days. Similarly longevity of the adult male was 57-61 days and 5-7 days with food and without food respectively.

Studies on relative resistance to *Sitophilus oryzae* Linn. attacking pop sorghum genotypes was carried out in laboratory condition. Genotypes viz., Talakal-6, Mugad local, Shiggaon local, CSH-16, CSH-14, DSV-3 were screened.

The damage of pop sorghum grains due to *S. oryzae* infestation was recorded upto 180 days at monthly interval. At 180 days after storage maximum (99.36) per cent grain damage was observed in Shiggaon local followed by Talakal-6 (86.70). Damage of grains was minimum in DSV-3 (55.60) followed by CSH-16 (70.90).

After a storage period of 180 days per cent weight loss due to infestation of *S. oryzae* ranged from 5.80 to 19.30. In Shiggaon local per cent weight loss was maximum (19.30) followed by Talakal-6 (16.50), while minimum weight loss was recorded in DSV-3 (5.80) followed by CSH-16 (10.10).

At 180 days after storage maximum (142.78) adults were emerged in Shiggaon local followed by Talakal-6 (125.83) when ten pairs of adults were released at the beginning. The least number of adults were emerged in DSV-3 (39.82) followed by Mugad local (109.51).

The damage due to *S. oryzae* infestation affected the germination of pop sorghum genotypes. At 180 days after storage maximum germination was recorded in DSV-3 (69.00) followed by CSH-16 (59.80). Per cent germination was minimum in Shiggaon local (30.30) followed by Talakal-6 (44.30).

Per cent popping was recorded at 180 days after storage wherein Mugad local recorded maximum (85.40) per cent popping followed by CSH-14 (69.40). Talakal-6 recorded minimum (43.00) per cent popping followed by CSH-16 (53.10). At the same interval the volume expansion ratio of genotypes was observed, Mugad local and CSH-16 recorded maximum 12.51, 12.10 expansion respectively. While Talakal-6 (10.87) Shiggaon local (10.17) recorded minimum volume expansion ratio.

Different plant products and inert materials were evaluated to test their bioefficacy against *S. oryzae* under laboratory conditions in plastic jar and jute bag.

The relative efficacy of grain protectants was assessed by mixing the seeds with different plant products and inert materials. Bioefficacy was measured based on adult mortality, population buildup, per cent seed damage, per cent weight loss, per cent germination and per cent popping.

At 180 days after storage in plastic jars, sweet flag powder caused cent per cent mortality followed by neem seed kernel powder, custard seed powder, kaolinite and malathion which were recorded 90 per cent adult mortality followed by bentonite (86.6). In ash least (16.6) adult mortality was seen.

Per cent grain damage was not observed in sweet flag powder, neem seed kernel powder, custard seed powder, kaolinite at 180 days after storage in plastic jars. Maximum grain damage seen in sawdust (92.30) followed by ash (88.30). Per cent weight loss was nil in sweet flag powder and custard seed powder. In kaolinite and bentonite treatment 0.6 and 0.9

per cent weight loss was observed respectively. Maximum weight loss was noticed in sawdust (10.8) followed by ash (10.4).

No adults were emerged in treatments viz., sweet flag powder, neem seed kernel powder, custard seed powder and kaolinite while, maximum adults were emerged in sawdust (125.66) followed by ash (112.6).

Seed maintained maximum viability (85.00%) when treated with sweet flag powder followed by neem seed kernel powder (81.6%), custard apple seed powder (81.6%) and malathion (81.6%) at 180 days after treatment in plastic jars. Least per cent germination was seen in sand (32.6%) and ash (34.00%).

At 180 days after storage in plastic jars, among all the treatments sweet flag powder recorded maximum per cent popping of 81.50 followed by custard seed powder (79.60) which was on par with malathion (79.90). Least per cent popping was recorded in sand (45.60) followed by lakke leaf powder (44.40) and (47.70). Regarding volume expansion ratio, all the treatments were statistically found similar.

Six months after storage in jutebag emergence of adults was maximum in seeds treated with saw dust (78.33) followed by Turmeric powder (75.00) and ash (68.33). No adults were emerged in grains treated with sweet flag powder followed by malathion (9.00).

Cent per cent adult mortality was recorded in sweet flag powder followed by neem seed kernel powder (86.60) and custard seed powder (83.30) which was on par with malathion (81.6), while zero per cent of adult mortality was recorded in untreated control and sawdust followed by ash (16.60) at six months after storage in jutebag.

Among all the treatments sweet flag powder proved superior by recording zero per cent grain damage followed by custard apple seed powder (6.5) and neem seed kernel powder (8.1) at 180 days after storage in jute bag. The maximum per cent grain damage (73.00) was recorded in untreated control followed by ash and turmeric which recorded 67.00 and 65.50 per cent of grain damage respectively.

At 180 days after storage in jutebag maximum per cent of weight loss was recorded in untreated control (24.40) followed by turmeric (22.00) and tulsi (20.00). Zero per cent weight loss was recorded in sweet flag powder followed by custard seed powder (2.1) which did not differ significantly from neem seed kernel powder (2.2) followed by Malathion (3.2).

Per cent popping was highest in treatment sweet flag powder (82.30) followed by malathion and custard apple seed powder which recorded 80.80, 80.40 per cent popping respectively. Untreated control recorded least per cent popping of 42.40 followed by sand (45.50) and ash (45.80) at 180 days after storage in jutebag. Volume expansion ratio did not differ significantly between the treatments.

With respect to per cent grain damage, per cent popping, overall acceptance, the treatment sweet flag powder was found superior followed by kaolinite and neem seed kernel powder. Malathion scored very low score as it was least preferred by experts for its chemical smell.

# FUTURE LINE OF WORK

1. Studies on screening of locally available different pop sorghum varieties
2. Comparative study on the biology of *S. oryzae* in pop and grain sorghum
3. Studies on the management of *Rhizopertha dominica* on pop sorghum

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# APPENDIX - I

**Monthly temperature and relative humidity recorded under laboratory condition during 2005- 06**

| Sl. No. | Month and year | Average temperature ($^0C$) | | Average RH (%) | |
|---|---|---|---|---|---|
| | | Max | Min | Max | Min |
| 1 | October 2005 | 29.9 | 11.7 | 86 | 61 |
| 2 | November | 29.3 | 12.7 | 84 | 63 |
| 3 | December | 29.5 | 11.9 | 85 | 687 |
| 4 | January 2006 | 30.0 | 14.5 | 84 | 77 |
| 5 | February | 31.9 | 15.6 | 83 | 64 |
| 6 | March | 36.3 | 20.2 | 77 | 56 |
| 7 | April | 39.5 | 21.3 | 70 | 58 |

# APPENDIX – II

**Score card for the evaluation of popped sorghum**

Name of the expert : Date :

Sex M ☐ F ☐ Age_____ Place _____________

Please write the score against the codes that you think is the most appropriate

| Characters | Sample code | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1. Appearance | | | | | | |
| 2. Colour | | | | | | |
| 3. Texture | | | | | | |
| 4. Taste | | | | | | |
| 5. Aroma | | | | | | |
| 6. Overall acceptability | | | | | | |

Scores : 5. Excellent
4. Very good
3. Good
2. Fair
1. Poor

Signature

Any remarks :

# BIOLOGY AND MANAGEMENT OF RICE WEEVIL, *SITOPHILUS ORYZAE* L. IN POP SORGHUM

**KAVITA JADHAV** **2006** **Dr. SHEKHARAPPA**
**Major Advisor**

**ABSTRACT**

Investigations on rice weevil, *Sitophilus oryzae* (L.) with respect to biology, reaction of genotypes, efficacy of grain protectants and organoleptic evaluations were carried out under laboratory condition at Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad during 2005-06.

The biology of the rice weevil, *S. oryzae* on pop sorghum grain variety Talakal-6 revealed the larval and pupal period of 25.8 ± 3.70 and 7.4 ± 0.54 days, respectively. Total life cycle from egg to adult completed in 40.2 ± 4.69 days. Among the different grain sorghum and pop sorghum varieties screened against *S. oryzae*, maximum per cent of grain damage, per cent weight loss, population buildup and minimum per cent of germination was observed in Shiggaon local, while Mugad local was proved relatively resistant. DSV-3 was found relatively resistant among grain sorghum varieties.

The relative efficacy of different grain protectants were assessed by mixing the seeds with different plant products and inert materials in plastic jars and jutebag. The treatments sweetflag powder, neem seed kernel powder, custard seed powder and kaolinite were found more effective by protecting the grains from *S. oryzae* damage. Maximum per cent of popping was observed in sweetflag powder treatment. Whereas, treatments *viz.,* sawdust, ash and sand were not found effective. Organoleptic evaluation of popped sorghum indicated maximum acceptance of grains treated with sweetflag powder followed by kaolinite and neem seed kernel powder.