Biology and Management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored Sorghum

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Biology and Management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored Sorghum

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ABSTRACT

Investigations were carried out during *kharif* 2007-08 and 2008-09 regarding "Biology and Management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum" at Main Sorghum Research Station, Navsari Agricultural University, Surat.

In the study of biology, the eggs were oval in shape with one end pointed and other being round. Freshly laid eggs were translucent and white and became opaque before hatching. The length and breadth of eggs varied from 0.35 to 0.39 mm (Av. 0.37 ± 0.01 mm) and 0.15 to 0.19 mm (Av. 0.17 ± 0.01 mm), respectively. The incubation period varied from 3.78 to 6.12 day (Av. 4.87 ± 0.31 day) at 25.20 to 31.55°C temperature and 77.10 to 87.50 per cent relative humidity. The egg hatching varied from 66.00 to 82.00 per cent (Av. 74.95 ± 5.50%). Grub was apodous, short, stout, yellowish white with brown colour head. First instars measured from 0.26 to 0.33 mm (Av. 0.30 ± 0.02 mm) in length and 0.09 to 0.11 mm (Av. 0.10 ± 0.01 mm) in width. Duration of first instar larvae was 5.50 to 7.00 day (Av. 6.17 ± 0.53 day) at 24.80 to 31.40°C temperature and 75.50 to 85.10 per cent relative humidity. The second instars measured from 0.42 to 0.48 mm (Av. 0.44 ± 0.02 mm) in length and 0.14 to 0.16 mm (Av. 0.15 ± 0.01 mm) in width. The duration of second instar larvae ranged from 6.00 to 7.50 day (Av. 6.60 ± 0.56 day) at 24.50 to 32.60°C temperature and 80.70 to 91.10 per cent relative humidity. The third instars measuring 4.50 to 9.85 mm (Av. 6.17 ±

1.27 mm) in length and 1.50 to 3.28 mm (Av. 2.06 ± 0.43 mm) in width. The duration of third instar larvae ranged from 7.50 to 9.50 day (Av. 8.42 ± 0.57 day) at 25.30 to 31.40°C temperature and 91.00 to 92.50 per cent relative humidity. Fourth instars measured 1.25 to 1.45 mm (Av. 1.39 ± 0.05 mm) in length and 0.42 to 0.48 mm (Av. 0.46 ± 0.02 mm) in width. The duration of fourth instar larvae varied from 4.50 to 6.50 day (Av. 5.20 ± 0.57 day) at 23.00 to 31.80°C temperature and 81.40 to 89.00 per cent relative humidity. The larval period ranged from 24.50 to 28.50 day (Av. 26.39± 1.24 day).

Pupae measured 3.25 to 3.50 mm (Av. 3.34 ± 0.09 mm) in length and 1.63 to 1.75 mm (Av. 1.67 ± 0.04 mm) in width. Pupation took place in larval tunnel inside the pupal case. Pupal period varied from 6 to 7 day (Av. 6.82 ± 0.24 day) at 25.20 to 36.40°C temperature and 68.50 to 88.10 per cent relative humidity.

Newly emerged adults were reddish brown which became black at the time of egg laying. Adults were elongate, sub-cylindrical with four orange colored patches on elytra. Male and female adults look alike externally 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. Male was measured 3.15 to 3.45 mm in length (Av. 3.32 ± 0.10 mm) and 1.26 to 1.38 mm in width (Av. 1.33 ± 0.04 mm). While, female measured 3.50 to 3.75 mm in length (Av. 3.62 ± 0.10 mm) and 1.40 to 1.50 mm in width (Av. 1.45 ± 0.04 mm). The adult longevity with food, adult females survived for 81 to 101 day (Av. 86.98 ± 5.17 day), while males survived for 55 to 60 day (Av. 57.75 ± 1.84 day) at 25.60 to 38.40°C temperature and 65.20 to 88.50 per cent relative humidity. Whereas, without food adult females survived for only 8 to 11 day (Av. 9.50 ± 0.87 day) but males survived for 5 to 7 day (Av. 5.40 ± 0.56 day) at 19.60 to 31.00°C temperature and 67.50 to 79.50 per cent relative humidity.

The pre-oviposition, oviposition and post-oviposition periods varied from 3 to 7 (Av. 4.95 ± 0.89), 33 to 61 (Av. 52.21 ± 8.16) and 18 to 37 (Av. 29.81 ± 4.52) day, respectively at 23.80 to 34.90°C temperature and 63.80 to 92.00 per cent relative humidity. The fecundity of rice weevil ranged from 122 to 265 (Av. 163.87 ± 27.37) eggs per female. The sex ratio of male: female of *S. oryzae* was 1: 1.15. The total life cycle of males of *S. oryzae* observed to be ranged from 91.45 to 99.96 (Av. 98.81 ± 2.33) day with food, while in case of without food it was ranged from 40.94 to 45.89 (Av. 43.47 ± 1.29) day. The total life cycle of female with food ranged from 117.89 to 140.96 (Av. 125.06 ±5.24) day, while in case of without food it ranged from 44.50 to 50.46 (Av. 47.57 ± 1.58) day.

Among twelve sorghum genotypes tested, the rice weevil preferred DJ 6514, SR 666, SR 1905 and SR 2460 genotypes for development as compared to other genotypes. On the basis of growth index and susceptible index, the genotypes SR 770, IS 6566, ICSV 700 and 168 II 108 were found less suitable. Among different varieties the sex ratio (male: female) ranged from 1:0.95 to 1:1.31. No remarkable influence on adult longevity was found when *S. oryzae* reared on different genotypes.

Twelve sorghum genotypes were also screened against the pest and 168 II 108 was found least susceptible to *S. oryzae* on the basis of grain damage, weight loss and population build up. The genotype DJ 6514 was most susceptible genotype on the basis of damage, weight loss and population build up. The SR 770 maintained maximum germination per cent. Correlation study on susceptibility to the pest and biochemical parameters of different genotypes revealed that negatively significant indicating negative relationship between population buildup and tannin content of the different genotypes of sorghum.

The results of study on per cent grain damage and weight loss of grains treated with various plant products revealed that mixing of powder

viz., sweet flag powder, custard apple seed powder and neem seed kernel powder 5 per cent were proved effective. The least grain damage and weight loss were found in grains treated with kaolinite clay 10 per cent and bentonite clay 10 per cent against *S. oryzae* on sorghum. Evaluation of edible and non edible oils against *S. oryzae* on the basis of per cent grain damage and weight loss revealed that the grains treated with groundnut oil 5ml/ kg seed, mustard oil 5 ml/ kg seed and groundnut oil 2.5 ml/ kg of seed were proved effective. The use of seed protectants like fenvalerate 0.005 per cent and deltamethrin 0.005 per cent were proved effective to reduce the grain damage and weight loss against *S. oryzae*.

Eight different grain commodities were tested for their suitability as hosts of *S. oryzae* of which four were found suitable for the development of the pest. The order of suitability was paddy > sorghum > maize > wheat > coriander > cumin > chilli > fenugreek.

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C E R T I F I C A T E

This is to certify that the thesis entitled "**Biology and Management of Sorghum rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum**" submitted by **Shri G. R. Bhanderi** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in the subject of **Agricultural Entomology** of the **Navsari Agricultural University, Navsari** is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.



Place: Navsari
Date: 24/12/2012

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D E C L A R A T I O N

This is to declare that the whole of the research work reported in this thesis "**Biology and Management of Sorghum rice weevil, Sitophilus oryzae (Linnaeus) on stored sorghum**" for the partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Agricultural Entomology by the undersigned is the result of investigations carried out by me under direct guidance and supervision of Dr. G. G. Radadia, Professor & Head, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari and that no part of the work has been submitted for any other degree so far.

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I. INTRODUCTION

Sorghum bicolor (L.) Moench is an important food crop valued both for grains as well as fodder. It is a self pollinating, diploid (2n=2x=20) crop with an about 25 per cent genome size of maize or sugarcane. It is also considered to be a fifth most important cereal crop of the world and is the dietary staple food for more than 500 million people of more than 30 countries. It is grown in Africa, Asia, Oceania and the U.S.A. Among them Nigeria, India, USA, Mexico, Sudan, China and Argentina are the major producers. While other sorghum producing countries are Mauritania, Gambia, Mali, Burkina Faso, Ghana, Niger, Somalia and Yemen, Chad, Sudan, Tanzania and Mozambique.

Grain is mostly used as food purpose (55%). This grain is commonly eaten with the hull, which retains the majority of the nutrients. The plant is very high in fiber and iron, with a fairly high protein level as well. Grain also consumed in the form of flat breads and porridges (thick or thin). It is also an important feed grain (33%), especially in the U.S.A. whereas stover is an important source of dry season maintenance rations for livestock, especially in Asia.

Besides food and fodder purpose, sorghum is also useful for some other purpose like fibers are used in wallboard, fences, biodegradable packaging materials, and solvents. Dried stalks are used for cooking fuel, and dye can be extracted from the plant to color leather.

A more recent use of sorghum is for ethanol. By-products from ethanol production, such as sorghum-DDGS (Distillers Dried Grains with Solubles) are also finding a place in the market.

India is the largest sorghum producer country of Asia and sorghum ranked third most important food grain cereal crop after rice and

wheat. Sorghum is raised for grain and fodder purposes in Central and Southern India, while as a fodder crop in Northern India. Sorghum is grown over an area of 7.79 million hectares in India with a total production of 6.70 million tones with an average production of 860 kg/ ha in the year 2009-10. The important sorghum growing states are Maharashtra, Karnataka, Tamil Nadu, Uttar Pradesh, Gujarat, Rajasthan and Haryana.

In Gujarat, sorghum is largely grown for fodder purpose than grain purpose with an area of 0.16 million hectares with a total production of 0.17 million hectares and average production of 1049 kg/ ha in the year 2009-10. While in South Gujarat it is mainly grown for grain purpose. It ranks third in area among food grain crops in Gujarat. It is mainly cultivated in two seasons *viz*., *kharif* (mid June to September) and *Rabi* (October to February) depending upon the climatic conditions of different agro-climatic zones of Gujarat. The important sorghum growing districts of Gujarat are Surat, Tapi, Bharuch, Dang, Narmada, Vadodara and Banaskantha.

The introduction of hybrids and high yielding improved varieties during 1950s greatly expanded grain production and a concomitant intensification of insect-pest problems in the world. However, grain yield is still low on farmers' field due to one or more limitations. Damage due to insect-pests is one of the major limitations for low grain yield of sorghum. In India, nearly 32.1 per cent of the actual produce is lost due to insect-pests (Borad and Mital, 1983). The losses due to panicle feeding insects alone have been estimated to be over $ 100 million annually. Avoidable losses due to insects have been estimated to be over 9 per cent in the USA, 20 per cent in Africa and 32 per cent in India (Leuschner and Sharma, 1983). They also recorded that 4 to 84 per cent of the sorghum crop is lost due to panicle feeding insect-pests in India. Annual grain loss at the minimum infestation level of 4.6 per cent is equivalent to $ 100 million. The annual losses due to

insect-pests differ in magnitude on a regional basis. Losses have been estimated to be $ 1089 million in the semi-arid and tropics and $ 10 million in Australia (Anon., 1992).

Like many crops insect and mite pests are major constraints to higher yields in sorghum. The intensification of agriculture incorporating high yielding varieties coupled with improved agronomic practices and availability of other hosts create a congenial environment for the pests and results in the occurrence as regular one, nearly 150 insect species have been listed as pests of sorghum in India which attack from sowing to crop harvest in field and storage (Seshu Reddy and Davies, 1979). But only few of these are pests of economic importance. These pests infest sorghum crop at the different growth stages and take heavy fall in yield if they are not managed below economic injury level through well designed pest management strategies. Beside these entire pests the harvested sorghum grains are also attacked by storage pest during the storage. Major pests of storage sorghum are rice moth, *Corcyra cephalonica* (Stainton); rice weevil, *Sitophilus oryzae* L.; maize weevil, *Sitophilus zeamais* Motschulsky; angoumois grain moth, *Sitotroga cerealella* (Olivier). Among them emphasis is made to study the rice weevil damaging to stored sorghum.

The most pre-requisite for developing resistant variety to a particular insect-pest is to identify resistant sources by screening the available germplasm. Other pre-requisite is to study the biology of the pest and some effective control strategies which would not pollute the environment.

A knowledge regarding resistance mechanisms and factors responsible for host plant resistance to insect is useful tool in deciding suitable selection criteria and methods of breeding for the genetic improvement of sorghum cultivars for insect-pest resistance. In the same way morphological and biochemical factors may possibly associate with insect-pest resistance should be studied.

Considering all these facts, the investigations were carried out on the following objects.

1. To study the biology of rice weevil, *S. oryzae* on sorghum.
2. To screen the different varieties of sorghum against *S. oryzae*.
3. To study eco-friendly approaches for the management of *S. oryzae* in stored sorghum.
4. To study the suitability of different host foods of *S. oryzae*.

II. REVIEW OF LITERATURE

The literature pertaining to "Biology and management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum" has been reviewed and presented below.

2.1 Biology of rice weevil, *S. oryzae*

The perusal of literature revealed the work done regarding biology of *S. oryzae* on sorghum. Here an attempt has been made to collect the information pertaining to biology of rice weevil on grain or seed sorghum, other cereals and pulses.

2.1.1 Egg

Calandra oryzae (L.) have six to nine days of egg stage on husked rice during summer was observed by Wille (1923), whereas Okuni (1924) found three to four days of incubation period under normal condition.

Newman (1927) reported three to five days of egg stage from Australia. While Wenholz (1927) reported that egg stage occupied on an average 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 was occupied on an average of 4.41 days (Anonymous, 1934). Treiman (1937) reared rice weevil in laboratory on unpolished rice at 27 to 28°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). Similarly, 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°C and 79 to 87 per cent relative humidity. Barbhuiya and Devashish-Kar (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°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 contained 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 up to 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, pigeonpea, 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 to 34 days on CSH-5 sorghum hybrid.

Urrelo and Wright (1989) observed four instars of *S. zeamais* on maize at 70 per cent relative humidity and temperature of 27°C. The larval period ranged from 16 to 20 days on maize grain at 23 to 35°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°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°C and 96 to 95 per cent, respectively.

Lopez-Cristobal (1953) reported that 6 to 16 day's 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 6 to 9 days (Av. 8.00 days) and pre-pupal period occupied 1 to 2 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°C and 55 to 88 per cent relative humidity.

2.1.4 Adult longevity and total life cycle

Wille (1923) stated that observed period required for completion of one generation were 45 days in summer, 5 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 months 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 in a 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 and female 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 different varieties of sorghum against rice weevil

2.2.1 Varietal influence on biological aspects of *S. oryzae*

The literature revealed that much work was carried out on this aspect. Here attempt has been made to collect the information on grain sorghum and other cereals.

Samuel and Chatterji (1953) reported that among 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) studied 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 17.96 to 31.34 per cent of the seeds were damaged in different varieties and the population varied from 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

infestations 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* and 31.34 infestations 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 large number of weevils.

The performances 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 genotypes. 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 CSH-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 studied the relative susceptibility of eight sorghum cultivars to rice weevil. They 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 fusion. Data revealed that kernels of CSH-8R received 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). Dethe *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) and highest on CSH-1 (360.33), CSH-1 recorded the highest grin loss(13.10 g) whereas DMS-652 recorded lowest grain weight loss (2.35 g). Balikai (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 whereas CSH-5 was found to be most susceptible.

Reddy *et al.* (2002) evaluated 35 grain sorghum genotypes representing 6 variable groups for the orientation, colonization and ovipositional response of the rice weevil, *S. oryzae*. Greater levels of oviposition were noticed in 2077 B, DJ-6514 and IS 11758 in free choice tests and M-148-138, 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 was observed on 2219 A/B, 116 B, IS 9487, IS 11758, CSV 8R (M) and local yellow.

2.2.2 Influence of biochemical properties of sorghum varieties on *S. oryzae*

Chemical composition of grains plays an important role in choice of food as well as behavioral process of insects. Some of the chemicals affect the behavioral processes that result in avoidance of grain as food and oviposition substrate.

Biochemical bases of resistance of sorghum grain to rice weevil are partially investigated. So far the literature pertaining to different biochemical constituents possibly associated with resistance is presented here.

2.2.2.1 Influence of tannin content of grain

Wongo (1998) reported that in short term (25 days) feeding test using *S. oryzae* adults, the presence of sorghum tannins from cv. BKS-5 in pallets significantly reduced the feeding by it.

2.2.2.2 Influence of protein content of grain

Protein content of the sorghum grain had negative correlation with insect infestation as confirmed by the Rehman *et al*. (2000). While, Dey and Sarup (1991) found that per cent weight loss was negatively correlated with percentage protein content of the grain. The same was also confirmed by Chunni-Ram and Singh (1996).

2.3 Eco friendly approaches for the management of rice weevil in sorghum

2.3.1 Efficacy of plant products

2.3.1.1 Sweet flag (*Acorus calamus* L.) rhizome powder

Jilani (1984) reported that *A. calamus* as good grain protectant against *S. oryzae*. 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 F_1 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 up to 240 days. Sweet flag powder 5 per cent was found to be most effective grain protectants even up to 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) reported that sweet flag was highly protective up to 180 days against *S. oryzae* 10 per cent dosage showing less than one per cent seed damage in sorghum. Yevoor (2003) found 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*.

2.3.1.2 Turmeric (*Curcuma longa* Rose) rhizome powder

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

2.3.1.3 Neem (*Azadirachta indica* A. Juss) leaf powder

Jilani and Su (1983) indicated the repellent activity of neem leaf powder to *S. granarius* and *R. dominica* on wheat seeds. They 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, *Callosobruchus analis* (F.) 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.

Sharvale and Borikar (1998) evaluated the neem leaf powder against *Callosobruchus chinensis* (L.) 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.

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

2.3.1.4 Custard apple (*Annona squamosa* L.) seed powder

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

Kalasagond (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 F_1 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 was 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). Sunilkumar (2003) concluded that custard seed powder at 1 per cent was effective in controlling *S. oryzae* on sorghum grains up to 90 days after storage.

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

2.3.1.5 Tulsi (*Oscimum basilicum* L.) leaf dust

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

Shivanna *et al* (1994) reported per cent weight loss due to first generation pulse beetle and it was maximum in untreated check (17.89%). 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 *Tribolium confusum* L.

2.3.1.6 Lakke (*Vitex negundo* L.) leaf powder

Mishra *et al.* (1992) showed that *V. 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) reported that there was 7 to 18 per cent seed damage in sorghum seeds treated with *V. 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.

2.3.2 Efficacy of inert materials against *S. oryzae*

2.3.2.1 Kaolinite clay

Besides the use of inert dusts such as calcium oxide, gypsum, kaolinite and attapulgite were used 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 worthwhile 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 the 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 montmorillonite 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*

St., *T. castaneum* and *S. oryzae* within 48 hours after treatment (Verma *et al*., 1976).

Yevoor (2003) opined that kaolinite 10 per cent caused up to 90 per cent mortality of adult at 28 days after release and also caused minimum grain damage and weight loss up to 90 DAS.

2.3.2.2 Cow dung (Ash)

Pawar (1980) reported that 1.25 cm layer of cow dung ash at the top was found to be 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 *Sitotroga cerealella* (Olivier) 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 was good in controlling *C. chinensis* activities in red gram seeds. The mortality of beetles at 24, 48 and 72 hours after treatment 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, 0.00, 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).

According to Kalasagond (1998), 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*. This was followed by 30 per cent ash admixture which was found to be moderately effective further preventing F_1 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.

2.3.2.3 Saw dust

Chahal and Judge (1988) studied saw dust as physical barrier against khapra beetle, *Trogoderma granarium* (E.) in wheat grains. An eight 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 were 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 up to 180 DAT.

2.3.2.4 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 red gram and bengal gram seeds from *C. chinensis* attack 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 hours after release 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.

2.4 Efficacy of edible and non edible oils against *S. oryzae*

Uttam *et al*. (2002) tested ten indigenous oils and found that mustard and sesamum oils provided best performance after 5 days of application. Whereas Shukla *et al*. (1992) reported that palm, mustard, soybean, sesamum and groundnut oil caused 90.48 per cent mortality of *S. oryzae.*

Dey and Sarup (1993) found that percentage reduction in the average weevil population was highest in case of soybean oil at 3.30 ml/ kg of grain followed by cotton seed and coconut oils.

2.5 Efficacy of seed protectants against *S. oryzae*

Srinivasachryulu and Yadav (1997) evaluated six chemicals under laboratory conditions and found that fluvalinate and malathion were less toxic insecticides while deltamethrin was most toxic to *S. zeamais*.

Yadav (1997) reported that application of deltamethrin on jute bag prior to storage of wheat gave excellent protection against the major storage insect pest.

A single application of deltamethrin prevented storage insect infestation for a period of up to 20 moths (Rani, 1997). While Dharm singh and Yadav (1998) tested five insecticides as seed protectants of wheat seed against *S. oryzae* and deltamethrin (3 ppm dust) was found the most effective and protected seeds for up to 9 months.

2.6 Suitability of different host foods of *S. oryzae*

Jacob (1992) tested five hosts for host plant resistance study under laboratory condition and found that the development period was shorter and the emergent adult’s weights were greater on wheat.

III. MATERIALS AND METHODS

Research studies on the "Biology and management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum" were carried out during the year 2007-08 and 2008-09 at the Main Sorghum Research Station, Navsari Agricultural University, Athwa farm, Surat, Gujarat state. The detailed procedure and methods adopted for various aspects are presented here.

3.1 Biology of rice weevil, *S. oryzae*

Studies on the biology of the rice weevil, *S. oryzae* was carried out on sorghum GJ 38 under laboratory condition during July to December, 2007 at the average room temperature of 29.41 ± 1.62°C and relative humidity of 59.43 ± 2.53 per cent.

3.1.1 Maintenance of stock culture

Adult weevils from the infested sorghum grains were collected from the storage house of Main Sorghum Research Station, Surat. The initial culture was reared in glass jar of two liter capacity containing the healthy sorghum grains (Plate I). The mouth of the container was covered with a muslin cloth. Fresh grains were provided periodically for the development of weevils. This stock culture was used for the entire period of investigation.

3.1.2 Pure culture

Pure culture of the beetles was developed by infesting insect free sorghum grains with freshly emerged single mating pair. The culture was maintained in the one litre glass jar on healthy sorghum grains. Mouth of the container was covered with muslin cloth (Plate II). The culture was used to study the biology of the weevil.



Plate I: Stock culture of rice weevil, *S. oryzae*



Plate II: Pure culture of rice weevil, *S. oryzae*

3.1.3 Methodology for egg collection

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

3.1.4 Egg

Eggs were examined under microscope for studying their colour, shape and size. For measuring length and breadth of eggs, the ocular micrometers were used with microscope.

For the study of incubation period and hatchability of the eggs, counted number of freshly laid eggs was observed daily till hatching. Average incubation period was then calculated. The eggs were considered as hatched when larva emerged out from it. Hatching percentage was calculated from the number of eggs hatched, out of total number of eggs kept under observation.

3.1.5 Larva

On hatching, the larvae of rice weevil were allowed to feed individually inside the grains in specimen tube (diameter 1.5 cm; length 7.5 cm) containing sorghum grains. Two days later, grains were dissected carefully to see the different stages of the larvae. The dissection of grains was made till larva reached the pupal stage. The period between egg hatching and pupation was recorded as larval period.

In order to determine the number of larval instars, the size of head capsule of individual larva was measured daily. The moulting was confirmed by the presence of casted head capsule of the larva of subsequent instars. The larvae in each instar were studied for their colour and size. Observations on number of instars, duration of instars and total larval period were recorded.

The body measurement of various instars was recorded under microscope with the help of stage and ocular micrometers.

3.1.6 Pupa

The pupal period was studied by observing the larvae for pupation inside the grains. This was maintained and the observations were made till the adult emergence. The period between formations of pupae till the adult emergence was noted as pupal period. Observations on pupal duration, colour and size also recorded.

3.1.7 Ovipositional studies

A pair of emerged weevils was collected in specimen tube (diameter 1.5 cm; length 7.5 cm) and such thirty specimen tubes were maintained. The weevils were allowed to mate. To determine the fecundity, eggs laid by each female were counted daily in the morning till the death of the female. The grains with eggs were discarded. A period between the time of emergence of the female and the time of starting the egg laying was considered as pre-ovipositional period. Period between starting of egg laying and stopping of egg laying was noted as ovipositional period, while period between stopping of egg laying and death of female was considered as post ovipositional period.

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. Thirty such vials were maintained for each of the male and female with and without food. During the entire study, the sex ratio of male: female was worked out based on adult emergence.

3.2 Screening of different varieties of sorghum against *S. oryzae*

Rice weevils were reared on grains of twelve different/ promising genotypes of sorghum replicated thrice to study the reaction of pest to different genotypes. For the purpose, freshly harvested grains of *kharif*

and *rabi* seasons were secured from Main Sorghum Research Station, Navsari Agricultural University, Surat. These genotypes were SR 666, IS 6566, ICSV 700, 168 II 108, SR 770, SR 2460, GJ 36, GJ 38, IS 2312, DJ 6514, SR 1905 and SR 2804. The healthy, sound, unaffected grains of each genotype were dried in hot air oven for six hours at 42° C in order to eliminate the infestation by store grain pests. The moisture content of grains was 10.7 ± 2 per cent. For the study 100 g grains of each variety were kept in plastic bottle having 500 ml capacity. Five 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.

3.2.1 Developmental period and growth index

To study the influence of sorghum varieties on larval and pupal development, the larvae were reared on the grains of twelve sorghum varieties and 100 grains of each variety were placed in specimen tube (diameter 3.5 cm x 7.5 cm) separately. Twenty five newly hatched larvae were released into each tube. The study was replicated thrice. The tube was covered with perforated lid and was kept in laboratory for the development of the larvae on the grains. After 10 days of release the grains were examined daily for the infestation up to pupal development and period from pupal development to adult emergence was considered as pupal period. The survival percentage and mean developmental period were worked out for each variety to calculate growth index. The growth index was calculated based on the formula described below:

$$\text{Growth index} = \frac{\text{Survival percentage}}{\text{Mean developmental period in days}}$$

3.2.2 Sex ratio

The number of adults emerged in each variety were counted daily and male and female adults were separated to determine sex ratio in different varieties.

3.2.3 Fecundity and longevity

The fecundity of female as well as longevity of male and female was also recorded for each variety separately.

3.2.4 Susceptibility index

The susceptibility index of each variety was calculated by applying formula suggested by Dobie (1977) as below.

$$\text{Susceptibility index} = \frac{\text{Natural log F}}{\text{D}} \times 100$$

Where,

F = Number of adults emerged

D = Mean developmental period

3.2.5 Germination test

Seed germination test 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.

3.2.6 Estimation of weight loss

For loss estimation, 100 g of seeds of each variety 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 at monthly interval for six months. Weight loss was worked out by using the formula (Adams and Schulton, 1978) as below.

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

Where,

U - Weight of uninfested grains (g)
NU - Number of uninfested grains (n)
D - Weight of infested grains (g)
ND - Number of infested grains (n)

3.2.7 Biochemical parameters

Biochemical parameters were studied at Chemistry laboratory of Main Cotton Research Station, Navsari Agricultural University, Surat. For the analysis, 100 g representative sample of grain flour of different sorghum genotypes was taken and it was repeated three times for resistance study against *S. oryzae* during the years 2012.

The fresh, dry and healthy grain samples were used for estimation of nitrogen, crude protein and tannin. The various biochemical parameters determined are as under.

3.2.7.1. Total nitrogen

Total nitrogen content of the grain flour of each genotype was determined by Micro-Kjeldahl's method using the procedure described by Association of Analytical Communities (Anon., 1960). The fresh, dry and healthy grain samples of different sorghum genotypes were analyzed separately during the year 2012.

3.2.7.2. Crude protein

The below given equation was used to work out per cent protein content of grain flour of different sorghum genotypes.

Per cent crude protein = per cent Kjeldahl's N x 6.25

3.2.7.3. Tannin

Tannin was determined by the method using the procedure given by C.B.M.S. (Anon., 1979). It was carried out from the fresh, dry and healthy grain samples of different sorghum genotypes.

3.3 Eco friendly approaches for the management of rice weevil in sorghum

Various botanicals (Plate III and Table 1), inert materials, edible and non edible oils and seed protectants were evaluated separately for their bio efficacy against rice weevil, *S. oryzae* in sorghum. The following aspects were included in the present study.



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



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

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

Sr. No.	Common Name	Scientific name	Part	Dosage (%)
1	Adasali	*Adhatoda vesica* L.	Leaves	5
2	Kharanja/honge	*Pongamia glabra* L.	Leaves	5
3	Sweet flag	*Acorus calamus* L.	Rhizome	5
4	Turmeric	*Curcuma longa* L.	Rhizome	5
5	Neem	*Azadirachta indica* A. Juss	Leaves	5
6	Custard apple	*Annona squamosa* L.	Seeds	5
7	Tulsi	*Oscimum basilicum* L.	Leaves	5
8	Neem	*Azadirachta indica* A. Juss	Kernels	5
9	Lakke	*Vitex negundo* L.	Leaves	5

3.3.1. Efficacy of plant products against *S. oryzae*

3.3.1.1 Rhizomes

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

3.3.1.2 Leaves

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

3.3.1.3 Seeds

Kernels of *Azadirachta indica* A. Juss and seeds of *Annona squamosa* L. were collected and made into powder using a grinder.

3.3.2. Efficacy of inert materials against *S. oryzae*

3.3.2.1. Preparation of inert materials

Dry cow dung pellets were collected and burnt to get the ash. Sawdust was collected from the carpenters. Kaolinite clay and bentonite clay were obtained from the Soil Science Laboratory, Main cotton Research Station, Surat (Plate IV). Each of the grain protectants at the desired dosage was thoroughly mixed with 100 g uninfected seeds of GJ-38 variety (popular grain variety in South Gujarat) in plastic bottles of 500 g capacity (Table 2). 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 seed damage and weight loss were recorded at 30 days interval up to 180 days. Per cent grain damage was recorded on the basis of number of healthy and damage grain. Per cent weight loss was calculated by using the formula (Adams and Schulton, 1978) as below:

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

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

Sr. No.	Name	Dosage in per cent (w/w)
1	Kaolinite clay	10
2	Cow dung ash	10
3	Sawdust	10
4	Sand	10
5	Bentonite	10

3.3.3 Efficacy of edible and non edible oils against *S. oryzae*

The seeds of sorghum variety GJ 38 were treated with five different edible and non edible oils *viz.* mustard oil, linseed oil, sunflower oil, groundnut oil and castor oil with two concentration of each 2.5 ml/ kg and 5.0 ml/ kg of seeds. These oils were thoroughly mixed with one kg of seed manually by hand for five minutes (Table.3).

Hundred grams of treated seeds were put into test tube (10 x 25 cm) in three sets for each treatment and observations on healthy and damage grains at frequent interval. Weight loss was estimated based on the loss in the weight of grains at 30 days interval up to 180 days.

3.3.4 Efficacy of seed protectants against *S. oryzae*

The seed of sorghum variety GJ-38 was treated with six insecticides and one plant product in combination with control. The different insecticides *viz.*, malathion 0.05 per cent, chlorpyriphos 0.06 per cent, cypermethrin 0.005 per cent, fenvalerate 0.005 per cent, alphamethrin 0.005 per cent, deltamethrin 0.005 per cent and azadiractin 0.125 per cent concentration were thoroughly mixed with one kg of seed manually by hand for five minutes (Table 4).

Hundred grams of treated seeds were put into test tube (10 x 25 cm^2) in three sets for each treatment and observations on percent damage and weight loss were recorded at 30 days interval up to 180 days.

3.4 Suitability of different host foods of *S. oryzae*

For this study, fifty grams healthy grains of each host *viz.*, maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), paddy (*Oryza sativa* L.), coriander (*Coriandum sativum* L.), cumin (*Cuminum cyminum* L.), chilli (*Capsicum annum* L.) and fenugreek (*Trigonella foenugraecum* L.) were taken separately in plastic jars (diameter 8 x 10 cm). Ten pairs of newly emerged male and female weevil were released in to each jar for oviposition. The jar was closed from the top by tying a piece of muslin cloth to prevent

Table 3: List of edible and non edible oil used against *S. oryzae*

Sr. No.	Name	Dosage (ml/kg)
1	Mustard oil	2.5
		5.0
2	Linseed oil	2.5
		5.0
3	Sunflower oil	2.5
		5.0
4	Ground nut oil	2.5
		5.0
5	Castor oil	2.5
		5.0

Table 4: List of seed protectants used against *S. oryzae*

Sr. No.	Name	Dosage (%)
1	Malathion	0.05
2	Chlorpyriphos	0.06
3	Cypermethrin	0.005
4	Fenvalerate	0.005
5	Alphamethrin	0.005
6	Deltamethrin	0.005
7	Active Azadiractin	0.125

the escape of weevil. Three days later, the weevil was removed and the jars were left as such till the development of adults from the eggs laid in the jars. The experiment was replicated thrice in complete randomized block design. From the day the weevil emergence started, weevils were counted daily and removed immediately from the jars to prevent fresh oviposition. The emergence was recorded till its end. The period required from the oviposition to adult emergence was considered as developmental period. The susceptibility index was worked out by adopting the formula suggested by Dobie (1977) as under:

$$\textbf{Susceptibility index} = \frac{\text{Natural log } F}{D} \times 100$$

Where,

F = Number of adults emerged

D = Mean developmental period

On the basis of the index host suitability was determined.

IV. RESULTS AND DISCUSSION

Research studies on "Biology and management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum" were carried out on the biology, varietal screening, management and host preference of rice weevil under laboratory conditions. The results obtained are presented and discussed here under.

4.1 Biology of rice weevil, *S. oryzae*

During the studies on various aspects of biology of *S. oryzae* under laboratory condition, the duration and measurements of different stages were recorded and described below. The study on biology of rice weevil, *S. oryzae* was carried out on sorghum GJ 38 at Main Sorghum Research Station, Navsari Agricultural University, Athwa farm, Surat during July to December 2007. The average room temperature was 23.5° C to 31.6° C, while the relative humidity was 56.8 to 74.2 per cent during the study period. Initial culture was successfully established on stock culture by collecting the adult weevils from the infested sorghum grains from Main Sorghum Research Station farm store house.

4.1.1 Egg

The females of *S. oryzae* laid the eggs inside the cavity on the sorghum grains. The eggs were oval in shape with one end pointed and other end being round. Freshly laid eggs were translucent and white and became opaque before hatching (Plate V).

The data on measurement of the eggs (Table 5) revealed that length and breadth of eggs varied from 0.35 to 0.39 mm and 0.15 to 0.19 mm with an average of 0.37 ± 0.01 mm and 0.17 ± 0.01 mm, respectively. The results on size of eggs are also in accordance with the findings of Sattigi (1982) and Bheemanna (1986).



Plate V: Eggs of rice weevil, *S. oryzae*

Table 5: Measurements of eggs of *S. oryzae*

Sr. No.	Length (mm)	Breadth (mm)	Sr. No.	Length (mm)	Breadth (mm)
1	0.35	0.15	18	0.35	0.15
2	0.39	0.19	19	0.35	0.15
3	0.35	0.15	20	0.36	0.17
4	0.38	0.16	21	0.37	0.17
5	0.36	0.17	22	0.37	0.18
6	0.39	0.18	23	0.36	0.15
7	0.35	0.15	24	0.38	0.19
8	0.36	0.16	25	0.38	0.15
9	0.38	0.15	26	0.38	0.15
10	0.39	0.17	27	0.39	0.19
11	0.36	0.18	28	0.36	0.16
12	0.37	0.19	29	0.35	0.15
13	0.37	0.18	30	0.37	0.17
14	0.35	0.15	**Min.**	**0.35**	**0.15**
15	0.36	0.16	**Max.**	**0.39**	**0.19**
16	0.37	0.17	**Av. ± SD**	**0.37 ± 0.01**	**0.17 ± 0.01**
17	0.38	0.17			

It is clear from the Table 6 that incubation period of eggs of *S. oryzae* was short and it varied from 3.78 to 6.12 day with an average of 4.87 ± 0.31 day at 25.20 to 31.55°C temperature and 77.10 to 87.50 per cent relative humidity. The incubation period as reported to be 5 to 9 day (Sattigi, 1982) is more or less in confirmation with present findings.

It can be seen from Table 6 that the hatching percentage of eggs of *S. oryzae* varied from 66.00 to 82.00 per cent with an average of 74.95 ± 5.50 per cent.

4.1.2 Larva

During the present study it was observed that the larva of *S. oryzae* moulted three times to attain maturity. Grub was apodous, short, stout, yellowish white and brown colored head (Plate VI). Grub development took place inside the grain. There were 13 segments with nine pairs of spiracles, one pair was on thoracic region and the rest were on abdominal segments. Body was covered with small setae. Similar observations have also been reported by Bheemanna (1986), Sattigi (1982) and Treiman (1937).

4.1.2.1 First instar

The body length of first instar larvae measured from 0.26 to 0.33 mm with an average of 0.30 ± 0.02 mm and breadth from 0.09 to 0.11 mm with an average of 0.10 ± 0.01 mm (Table 7). Duration of first instar larvae was 5.50 to 7.00 day with an average of 6.17 ± 0.53 day at 24.80 to 31.40°C temperature and 75.50 to 85.10 per cent relative humidity (Table 8).

4.1.2.2 Second instar

The second instar larva was larger than first instar larva. The length of second instar larvae ranged from 0.42 to 0.48 mm with an average of 0.44 ± 0.02 mm and breadth from 0.14 to 0.16 mm with an average of 0.15 ± 0.01 mm (Table 7). The duration of second instar larvae ranged from 6.00 to 7.50 day with an average of 6.60 ± 0.56 day at 24.50 to 32.60°C temperature and 80.70 to 91.10 per cent relative humidity (Table 8).

First Instar



Second Instar



Third Instar



Fourth Instar



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

Table 6: Incubation period and hatching percentage of eggs of *S. oryzae*

Date	No. of Egg observed	Incubation period (Days)			No. of Egg hatch	Hatching (%)
		Min.	Max.	Av. ± SD		
06/7/2007	50	3.75	4.25	4.00 ± 0.23	33	66.00
12/7/2007	50	3.50	4.50	4.11 ± 0.31	40	80.00
18/7/2007	50	3.25	4.75	3.99 ± 0.46	38	76.00
22/7/2007	50	4.25	6.25	5.54 ± 0.65	33	66.00
26/7/2007	50	4.50	5.75	5.02 ± 0.75	38	76.00
29/7/2007	50	3.75	5.25	4.59 ± 0.65	40	80.00
01/8/2007	50	3.75	5.50	4.49 ± 0.75	40	80.00
03/8/2007	50	3.50	4.75	3.99 ± 0.56	41	82.00
05/8/2007	50	3.25	4.75	3.78 ± 0.46	35	70.00
07/8/2007	45	3.50	4.25	3.97 ± 0.39	32	71.11
11/8/2007	50	4.50	6.25	5.54 ± 0.89	33	66.00
14/8/2007	48	5.25	6.75	6.05 ± 0.63	34	70.83
17/8/2007	50	5.50	6.75	6.12 ± 0.45	38	76.00
21/8/2007	50	4.75	6.25	5.49 ± 0.76	40	80.00
23/8/2007	50	4.25	6.50	5.45 ± 0.92	41	82.00
26/8/2007	50	5.25	6.75	5.99 ± 0.52	41	82.00
29/8/2007	43	3.75	6.25	4.45 ± 0.94	32	74.42
01/9/2007	50	3.75	5.50	4.51 ± 0.64	38	76.00
03/9/2007	50	4.25	5.75	4.97 ± 0.59	35	70.00
07/9/2007	50	4.50	5.25	5.04 ± 0.27	34	68.00
08/9/2007	50	4.00	5.50	4.89 ± 0.43	33	66.00
11/9/2007	50	3.75	5.75	4.12 ± 0.54	39	78.00
13/9/2007	50	4.25	5.50	4.99 ± 0.39	36	72.00
15/9/2007	50	4.25	5.25	4.46 ± 0.34	38	76.00
18/9/2007	50	4.50	5.75	5.01 ± 0.43	40	80.00
21/9/2007	50	5.25	6.75	6.07 ± 0.51	41	82.00
24/9/2007	50	3.75	6.25	4.98 ± 0.67	35	70.00
26/9/2007	50	3.75	5.50	4.44 ± 0.53	37	74.00
29/9/2007	50	4.50	5.75	5.08 ± 0.47	38	76.00
30/9/2007	50	4.25	5.75	5.01 ± 0.38	41	82.00
Min.	**-**	**-**	**-**	**3.78 ± 0.46**	**32**	**66.00**
Max.	**-**	**-**	**-**	**6.12 ± 0.45**	**41**	**82.00**
Av. ± SD	**-**	**-**	**-**	**4.87 ± 0.31**	**37.13± 3.10**	**74.95 ± 5.50**

Table 7: Measurements of larval instars of *S. oryzae*

Sr. No	I instar		II instar		III instar		IV instar	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
1	0.26	0.09	0.45	0.15	4.90	1.63	1.25	0.42
2	0.28	0.09	0.45	0.15	4.95	1.65	1.35	0.45
3	0.30	0.10	0.48	0.16	5.20	1.73	1.35	0.45
4	0.33	0.11	0.42	0.14	5.00	1.67	1.33	0.44
5	0.28	0.09	0.43	0.14	5.50	1.83	1.38	0.46
6	0.29	0.10	0.45	0.15	5.35	1.78	1.45	0.48
7	0.28	0.09	0.48	0.16	9.85	3.28	1.39	0.46
8	0.28	0.09	0.44	0.15	7.85	2.62	1.35	0.45
9	0.26	0.09	0.42	0.14	6.65	2.22	1.39	0.46
10	0.27	0.09	0.42	0.14	5.50	1.83	1.38	0.46
11	0.28	0.09	0.43	0.14	6.80	2.27	1.40	0.47
12	0.30	0.10	0.45	0.15	5.50	1.83	1.45	0.48
13	0.33	0.11	0.48	0.16	4.50	1.50	1.45	0.48
14	0.30	0.10	0.44	0.15	5.50	1.83	1.35	0.45
15	0.30	0.10	0.45	0.15	6.25	2.08	1.33	0.44
16	0.29	0.10	0.43	0.14	6.50	2.17	1.39	0.46

Table 7: Conti.....

Sr. No	I instar		II instar		III instar		IV instar	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
17	0.28	0.09	0.48	0.16	6.25	2.08	1.45	0.48
18	0.29	0.10	0.48	0.16	5.45	1.82	1.45	0.48
19	0.33	0.11	0.45	0.15	7.45	2.48	1.43	0.48
20	0.33	0.11	0.42	0.14	6.45	2.15	1.45	0.48
21	0.33	0.11	0.42	0.14	6.35	2.12	1.29	0.43
22	0.31	0.10	0.43	0.14	5.00	1.67	1.35	0.45
23	0.32	0.11	0.48	0.16	5.85	1.95	1.45	0.48
24	0.30	0.10	0.45	0.15	6.25	2.08	1.43	0.48
25	0.31	0.10	0.42	0.14	6.85	2.28	1.39	0.46
26	0.32	0.11	0.44	0.15	5.65	1.88	1.40	0.47
27	0.33	0.11	0.43	0.14	5.65	1.88	1.39	0.46
28	0.33	0.11	0.42	0.14	6.80	2.27	1.35	0.45
29	0.33	0.11	0.43	0.14	9.84	3.28	1.45	0.48
30	0.32	0.11	0.45	0.15	5.35	1.78	1.45	0.48
Min.	**0.26**	**0.09**	**0.42**	**0.14**	**4.50**	**1.50**	**1.25**	**0.42**
Max.	**0.33**	**0.11**	**0.48**	**0.16**	**9.85**	**3.28**	**1.45**	**0.48**
Av. ± SD	**0.30 ± 0.02**	**0.10 ± 0.01**	**0.44 ± 0.02**	**0.15 ± 0.01**	**6.17 ± 1.27**	**2.06 ± 0.43**	**1.39 ± 0.05**	**0.46 ± 0.02**

Table 8: Duration of different stages of *S. oryzae*

Sr. No	Duration of larval development (days)				Total larval period (days)	Pupal period (days)	Longevity of adult (days)				Total life cycle (days)		Total life cycle (days)	
							Male		Female		With Food		Without Food	
	I instar	II instar	III instar	IV instar			With Food	Without Food	With Food	Without Food	Male	Female	Male	Female
1	7.00	6.00	7.50	5.00	25.50	7.00	55.00	5.00	82.00	8.00	91.50	118.50	41.50	44.50
2	6.00	7.00	8.00	5.00	26.00	6.75	60.00	5.00	83.00	9.00	96.86	119.86	41.86	45.86
3	6.50	7.50	8.50	6.00	28.50	7.00	58.00	6.00	85.00	8.00	97.49	124.49	45.49	47.49
4	5.50	7.00	9.00	6.50	28.00	6.85	57.00	5.50	86.00	8.50	97.39	126.39	45.89	48.89
5	5.50	7.00	7.50	5.00	25.00	6.25	59.00	5.00	89.00	8.75	95.27	125.27	41.27	45.02
6	6.00	7.50	8.00	4.50	26.00	6.00	60.00	6.50	90.00	8.00	96.59	126.59	43.09	44.59
7	7.00	7.00	8.00	5.00	27.00	6.75	60.00	5.50	92.00	9.50	98.24	130.24	43.74	47.74
8	7.00	6.00	7.50	5.00	25.50	6.45	55.00	5.00	100.00	10.00	90.94	135.94	40.94	45.94
9	6.00	6.00	9.00	5.50	26.50	6.85	58.00	5.15	92.00	10.15	95.13	129.13	42.28	47.28
10	6.00	6.00	9.00	5.50	26.50	6.95	59.00	5.20	95.00	11.00	96.42	132.42	42.62	48.42
11	6.00	6.60	9.00	5.00	26.60	7.00	57.00	5.00	93.00	10.50	96.14	132.14	44.14	49.64
12	5.50	6.00	8.50	5.00	25.00	6.95	60.00	5.00	85.00	10.00	98.00	123.00	43.00	48.00
13	5.50	6.00	8.50	5.00	25.00	7.00	59.00	5.50	84.00	10.20	97.12	122.12	43.62	48.32
14	5.50	6.00	8.00	5.00	24.50	6.90	60.00	5.65	81.00	9.00	96.89	117.89	42.54	45.89
15	6.00	6.00	8.00	4.50	24.50	6.50	55.00	6.50	83.00	9.00	91.45	119.45	42.95	45.45
16	6.00	6.00	8.00	4.50	24.50	6.65	58.00	6.65	84.00	9.50	95.14	121.14	43.79	46.64
17	6.00	6.00	8.00	6.00	26.00	7.00	59.00	7.00	85.00	8.75	96.45	122.45	44.45	46.20
18	6.00	7.00	9.00	5.00	27.00	6.75	58.00	5.00	85.00	9.90	96.26	123.26	43.26	48.16

Table 8: Conti.....

Sr. No	Duration of larval development (days)				Total larval period (days)	Total Pupal period (days)	Longevity of adult (days)				Total life cycle (days)		Total life cycle (days)	
							Male		Female		With Food		Without Food	
	I instar	II instar	III instar	IV instar			With Food	Without Food	With Food	Without Food	Male	Female	Male	Female
19	7.00	7.00	9.50	4.50	28.00	6.85	57.50	5.00	84.50	9.60	97.32	124.32	44.82	49.42
20	6.50	7.50	9.00	5.00	28.00	6.90	57.00	5.10	85.00	9.60	96.94	124.94	45.04	49.54
21	6.50	7.00	8.50	5.00	27.00	6.80	55.00	5.30	86.00	10.15	93.69	124.69	43.99	48.84
22	6.50	7.00	8.50	5.00	27.00	7.00	56.00	5.00	87.00	10.25	94.12	125.12	43.12	48.37
23	6.00	7.00	8.00	5.00	26.00	6.90	58.00	5.00	87.00	10.00	95.89	124.89	42.89	47.89
24	7.00	7.50	9.00	5.00	28.50	7.00	60.00	5.00	101.00	10.50	99.96	140.96	44.96	50.46
25	5.50	6.00	9.50	4.50	25.50	6.95	55.00	5.15	89.00	11.00	92.46	126.46	42.61	48.46
26	6.00	6.50	8.00	5.00	25.50	6.90	56.00	5.30	88.00	10.50	94.47	126.47	43.77	48.97
27	5.50	6.00	8.00	6.00	25.50	6.65	55.00	5.20	82.00	9.50	92.13	119.13	42.33	46.63
28	6.00	6.50	8.50	6.50	27.50	7.00	59.00	5.00	82.00	8.50	97.94	120.94	43.94	47.44
29	7.00	6.50	8.00	6.00	27.50	6.95	60.00	5.40	81.00	8.75	99.53	120.53	44.93	48.28
30	6.50	7.00	9.00	5.50	28.00	7.00	56.50	5.40	83.00	8.80	96.51	123.01	45.41	48.81
Min.	**5.50**	**6.00**	**7.50**	**4.50**	**24.50**	**6.00**	**55.00**	**5.00**	**81.00**	**8.00**	**91.45**	**117.89**	**40.94**	**44.50**
Max.	**7.00**	**7.50**	**9.50**	**6.50**	**28.50**	**7.00**	**60.00**	**7.00**	**101.00**	**11.00**	**99.96**	**140.96**	**45.89**	**50.46**
Av. ± SD	**6.17 ± 0.53**	**6.60 ± 0.56**	**8.42 ± 0.57**	**5.20 ± 0.57**	**26.39 ± 1.24**	**6.82 ± 0.24**	**57.73 ± 1.84**	**5.40 ± 0.56**	**86.98 ± 5.17**	**9.50 ± 0.87**	**98.81 ± 2.33**	**125.06 ± 5.24**	**43.47 ± 1.29**	**47.57 ± 1.58**

4.1.2.3 Third instar

The third instar larva was bigger in size than the earlier instars. The body length of third instar larvae ranged from 4.50 to 9.85 mm with an average of 6.17 ± 1.27 mm and breadth from 1.50 to 3.28 mm with an average of 2.06 ± 0.43 mm (Table 7). The duration of third instar larvae ranged from 7.50 to 9.50 day with an average of 8.42 ± 0.57 day at 25.30 to 31.40°C temperature and 91.00 to 92.50 per cent relative humidity (Table 8).

4.1.2.4 Fourth instar

The body length of fourth instar larvae ranged from 1.25 to 1.45 mm with an average of 1.39 ± 0.05 mm and breadth from 0.42 to 0.48 mm with an average of 0.46 ± 0.02 mm (Table 7). The duration of fourth instar larvae ranged from 4.50 to 6.50 day with an average of 5.20 ± 0.57 day at 23.00 to 31.80°C temperature and 81.40 to 89.00 per cent relative humidity (Table 8).

4.1.2.5 Total larval period

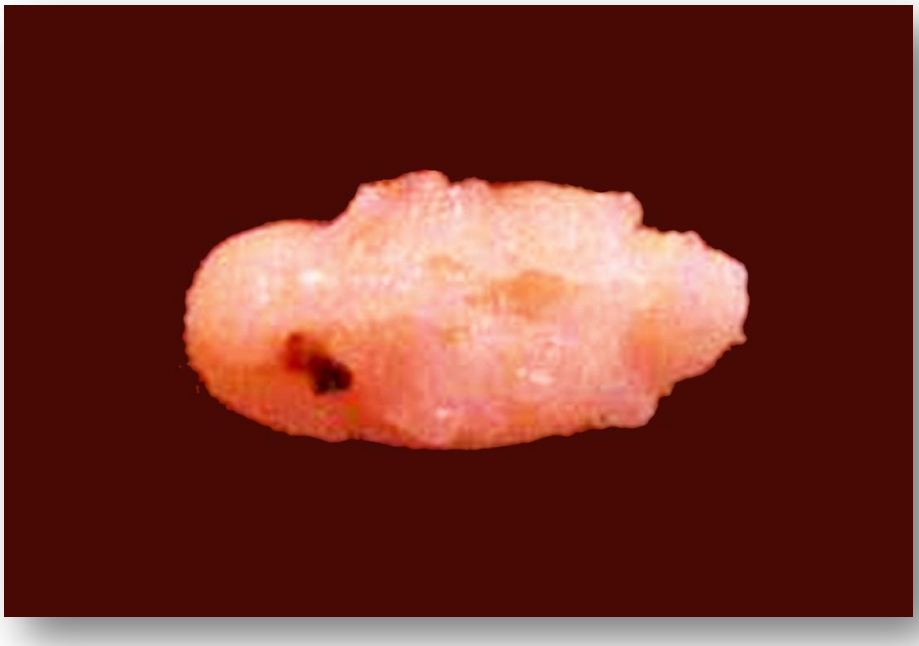
The total larval period varied from 24.50 to 28.50 day with an average of 26.39 ± 1.24 day (Table 8).

4.1.3 Pupa

Pupa was white to yellowish white; excrete with clearly visible head thorax and abdomen (Plate VII). Pupa measured 3.25 to 3.50 mm in length with an average of 3.34 ± 0.09 mm and the width measured 1.63 to 1.75 mm with average of 1.67 ± 0.04 mm (Table 9). Pupal period occupied 6 to 7 day with an average of 6.82 ± 0.24 day at 25.20 to 36.40°C temperature and 68.50 to 88.10 per cent relative humidity (Table 8). Pupation took place in larval tunnel inside pupal case.

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 day of pupal period at 23 to 30°C temperature and 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.

Ventral side of Pupae



Dorsal side of Pupae

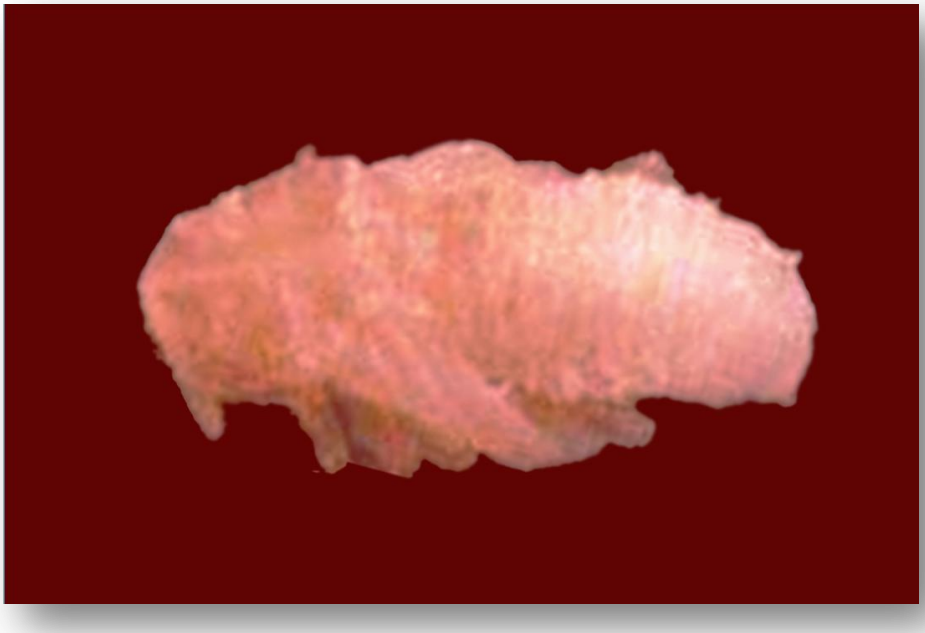


Plate VII: Pupae of rice weevil, *S. oryzae*

Table 9: Measurements of pupa of *S. oryzae*

Sr. No.	Length (mm)	Breadth (mm)	Sr. No.	Length (mm)	Breadth (mm)
1	3.45	1.73	18	3.40	1.70
2	3.50	1.75	19	3.45	1.73
3	3.25	1.63	20	3.30	1.65
4	3.45	1.73	21	3.30	1.65
5	3.35	1.68	22	3.25	1.63
6	3.25	1.63	23	3.45	1.73
7	3.30	1.65	24	3.48	1.74
8	3.30	1.65	25	3.45	1.73
9	3.25	1.63	26	3.25	1.63
10	3.25	1.63	27	3.25	1.63
11	3.29	1.65	28	3.35	1.68
12	3.35	1.68	29	3.25	1.63
13	3.45	1.73	30	3.25	1.63
14	3.40	1.70	**Min.**	**3.25**	**1.63**
15	3.30	1.65	**Max.**	**3.50**	**1.75**
16	3.25	1.63	**Av. ± SD**	**3.34 ± 0.09**	**1.67 ± 0.04**
17	3.35	1.68			

4.1.4 Adult

Newly emerged adults were reddish brown which become black at the time of egg laying. Adults were elongated, sub-cylindrical with four orange colored patches on elytra (Plate VIII). Male and female adults look alike externally 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. Male measured 3.15 to 3.45 mm in length with an average of 3.32 ± 0.10 mm and 1.26 to 1.38 mm width with an average of 1.33 ± 0.04 mm. While, female measured 3.50 to 3.75 mm in length with an average of 3.62 ± 0.10 mm and 1.40 to 1.50 mm width with an average of 1.45 ± 0.04 mm (Table 10).

4.1.5 Pre-oviposition, oviposition and post-oviposition periods

The data presented in Table 11 revealed that pre-oviposition, oviposition and post-oviposition periods varied from 3 to 7 (Av. 4.95 ± 0.89), 33 to 61 (Av. 52.21 ± 8.16) and 18 to 37 (Av.29.81 ± 4.52) day, respectively at 23.80 to 34.90°C temperature and 63.80 to 92.00 per cent relative humidity. Yevoor (2003) have made similar kind of observations.

4.1.6 Fecundity

The fecundity of each female was recorded by counting the eggs within the cavity of grains laid during different periods of oviposition by each female. The results obtained are presented in Table 11. The data revealed that the fecundity ranged from 122 to 265 with an average of 163.87 ± 27.37 eggs per female during its entire life cycle.

4.1.7 Longevity

The data presented in Tables 8, 12 and 13 showed the longevity of males and females. In case of adult longevity with food, adult females survived for 81 to 101 day with an average of 86.98 ± 5.17 day while males





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

Table 10: Measurements of adult males and females of *S. oryzae*

Sr. No.	Males		Females	
	Length(mm)	Breadth (mm)	Length(mm)	Breadth (mm)
1	3.20	1.28	3.50	1.40
2	3.25	1.30	3.75	1.50
3	3.30	1.32	3.65	1.46
4	3.45	1.38	3.50	1.40
5	3.30	1.32	3.55	1.42
6	3.15	1.26	3.65	1.46
7	3.20	1.28	3.69	1.48
8	3.45	1.38	3.70	1.48
9	3.40	1.36	3.75	1.50
10	3.30	1.32	3.75	1.50
11	3.35	1.34	3.50	1.40
12	3.25	1.30	3.50	1.40
13	3.15	1.26	3.65	1.46
14	3.45	1.38	3.45	1.38
15	3.35	1.34	3.50	1.40
16	3.45	1.38	3.59	1.44
17	3.30	1.32	3.55	1.42
18	3.25	1.30	3.65	1.46
19	3.35	1.34	3.70	1.48
20	3.25	1.30	3.75	1.50
21	3.45	1.38	3.50	1.40
22	3.35	1.34	3.75	1.50
23	3.25	1.30	3.75	1.50
24	3.25	1.30	3.65	1.46
25	3.35	1.34	3.55	1.42
26	3.45	1.38	3.58	1.43
27	3.25	1.30	3.69	1.48
28	3.35	1.34	3.65	1.46
29	3.45	1.38	3.65	1.46
30	3.25	1.30	3.50	1.40
Min.	**3.15**	**1.26**	**3.50**	**1.40**
Max.	**3.45**	**1.38**	**3.75**	**1.50**
Av. ± SD	**3.32 ± 0.09**	**1.33 ± 0.04**	**3.62 ± 0.10**	**1.45 ± 0.04**

Table 11: Pre-oviposition, oviposition, post-oviposition period and fecundity of female of *S. oryzae*

Sr. No.	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Total no. of eggs laid/female
1	3.00	59.00	32.21	125.00
2	3.50	58.00	33.63	265.00
3	3.75	45.00	33.00	145.00
4	4.95	46.00	22.00	156.00
5	5.00	33.00	27.00	178.00
6	5.00	33.50	19.00	133.00
7	4.65	59.00	18.00	198.00
8	4.85	53.25	29.00	154.00
9	4.80	61.00	37.00	176.00
10	5.95	58.00	28.00	167.00
11	4.15	54.00	34.75	156.00
12	4.95	45.00	28.00	187.00
13	4.65	55.25	29.33	159.00
14	5.00	48.00	35.55	155.00
15	4.95	49.50	26.00	187.00
16	7.00	48.00	29.95	163.00

Table 11: Conti.....

Sr. No.	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Total no. of eggs laid/female
17	4.35	59.95	29.00	177.00
18	4.55	61.00	35.00	188.00
19	4.75	49.00	29.00	145.00
20	4.95	60.25	31.00	165.00
21	4.85	59.95	29.00	132.00
22	4.90	48.00	27.00	178.00
23	4.90	52.00	31.00	144.00
24	7.00	33.00	35.90	153.00
25	4.85	58.58	32.00	177.00
26	4.55	59.00	31.00	145.00
27	6.38	55.00	31.00	122.00
28	6.55	54.00	28.00	165.00
29	4.95	56.00	29.00	178.00
30	4.85	55.00	34.00	143.00
Min.	**3.00**	**33.00**	**18.00**	**122**
Max.	**7.00**	**61.00**	**37.00**	**265**
Av.± SD	**4.95 ± 0.89**	**52.21 ± 8.16**	**29.81 ± 4.52**	**163.87 ± 27.37**

Table 12: Summary of entire life cycle from egg to death of *S. oryzae*

Stage	No. of observations	Range (days)		Mean (days)
		Min	Max	
Egg	30	3.78	6.12	4.87 ± 0.31
Egg hatching (%)	30	66.00	82.00	74.95 ± 5.50
Larva				
1st instar	30	5.50	7.00	6.17 ± 0.53
2nd instar	30	6.00	7.50	6.60 ± 0.56
3rdinstar	30	7.50	9.00	8.42 ± 0.57
4th instar	30	4.50	6.50	5.20 ± 0.57
Total larval period	30	24.50	28.50	26.39 ± 1.24
Pupa	30	6.00	7.00	6.82 ± 0.24
Adult longevity				
With food				
Male	30	55.00	60.00	57.73 ± 1.84
Female	30	81.00	101.00	86.98 ± 5.17
Without food				
Male	30	5.00	7.00	5.40 ± 0.56
Female	30	8.00	11.00	9.50 ± 0.87
Pre-oviposition	30	3.00	7.00	4.95 ± 0.89
Oviposition	30	33.00	61.00	52.21 ± 8.16
Post-oviposition	30	15.00	37.00	29.81 ± 4.52
Fecundity	30	122.00	265.00	163.87 ± 27.37
Sex ratio (male: female)	275	1:1.08	1:1.22	1:1.15
Total life cycle				
With food				
Male	30	91.45	99.96	98.81 ± 2.33
Female	30	117.89	140.96	125.06 ± 5.24
Without food				
Male	30	40.94	45.89	43.47 ± 1.29
Female	30	44.50	50.46	47.57 ± 1.58
Temperature (°C)	180 days	23.5	31.6	29.41 ± 1.62
Humidity (%)	180 days	56.8	74.2	59.43 ± 2.53

Table 13: Measurements of different stages of *S. oryzae*

Stages	No. of observations	Length (mm)			Breadth (mm)		
		Min.	Max.	Av. ± SD	Min.	Max.	Av. ± SD
Egg	30	0.35	0.39	0.37 ± 0.01	0.15	0.19	0.17 ± 0.01
Larva							
I instar	30	0.26	0.33	0.30 ± 0.02	0.09	0.11	0.10 ± 0.01
II instar	30	0.42	0.48	0.44 ± 0.02	0.14	0.16	0.15 ± 0.01
III instar	30	4.50	9.85	6.17 ± 1.27	1.50	3.28	2.06 ± 0.42
IV instar	30	1.25	1.45	1.39 ± 0.05	0.42	0.48	0.46 ± 0.02
Pupa	30	3.25	3.50	3.34 ± 0.09	1.63	1.75	1.67 ± 0.04
Adult							
Male	30	3.15	3.45	3.32 ± 0.09	1.26	1.38	1.33 ± 0.04
Female	30	3.50	3.65	3.62 ± 0.10	1.40	1.46	1.45 ± 0.04

survived for 55 to 60 day with an average of 57.75 ± 1.84 day at 25.60 to 38.40°C temperature and 65.20 to 88.50 per cent relative humidity. Whereas, without food adult females survived for only 8 to 11 day with an average of 9.50 ± 0.87 day but males survived for 5 to 7 day with an average of 5.40 ± 0.56 day at 19.60 to 31.00°C temperature and 67.50 to 79.50 per cent relative humidity. Thus, males lived shorter than females.

The present findings draw the support of Bheemanna (1986) who observed adult longevity ranging from 14 to 165 day and 7 to 11 day with and without food, respectively. Sattigi (1982) reported that longevity of adult weevil ranging from 16 to 172 day with food. While, the longevity of adult male and female was 14 to 115 and 119 to 120 day, 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.

4.1.8 Sex ratio

The sex ratio of male: female of *S. oryzae* was 1:1.15 as observed when reared in the laboratory (Table 14). Thus, females were more emerged as compared to the males.

4.1.9 Total life cycle

In the present study, the total life cycle of males of *S. oryzae* (Plate IX) observed to be ranged from 91.45 to 99.96 (Av. 98.81 ± 2.33) day with food, while in case of without food it was ranged from 40.94 to 45.89 (Av. 43.47 ± 1.29) day. The total life cycle of female with food was ranged from 117.89 to 140.96 (Av. 125.06 ± 5.24) day, while in case of without food it was ranged from 44.50 to 50.46 (Av. 47.57 ± 1.58) day (Table 8).

The findings are in agreement with Howe (1952) who reported 21 to 46 day. But these results do not agree with observation of Bheemanna (1986) who reported 38 to 53 days of total life cycle on sorghum hybrid

Table 14: Sex ratio of laboratory reared *S. oryzae*

Date of grouping fourth instar rice weevil	No of 4th instar larva/ set kept for observation	Sex		Sex ratio M: F
		Male	Female	
Laboratory population (October to November)				
03.10.2007	50	23	27	1: 1.18
17.10.2007	55	26	29	1: 1.12
31.10.2007	60	28	32	1: 1.14
14.11.2007	50	24	26	1: 1.08
28.11.2007	60	27	33	1: 1.22
Total	275	128	147	1: 1.15

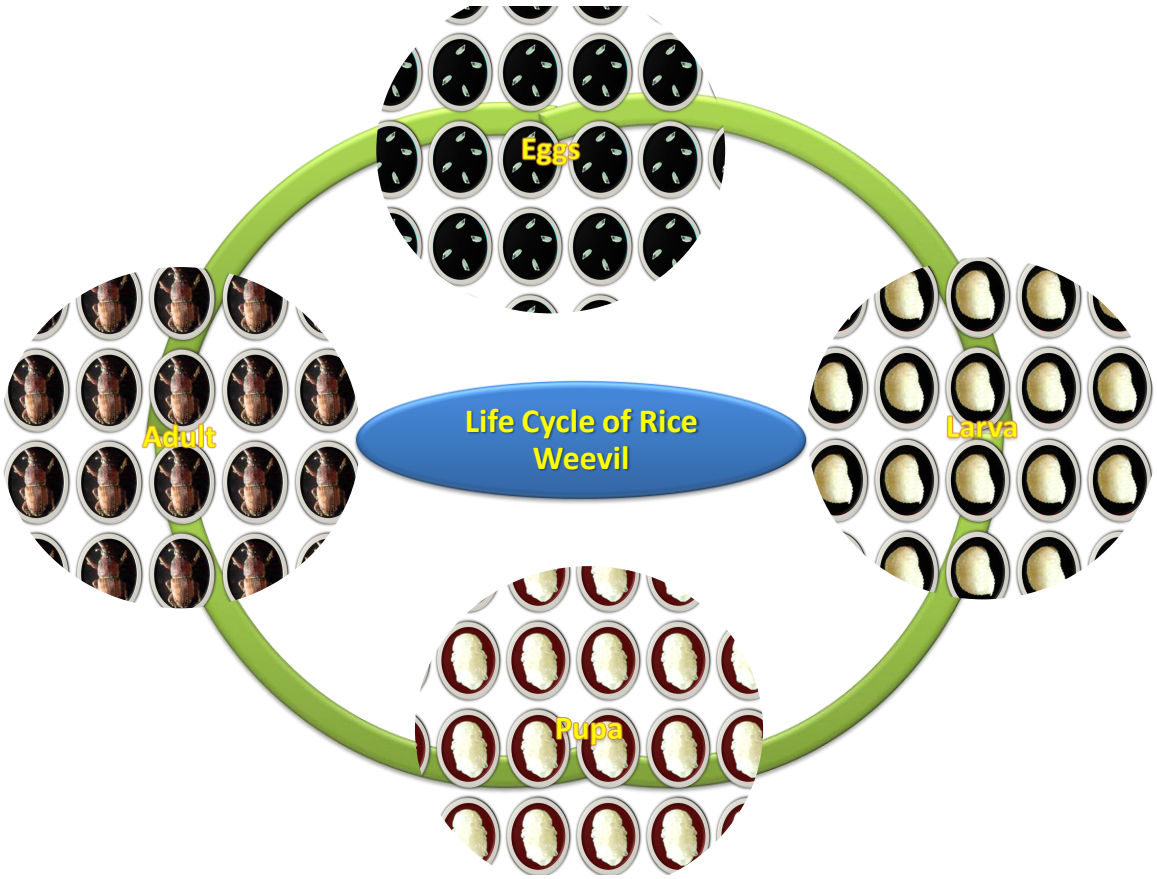


Plate IX: Life cycle of rice weevil, *S. oryzae*

CSH-5. The difference may be attributed to variation in genotype and different climatic conditions.

4.2 Screening of different varieties of sorghum against *S. oryzae*

Twelve sorghum genotypes were tested for their influence on some biological aspects of the pest. The observations on biological aspects, per cent weight loss, germination percentage, adult emergence, were taken into consideration to decide the susceptibility of sorghum genotypes to *S. oryzae.* Results on these parameters are presented in the Tables 15 to 22.

4.2.1. Developmental period and growth index

The larval and pupal duration as well as growth index of *S. oryzae* were studied for different sorghum genotype. The results are presented in Table 15.

From the Table 15, it can be seen that the grub period on different genotypes of sorghum varied from 24.05 to 27.97 day. Grub period was shorter on genotype DJ 6514 (24.05 day) and it was at par with SR 666 (24.17 day) followed by SR 1905 (24.43 day) and SR 2460 (24.47 day). The longer grub duration ranged from 27.80 to 27.97 day was recorded on genotypes ICSV 700, IS 6566, 168 II 108 and SR 770. These genotypes were found at par with each other in view of grub duration. Bheemanna (1986) reported the larval period of 25 to 34 day on CSH-5 sorghum hybrid. whereas according to Bhuiyah *et al.* (1990), the larval period ranged from 16 to 20 day on maize grain at 23 to 35°C and 79 to 87 per cent relative humidity. The larval period of 27.25 days on maize grains at temperature of 14 to 34°C and 55 to 88 per cent relative humidity was observed by Yevoor (2003). Thus present finding is more or less in confirmation with findings by other scientist however slight variation in duration was might due to variation in variety, temperature and humidity.

The pupal period ranged from 5.13 to 8.92 day on different genotypes of sorghum (Table 15). The lowest pupal period of 5.13 day was

Table 15: Varietal influence on biological aspects of rice weevil, *S. oryzae*

Sr. No.	Variety	Grub period (days)	Pupal period (days)	Sex ratio (Male: Female)	Adult longevity (Days)		Survival %	Growth index
					Male	Female		
1	SR 666	24.17	5.43	1:0.96	56.17	84.00	60.38	2.04
2	IS 6566	27.82	8.72	1:1.24	56.33	84.17	43.00	1.18
3	ICSV 700	27.80	8.87	1:1.31	56.50	84.50	44.00	1.20
4	168 II 108	27.88	8.78	1:1.13	56.00	84.00	46.00	1.25
5	SR 770	27.97	8.92	1:1.08	56.83	84.33	43.00	1.17
6	SR 2460	24.47	5.23	1:1.07	56.17	85.00	59.47	2.00
7	GJ 36	25.55	6.08	1:0.95	56.80	84.33	53.67	1.70
8	GJ 38	25.37	6.23	1:1.25	56.83	84.00	53.33	1.69
9	IS 2312	25.43	6.43	1:1.00	57.00	85.17	52.67	1.65
10	DJ 6514	24.05	5.42	1:1.18	56.17	84.33	60.55	2.05
11	SR 1905	24.43	5.13	1:1.31	56.00	84.50	57.65	1.95
12	SR 2804	25.63	6.47	1:1.05	56.83	84.17	51.67	1.61
	S.Em. ±	0.09	0.14	-	0.27	0.32	0.91	0.04
	CD at 5%	0.28	0.41	-	NS	NS	2.66	0.10
	CV %	0.92	2.78	-	10.42	5.96	3.03	3.81

recorded on genotype SR 1905. The longer pupal period ranging from 8.72 to 8.92 day on genotypes IS 6566, ICSV 700, 168 II 108 and SR 770 which were at par with each other.

The data regarding to growth index (Table 15 and figure 1) reveled that there was significant difference among genotypes. The growth index was the highest in genotype DJ 6514 (2.05) which was at par with SR 666 (2.04), SR 2460 (2.00) and SR 1905 (1.95) which were found significantly higher over rest of the genotypes. The genotype SR 770 was found to be less suitable for *S. oryzae* as it showed the lowest growth index (1.17) and was at par with IS 6566 (1.18), ICSV 700 (1.20) and 168 II 108 (1.25). The remaining genotypes were having intermediate growth index. Thus, on the basis of growth index, it can be concluded that the genotypes DJ 6514, SR 666, SR 2460 and SR 1905 were more suitable for *S. oryzae*, whereas SR 770, IS 6566, ICSV 700 and 168 II 108 were less suitable for it.

4.2.2 Sex ratio

The adults emerged from different sorghum genotype were identified as male and female after that the sex ratio was worked out for each genotype. The data are presented in Table 15.

The observations revealed that the sex ratio (male: female) ranged from 1:0.95 to 1:1.31 among different genotypes. Proportion of female was higher than male in almost all the genotypes except in SR 666 and GJ 36 and equal in IS 2312. So it can be concluded that the sex ratio of *S. oryzae* was influenced by genotype.

4.2.3 Longevity of adult

The data presented in Tables 15 show that the longevity of males and females. The longevity of male and female were found lowest on 168 II 108 and SR 1905 genotypes, whereas highest longevity was found on genotype IS 2312.

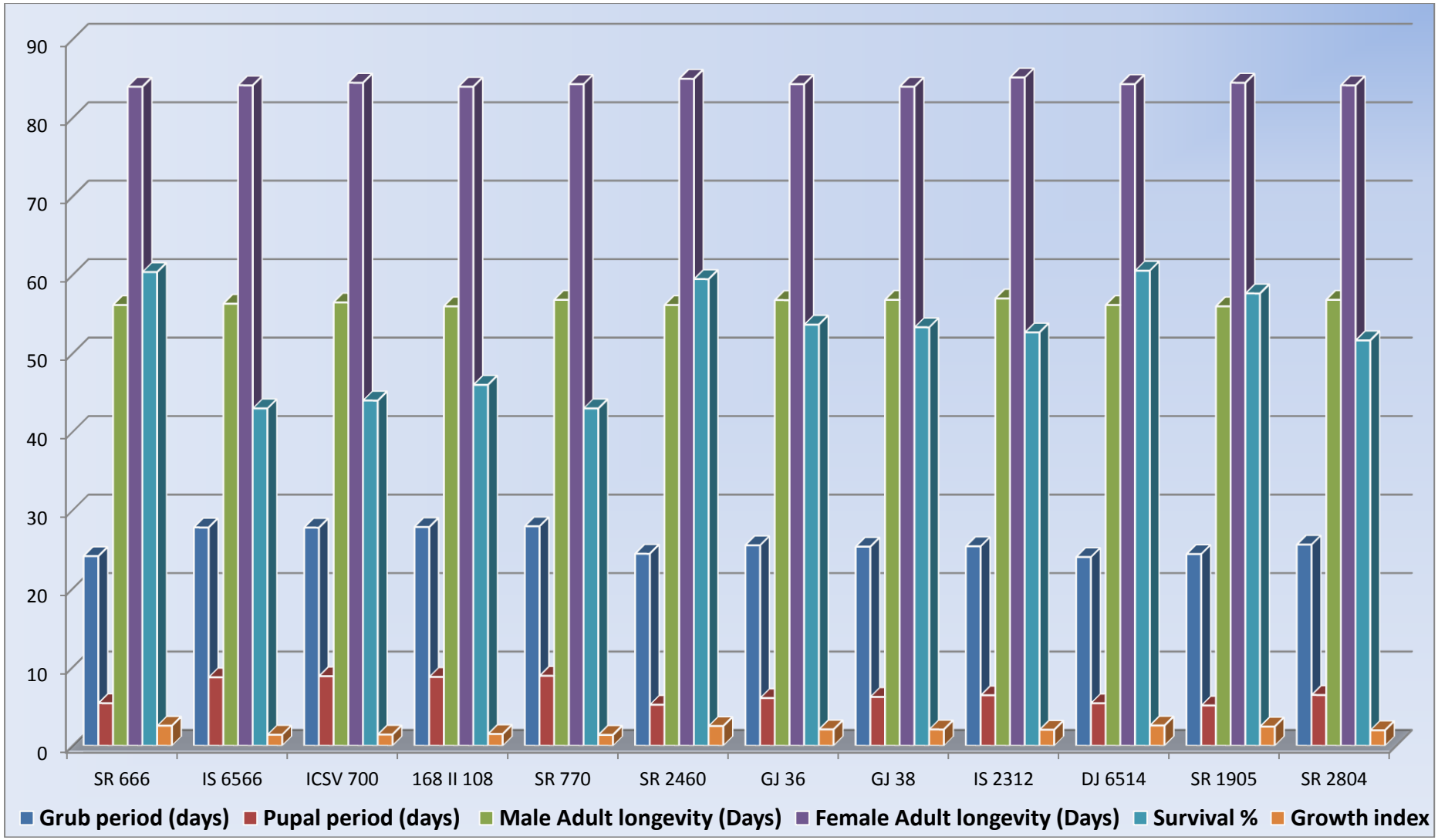


Figure 1: Varietal influence on biological aspects of rice weevil, *S. oryzae*

Table 16: Average number of adults emerged and susceptibility index of rice weevil, *S. oryzae* on different sorghum genotypes

Sr. No.	Variety	Average number of adults emerged	Susceptibility index
1	SR 666	42.33	15.33
2	IS 6566	26.33	9.00
3	ICSV 700	26.00	9.33
4	168 II 108	27.33	9.67
5	SR 770	26.67	3.67
6	SR 2460	38.67	11.83
7	GJ 36	19.00	12.00
8	GJ 38	18.67	12.83
9	IS 2312	18.00	13.33
10	DJ 6514	38.00	12.00
11	SR 1905	45.67	14.67
12	SR 2804	19.67	12.33
	S.Em. ±	1.02	0.50
	CD at 5%	2.99	1.49
	CV %	6.14	7.64

4.2.4 Susceptibility index

The data on average number of adult emerged and susceptibility index are presented in Table 16.

From the data it can be seen that the lowest number of adults were emerged in genotype IS 2312 (18.00 adult) which was at par with GJ 38 (18.38 adult), GJ 38 (18.67 adult), GJ 36 (19.00 adult) and SR 2804 (19.67 adult) respectively, which was significantly superior to rest of the genotypes. This was followed by ICSV 700 (26.00 adult), IS 6566 (26.33 adult), SR 770 (26.67 adult) and 168 II 108 (27.33 adult) which were at par with each other. The highest numbers of adults were emerged in genotype SR 1905 (45.67 adult) which remained at par with SR 666 (42.33 adult) and followed by SR 2460 (38.67 adult) and DJ 6514 (38.00 adult). The highest susceptibility index was found on genotypes SR 666 (15.33) which was at par SR 1905 (14.67), whereas the lowest susceptibility index was found on genotypes SR 770 (3.67).

4.2.5 Per cent grains damage

The data on per cent grain damage (Table 17 and Plate X) showed the following trends

4.2.5.1 30 DAS

At 30 days after storage, sorghum genotype 168 II 108 recorded significantly minimum grain damage of 21.33 per cent which was at par with ICSV 700 (23.00%) and SR 770 (21.67%) which were followed by IS 6566 (26.67%). Significantly maximum per cent damaged was noticed in DJ 6514 (55.00%) and it was at par with SR 2460 (51.67%) and SR 1905 (51.67%). Rest of the genotypes showed intermediate reaction to grains damage.

4.2.5.2 60 DAS

At 60 days after storage, maximum per cent grain damage was observed in DJ 6514 (70.67) and it was at par with SR 666 (68.33%) followed by SR 1905 (64.00 %) and SR 2460 (63.33%). Significantly

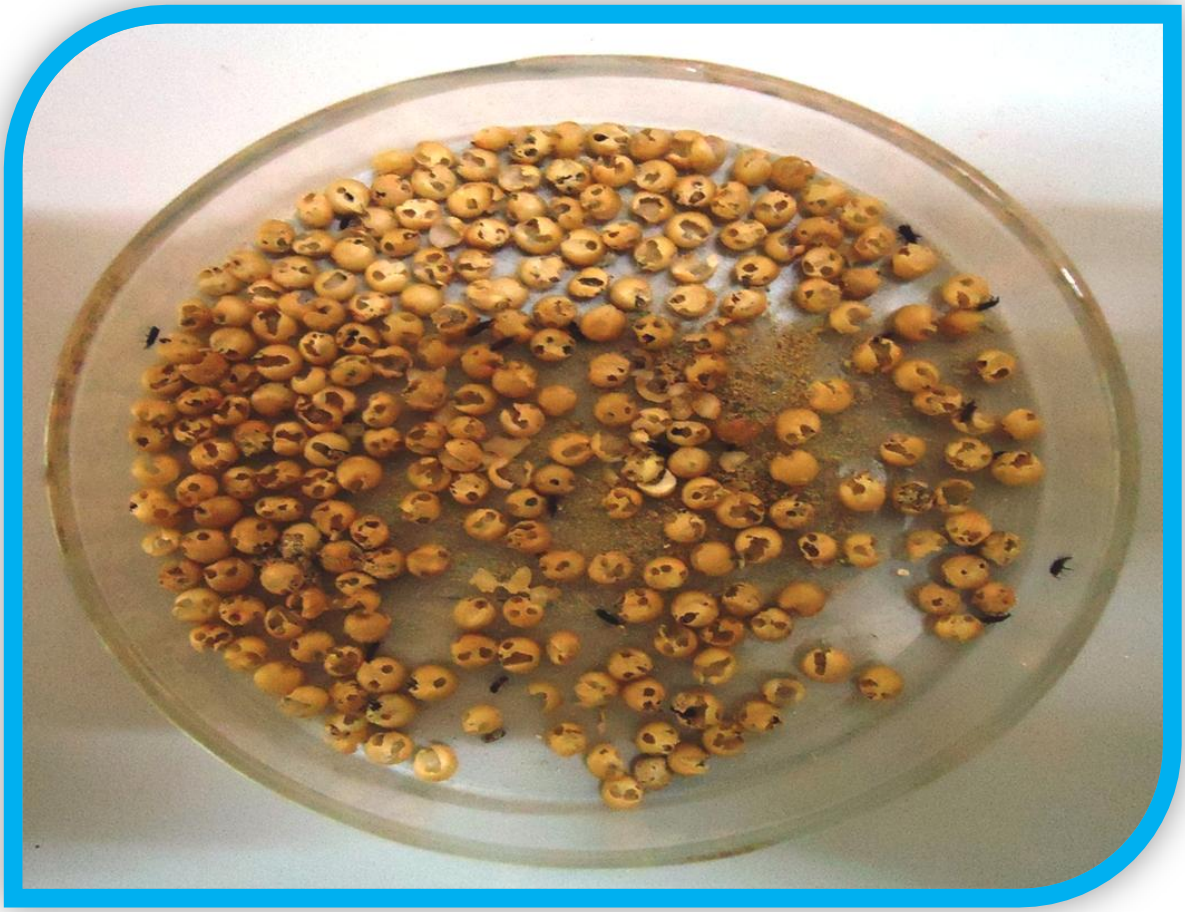


Plate X: Grains of sorghum damaged by *S. oryzae*

Table 17: Screening of sorghum varieties against rice weevil, *S. oryzae* on the bases of per cent grain damage

Sr. No	Variety	Percent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	SR 666	42.43ef (45.00)*	55.73e (68.33)	80.54bc (97.33)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	67.29ab (85.11)
2	IS 6566	31.11c (26.67)	45.17a (50.33)	74.32ab (92.67)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	62.24 ab (78.28)
3	ICSV 700	28.56ab (23.00)	47.12ab (53.67)	76.19b (94.33)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	62.37 ab (78.50)
4	168 II 108	27.49a (21.33)	46.83ab (53.33)	75.46ab (93.67)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	62.03a (78.06)
5	SR 770	27.76ab (21.67)	47.12ab (53.67)	75.00ab (93.33)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	62.10ab (78.11)
6	SR 2460	45.97f (51.67)	52.65cd (63.33)	89.56d (100.00)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	67.86 ab (85.83)
7	GJ 36	37.70de (37.33)	50.77c (60.00)	71.56a (90.00)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	64.30 ab (81.22)
8	GJ 38	39.64e (40.67)	52.06cd (62.33)	75.00ab (92.33)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	65.35 ab (82.56)
9	IS 2312	35.49d (33.67)	51.41cd (61.00)	72.54ab (91.00)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	64.05 ab (80.94)
10	DJ 6514	47.87fg (55.00)	57.23ef (70.67)	89.56d (100.00)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	69.38 b (87.61)
11	SR 1905	45.97f (51.67)	53.13d (64.00)	77.08bc (95.00)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	67.29 ab (85.11)
12	SR 2804	34.02cd (31.33)	50.94cd (60.33)	76.69bc (94.67)	89.56a (100.00)	89.56a (100.00)	89.56a (100.00)	64.16 ab (81.06)
	S.Em. ±	1.05	0.72	1.54	-	-	-	2.08
	CD at 5%	3.05	2.09	4.49	-	-	-	6.10
	CV %	4.90	2.44	3.42	-	-	-	3.61

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

minimum damaged grains were noticed in IS 6566 (50.33%) followed by 168 II 108 (53.33%), ICSV 700 (53.67%) and SR 770 (53.67%) and remained at par with each other.

4.2.5.3 90 DAS

At 90 DAS, cent per cent grain damage was found in genotype DJ 6514 and SR 2460. While, significantly minimum per cent of damaged grains was observed in GJ 36 (90.00%) followed by IS 2312 (91.00%), GJ 38 (92.33%), IS 6566 (92.67%), SR 770 (93.33%), and 168 II 108 (93.67%) and remained at par with each other.

4.2.5.4 120 DAS

The hundred per cent grain damage was found in all the genotypes after 120 days of storage. There was not found any differences among genotypes of sorghum.

4.2.5.5 150 DAS

The hundred per cent grain damage was found in all the genotypes after 150 days of storage. There was not found any differences among genotypes of sorghum.

4.2.5.6 180 DAS

The hundred per cent grain damage was found in all the genotypes after 180 days of storage. There was not found any differences among genotypes of sorghum.

The mean per cent grain damage data (Table 17 and Figure 2) indicated that the most susceptible genotypes was DJ 6514 with 87.61 per cent grain damage, while 168 II 108 was the most resistance sorghum genotype (78.06%). The remaining genotypes react intermediate and found no significant differences.

4.2.6. Per cent weight loss

The data on per cent weight loss in different genotype caused *S. oryzae* presented in Table 18 and depicted in Figure 3.

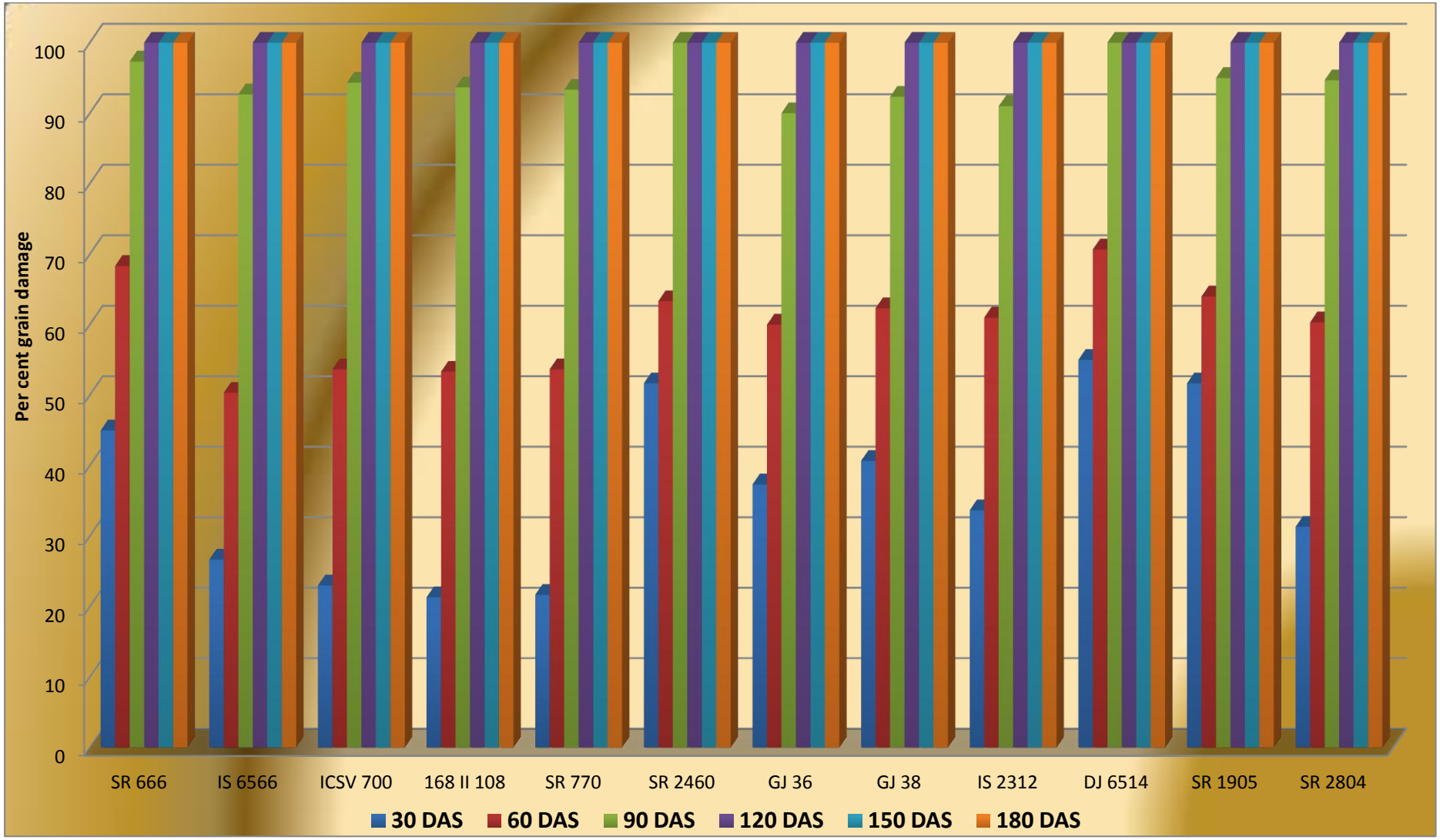


Figure 2: Screening of sorghum varieties against rice weevil, *S. oryzae* on the bases of per cent grain damage

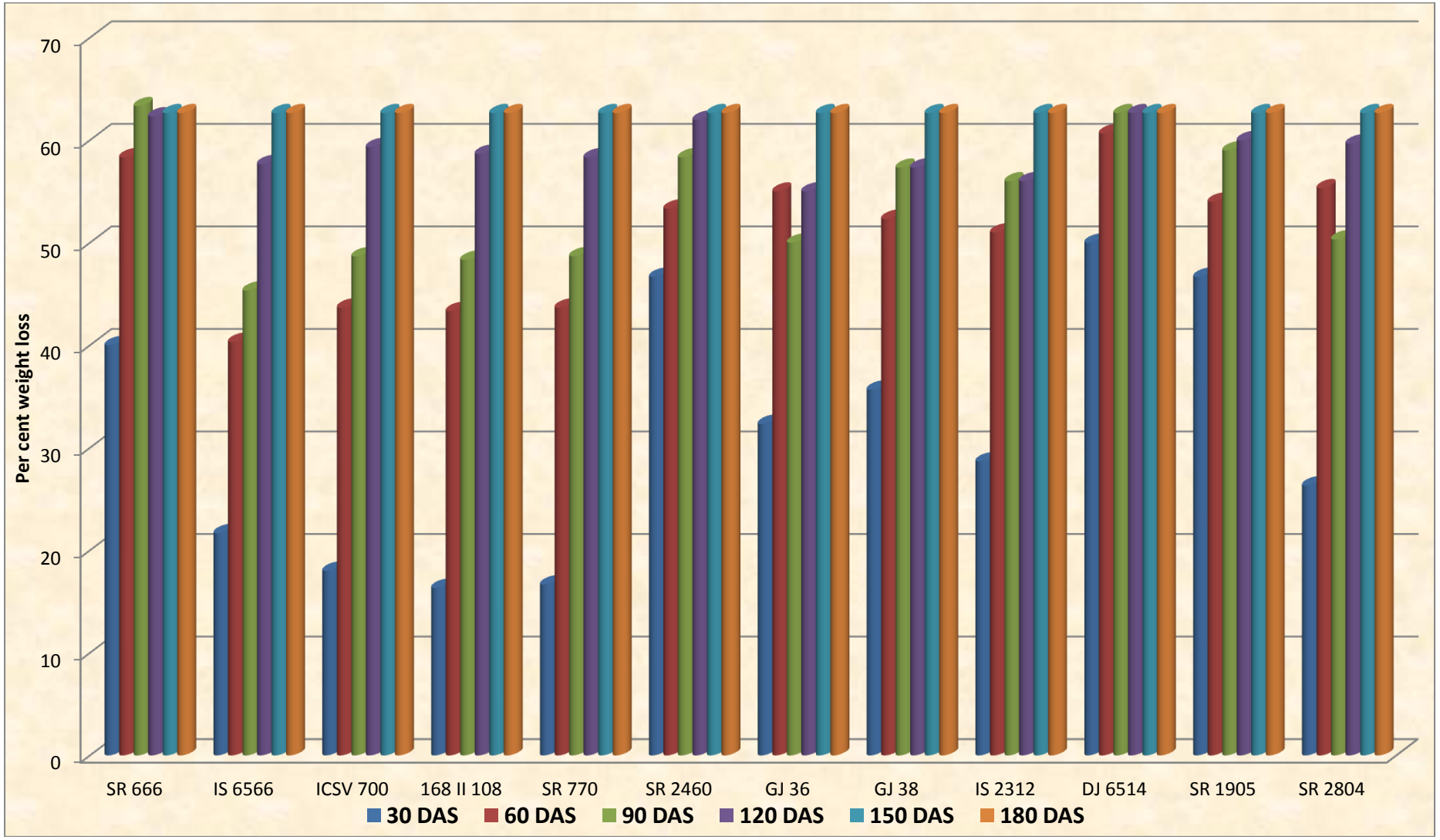


Figure 3: Per cent weight loss to different varieties of sorghum due to *S. oryzae* infestation

4.2.6.1 30 DAS

At 30 days after storage, sorghum genotype 168 II 108 recorded significantly minimum of 16.33 per cent weight loss and it was at par with SR 770 (16.67%) and ICSV 700 (18.00%). Whereas maximum per cent of weight loss was noticed in DJ 6514 (50.00%) followed by SR 2460 (46.67%) and SR 1905 (46.67%). Rest of the genotypes showed intermediate reaction to per cent weight loss.

4.2.6.2 60 DAS

At 60 days after storage, maximum of 60.67 per cent weight loss was observed in DJ 6514 and it was followed by SR 666 (58.33%) and SR 1095 (54.00%). Whereas, minimum of 40.33 per cent weight loss observed in IS 6566 and was at par with ICSV 700 (43.67%) and SR 770 (43.67%).

4.2.6.3 90 DAS

At 90 days after storage, sorghum genotype IS 6566 recorded significantly minimum of 45.33 per cent weight loss was observed and it was at par with 168 II 108 (48.33%), SR 770 (48.67%), ICSV 700 (48.68%) and SR 2804 (50.33%). The highest weight loss was noticed in DJ 6514 (62.65%) and GJ 38 (57.33%).

4.2.6.4 120 DAS

At 120 days after storage, sorghum genotype GJ 36 recorded significantly minimum of 55.00 per cent weight loss was observed and it was at par with GJ 38 (57.33%), and IS 6566 (57.67%). The highest weight loss was noticed in DJ 6514 (62.65%).

4.2.6.5 150 DAS

At 150 days after storage, weight loss does not show any differences among sorghum genotypes.

4.2.6.6 180 DAS

At 180 days after storage, weight loss does not show any differences among sorghum genotypes.

The mean per cent weight loss data (Table 18) indicate that the most susceptible genotype DJ 6514 with 61.11 per cent weight loss, while IS 6566 was the most resistance sorghum genotype where there was 48.38 per cent weight loss. The remaining genotypes reacting intermediate and found no significant differences.

4.2.7 Population build up

4.2.7.1 30 DAS

Significantly higher number of adults were emerged in DJ 6514 (123.33) and it is at par with SR 666 (122.33 adult) while less number of adults were observed in SR 770 (61.00 adult) and remained at par with 168 II 108 (61.67 adult), ICSV 700 (62.67 adult) and IS 6566 (63.33 adult) at 30 days after storage when five pairs of weevils were released at the beginning of storage (Table 19).

4.2.7.2 60 DAS

The population build up was significantly more in DJ 6514 (278.67) after 60 days of storage which was at par with SR 666 (278.00 adult). It was followed by SR 2460 (273.33 adult) and SR 1905 with 273.33 adult, respectively. Whereas, it was less in SR 770 (217.33 adult) which was at par with 168 II 108 (218.33 adult), ICSV 700 (219.00 adult) and IS 6566 (219.33 adult).

4.2.7.3 90 DAS

Population of live insects was minimum in SR 770 (370.00) and remained at par with ICSV 700 (371.33 adult), 168 II 108 (371.33 adult) and IS 6566 (372.00 adult). The maximum population was in DJ 6514 (436.00 adult) which was at par with SR 666 (434.67 adult) was followed by SR 2460 (430.00 adult) and it is at par with SR 1905 (428.67 adult).

4.2.7.4 120 DAS

Emergence of adults was significantly higher in DJ 6514 (596.00) and it was at par with SR 666 (594.33 adult). This was followed by

Table 18: Per cent weight loss of different varieties of sorghum due to *S. oryzae* infestation

Sr. No	Variety	Percent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	SR 666	39.23g (40.00)*	49.78f (58.33)	52.65c (63.33)	52.12ab (62.33)	52.36a (62.65)	52.36a (62.65)	49.72ab (58.22)
2	IS 6566	27.76c (21.67)	39.41a (40.33)	42.39a (45.33)	49.43ab (57.67)	52.36a (62.65)	52.36a (62.65)	44.08a (48.38)
3	ICSV 700	25.10ab (18.00)	41.38ab (43.67)	44.31ab (48.67)	50.36ab (59.33)	52.36a (62.65)	52.36a (62.65)	44.54a (49.16)
4	168 II 108	23.81a (16.33)	41.15b (43.33)	44.08ab (48.33)	50.01ab (58.67)	52.36a (62.65)	52.36a (62.65)	44.25a (48.66)
5	SR 770	24.12ab (16.67)	41.38ab (43.67)	44.25ab (48.68)	49.78ab (58.33)	52.36a (62.65)	52.36a (62.65)	44.31a (48.77)
6	SR 2460	43.68h (46.67)	46.89de (53.33)	49.78bc (58.33)	51.94bc (62.00)	52.36a (62.65)	52.36a (62.65)	49.66ab (58.11)
7	GJ 36	34.63ef (32.33)	47.87ef (55.00)	45.00ab (50.00)	47.87b (55.00)	52.36a (62.65)	52.36a (62.65)	46.66ab (52.94)
8	GJ 38	36.69f (35.67)	46.83cd (52.33)	49.12cd (57.33)	49.12bc (57.33)	52.36a (62.65)	52.36a (62.65)	47.70ab (54.66)
9	IS 2312	32.39de (28.67)	45.57c (51.00)	48.45b (56.00)	48.45ab (56.00)	52.36a (62.65)	52.36a (62.65)	46.61ab (52.83)
10	DJ 6514	45.00i (50.00)	51.18g (60.67)	52.36cd (62.65)	52.36ab (62.65)	52.36a (62.65)	52.36a (62.65)	51.41b (61.11)
11	SR 1905	43.11h (46.67)	47.29e (54.00)	50.18bc (59.00)	50.77ab (60.00)	52.36a (62.65)	52.36a (62.65)	49.31ab (57.50)
12	SR 2804	30.85d (26.33)	48.04ef (55.33)	45.17ab (50.33)	50.59ab (59.67)	52.36a (62.65)	52.36a (62.65)	46.61ab (52.83)
	S.Em. ±	0.85	0.70	1.12	1.05	-	-	2.01
	CD at 5%	2.47	2.03	3.26	3.10	-	-	5.88
	CV %	4.34	2.51	2.71	2.15	-	-	3.06

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 19: Population buildup of *S. oryzae* on different sorghum genotypes

Sr. No	Variety	Population buildup						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	SR 666	122.33e	278.00f	434.67e	594.33g	803.33f	1020.67d	542.22d
2	IS 6566	63.33a	219.33a	372.00a	524.00b	726.33a	930.33a	472.55a
3	ICSV 700	62.67a	219.00a	371.33a	523.33a	726.00a	931.00a	472.22a
4	168 II 108	61.67a	218.33a	371.33a	523.67a	726.33a	932.33a	472.28a
5	SR 770	61.00a	217.33a	370.00a	521.67a	724.67a	930.00a	470.78a
6	SR 2460	117.67d	273.33e	430.00d	584.67f	791.00d	1003.33c	533.33c
7	GJ 36	95.67c	251.33c	408.00b	564.33c	770.67b	981.67b	511.95b
8	GJ 38	94.67c	254.33d	412.00c	567.67d	772.33b	983.00b	514.00b
9	IS 2312	97.67c	254.33d	411.67c	570.00e	774.67c	985.67b	515.67b
10	DJ 6514	123.33e	278.67f	436.00e	596.00h	818.33g	1033.00e	547.56d
11	SR 1905	117.00d	273.33e	428.67d	585.00f	794.67e	1004.00c	533.78c
12	SR 2804	90.00b	246.00b	410.33b	567.67d	772.00b	983.00b	511.50b
	S.Em. ±	0.87	0.96	0.83	0.78	1.71	2.16	2.32
	CD at 5%	2.52	2.79	2.43	2.26	4.99	6.61	6.57
	CV %	3.55	3.41	2.64	2.23	4.44	4.89	3.95

SR 1905 (585.00 adult) and it was at par with SR 2460 (584.67 adult). Minimum adult emergence was observed in SR 770 (521.67 adult) and at par with ICSV 700 (523.33 adult), 168 II 108 (523.67 adult) and IS 6566 (524.00 adult).

4.2.7.5 150 DAS

Population buildup was minimum in SR 770 (724.67) and it was at par with ICSV 700 (726 adult), IS 6566 (726.33 adult) and 168 II 108 (726.33 adult). While maximum population was observed in DJ 6514 (818.33 adult) and it was at par with SR 666 (803.33 adult)

4.2.7.6 180 DAS

More number of live adults were recorded in DJ 6514 (1033.00) followed by SR 666 (1020.67 adult). While it was least number of adults were observed in SR 770 (930.00 adult). This was at par with the IS 6566 (930.33 adult), ISCV 700 (931.00 adult) and 168 II 108 (932.33 adult).

The mean population buildup in different sorghum genotypes, the data (Table 19) indicated that the highest population buildup of *S. oryzae* was found in susceptible genotype is DJ 6514 with 547.56 adults and it was at par with SR 666 (542.22 adult). The most resistant sorghum genotype was SR 770 (470.78 adult).

4.2.8. Per cent seed germination in sorghum infested by *S. oryzae*

4.2.8.1 30 DAS

At 30 days after storage (Table 20), SR 770 maintained maximum germination per cent (62.67) followed by ICSV 700 (61.00%) and it was at par with IS 6566 (59.00%). While minimum germination was observed in DJ 6514 (22.00%) followed by SR 1905 (28.33%).

4.2.8.2 60 DAS

Minimum germination per cent was recorded at 60 DAS in DJ 6514 (8.33%) with followed by SR 1905 (13.67%) and it was at par SR 666 (15.00%). The maximum germination was observed in ICSV 700 (34.33%)

Table 20: Per cent germination in different sorghum genotypes infested by *S. oryzae*

Sr. No	Variety	Per cent germination						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	SR 666	32.39bc (28.67)*	22.79bc (15.00)	5.74b (1.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	15.89ab (7.45)
2	IS 6566	50.18g (59.00)	35.06f (33.00)	8.72bc (2.33)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	23.34cd (15.72)
3	ICSV 700	51.35gh (61.00)	35.85f (34.33)	6.55bc (1.33)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	23.66cd (16.11)
4	168 II 108	49.60f (58.00)	34.02ef (31.33)	8.13bc (2.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	22.95cd (15.22)
5	SR 770	52.36h (62.67)	35.67ef (34.00)	7.49bc (1.67)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	23.89cd (16.39)
6	SR 2460	33.40bc (30.33)	25.62c (18.67)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	16.54ab (8.17)
7	GJ 36	45.97de (51.67)	33.21e (30.00)	11.54d (4.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	22.22cd (14.28)
8	GJ 38	45.17d (50.33)	31.11de (26.67)	8.72bc (2.33)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	21.30cd (13.22)
9	IS 2312	43.11c (46.67)	30.41d (25.67)	7.49bc (1.67)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	20.53c (12.34)
10	DJ 6514	27.97a (22.00)	16.74a (8.33)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	12.95a (5.06)
11	SR 1905	32.14b (28.33)	21.72b (13.67)	5.74b (1.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	15.56ab (7.17)
12	SR 2804	45.17d (50.33)	32.14de (28.33)	6.55bc (1.33)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	21.39cd (13.33)
	S.Em. ±	0.58	0.95	1.27	-	-	-	2.05
	CD at 5%	1.70	2.77	3.71	-	-	-	6.01
	CV %	2.38	5.57	5.51	-	-	-	6.49

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

and it was at par with SR 770 (34.00%) and 168 II 108 (31.33%).

4.2.8.3 90 DAS

The genotypes DJ 6514 and SR 2460 were recorded zero per cent germination after 90 days after storage. While, other genotypes were also recorded very low per cent of germination.

4.2.8.4 120 DAS

After 120 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

4.2.8.5 150 DAS

After 150 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

4.2.8.6 180 DAS

After 180 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

The mean per cent germination in different sorghum genotypes data (Table 20 and Figure 4) indicated that the lowest per cent of germination in different sorghum genotypes was found in susceptible genotype was DJ 6514 (5.06) and it was at par with SR 1905 (7.17%), SR 666 (7.45%) and SR 2460 (8.17%). The highest per cent of germination was found in sorghum genotype SR 770 (16.39).

4.2.9 Biochemical parameters of sorghum genotypes

The observations on the major biochemical plant constituents such as total nitrogen, crude protein and tannin content from twelve sorghum genotypes possibly associated with resistance to *S. oryzae* were recorded during 2012 (Table 21).

4.2.9.1 Total nitrogen

The observations related to total nitrogen per cent are presented in Table 21. The total nitrogen per cent varied from 2.18 to 3.51 per cent and it is found maximum in genotype DJ 6514 (3.51%). While, the minimum

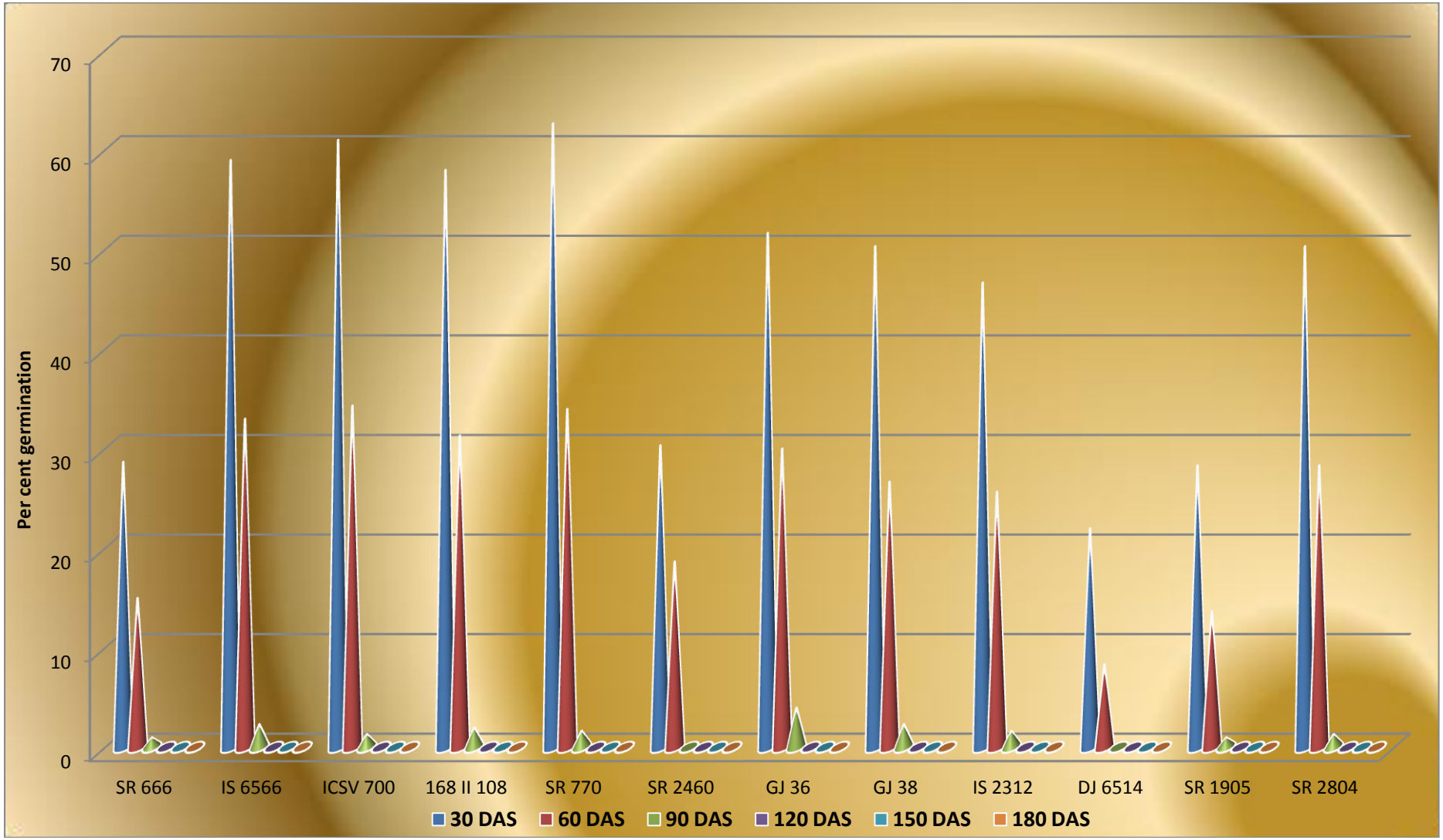


Figure 4: Per cent germination in different sorghum genotypes due to *S. oryzae* infestation

Table 21: Per cent total nitrogen, crude protein and tannin content in different sorghum genotypes infested by *S. oryzae*

Sr. No.	Genotypes	Population buildup	Total nitrogen content (%)	Total Crude protein content (%)	Tannin content (%)
1	SR 666	92.22	9.36b (2.66)*	23.99b (16.60)	2.36b (0.17)
2	IS 6566	22.56	10.56c (3.36)	27.27d (21.01)	3.00c (0.27)
3	ICSV 700	22.22	10.27c (3.18)	26.48c (19.89)	3.10c (0.29)
4	168 II 108	22.28	10.13c (3.10)	26.10c (19.36)	3.11c (0.29)
5	SR 770	20.78	9.07a (2.50)	23.21a (15.62)	3.25d (0.32)
6	SR 2460	83.33	9.91c (2.96)	25.48c (18.53)	2.04a (0.13)
7	GJ 36	61.94	9.60b (2.78)	24.62b (17.38)	2.80b (0.24)
8	GJ 38	64.00	9.29b (2.61)	23.80b (16.30)	2.56b (0.20)
9	IS 2312	65.67	9.15b (2.53)	23.42b (15.81)	2.54b (0.20)
10	DJ 6514	97.56	10.80d (3.51)	27.92d (21.94)	1.82a (0.10)
11	SR 1905	83.78	9.00a (2.46)	23.04a (15.35)	1.93a (0.11)
12	SR 2804	61.50	8.49a (2.18)	21.66a (13.64)	2.62b (0.21)
	S.Em. ±		0.22	0.60	0.08
	CD at 5%		0.65	1.75	0.24
	CV %		4.00	4.19	5.59

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values

total nitrogen per cent was found in genotype SR 2804 (2.18%) and it was at par with SR 1905 (2.46%).The interaction effect between nitrogen content and population build up was found non significant and had no significant effect on population build up of the *S. oryzae* (Table 22)

4.2.9.2 Crude protein

The data pertaining to crude protein are presented in Table 21. Crude protein per cent varied from 13.64 to 21.94. The minimum per cent was observed in sorghum genotype SR 2804 (13.64) and it was at par with SR 1905 (15.35%). Sorghum genotype DJ 6514 had maximum per cent of crude protein (21.94) and it remained at par with IS 6566 (21.01%).

The correlation between crude protein and population build up showed negative but non significant (-0.34). Therefore the data indicating no effect of crude protein on population build up of *S. oryzae* on different genotypes of sorghum.

On the contrary earlier workers reported that protein content of the sorghum grain had negative correlation with insect infestation (Rehman *et al.*, 2000). Dey and Sarup (1991) also found that per cent weight loss was negatively correlated with percentage protein content of the grain.

4.2.9.3 Tannin

The data pertaining to tannin content in different genotypes of sorghum are presented in Table 21.

The highest tannin content was recorded in SR 770 (0.32%) and it was at par with 168 II 108 (0.29%), ICSV 700 (0.29%) and IS 6566 (0.27%). Whereas the minimum tannin per cent was found in DJ 6514 (0.10%) and it was at par with SR 1905 (0.11%).

The relationship between population build up and content of tannin per cent of the different genotypes of sorghum (Table 22) was negatively correlated.

Table 22: Simple correlation between different biochemical parameters of sorghum genotypes and population buildup of *S. oryzae*

Sr. No.	Characters	Correlation coefficient(r)
1	Total nitrogen content (%)	-0.34
2	Crude protein content (%)	-0.34
3	Tannin content (%)	-0.93*

* Significant at 5%

The present finding was confirmed with the finding of Wongo (1998) who reported that in short term (25 days) feeding test using *S. oryzae* adults, the presence of sorghum tannin from cv. BKS 5 in pallets significantly reduced the feeding by it.

4.3 Eco friendly approaches for the management of rice weevil in sorghum

4.3.1 Efficacy of various plant products against *S. oryzae* in sorghum

4.3.1.1 Per cent grain damage due to *S. oryzae* in sorghum

The data on per cent grain damage after grains treated with various plant products during 2007-08 (Table 23), 2008-09 (Table 24) and pooled data of two year (Table 25) revealed the trends of per cent grain damage at different days after storage as follows:

4.3.1.1.1 30 DAS

The data of 2007-08 after 30 DAS showed no grain damage due to rice weevil observed in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder stood second (16.00%) and it was at par with the treatment of lakke leaf powder 5 per cent with 17.00 per cent grain damage. The maximum per cent of grain damage (39.33) was observed in tulsi leaf powder 5 per cent (Table 23).

Table 24 pertaining to data of 2008-09 indicate that there was no grain damage in treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (15.67%) and it was at par with the treatment of neem leaf powder 5 per cent with 16.33 per cent grain damage. The maximum per cent of grain damage was observed in tulsi leaf powder 5 per cent (37.67).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 25) revealed that there was no grain damage in the

Table 23: Grain damage due to *S. oryzae* when treated with plant products during 2007-08

Sr. No	Treatments	Per cent grain damage						
		30 DAS	60DAS	90DAS	120DAS	150DAS	180DAS	Mean
1	Adasali LP 5%	31.72f (27.67)*	42.31e (45.33)	47.66e (54.67)	53.91e (65.33)	57.61d (71.33)	60.20c (75.33)	48.90d (56.61)
2	Kharanja/honge leaf powder 5%	27.25e (21.00)	38.04d (38.00)	45.55d (51.00)	51.92d (62.00)	55.73c (68.33)	59.98c (75.00)	46.41c (52.56)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	34.64g (32.33)	45.75f (51.33)	54.11g (65.67)	68.85g (87.00)	71.86f (90.33)	76.21e (94.33)	55.57f (70.17)
5	Neem leaf powder 5%	23.56b (16.00)	29.09c (23.67)	35.65b (34.00)	40.38b (42.00)	45.75b (51.33)	48.43b (56.00)	37.14b (37.17)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	38.82h (39.33)	48.23g (55.67)	52.91f (63.67)	59.54f (74.33)	63.65e (80.33)	68.01d (86.00)	55.20e (66.56)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakke leaf powder 5%	24.33c (17.00)	26.79b (20.33)	36.85c (36.00)	41.92c (44.67)	45.24b (51.67)	48.73b (56.00)	37.38b (37.61)
10	Control	51.73h (61.67)	58.89h (73.33)	70.93h (89.33)	83.43h (98.67)	89.56g (100.00)	89.56f (100.00)	74.02g (87.17)
	S.Em. ±	0.45	0.30	0.31	0.37	0.22	0.29	2.63
	CD at 5%	0.67	0.86	0.91	1.08	0.66	0.84	7.49
	CV %	3.36	1.77	1.56	1.59	0.89	1.10	0.98

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 24: Grain damage due to *S. oryzae* when treated with plant products during 2008-09

Sr. No	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Adasali LP 5%	32.36d (28.67)*	42.88e (46.33)	47.47e (54.33)	53.51e (64.67)	57.82e (71.67)	59.98c (75.00)	49.00e (56.78)
2	Kharanja/honge leaf powder 5%	26.79c (20.33)	37.84d (37.67)	45.94d (51.67)	52.12d (62.33)	55.32d (67.67)	59.76c (74.67)	46.29d (52.39)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	34.23e (31.67)	45.75f (51.33)	53.91f (65.33)	68.84g (87.00)	72.19g (90.67)	75.79e (94.00)	58.45g (70.00)
5	Neem leaf powder 5%	23.83b (16.33)	28.87c (23.33)	35.45b (33.67)	40.19b (41.67)	45.94b (51.67)	48.24b (55.67)	37.08b (37.06)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	37.84f (37.67)	48.62g (56.33)	53.11g (64.00)	59.76f (74.67)	63.89f (80.67)	67.73d (85.67)	55.16f (66.50)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakke leaf powder 5%	23.31b (15.67)	27.03b (20.67)	37.05c (36.33)	41.73c (44.33)	46.13c (52.00)	48.62b (56.33)	37.31c (37.56)
10	Control	50.55g (59.67)	58.90h (73.33)	71.22h (89.67)	82.63h (98.33)	89.56h (100.00)	89.56f (100.00)	73.74h (86.83)
	S.Em. ±	0.28	0.34	0.20	0.29	0.17	0.18	2.65
	CD at 5%	0.82	0.99	0.60	0.85	0.50	0.52	7.55
	CV %	2.08	1.99	1.01	1.25	0.68	0.67	1.21

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 25: Grain damage due to *S. oryzae* when treated with plant products (Pooled of 2007-08 & 2008-09)

Sr. No	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Adasali LP 5%	32.04d (28.17)*	42.59e (45.83)	47.56e (54.50)	53.71e (65.00)	57.71d (71.50)	60.09c (75.17)	46.95e (56.69)
2	Kharanja/honge leaf powder 5%	27.02c (20.67)	37.94d (37.84)	45.75d (51.34)	52.02d (62.17)	55.53c (68.00)	59.87c (74.84)	45.35d (52.47)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	34.43e (32.00)	45.75f (51.33)	54.01g (65.50)	68.84g (87.00)	72.02f (90.50)	76.00f (94.17)	55.51g (70.08)
5	Neem leaf powder 5%	23.69b (16.17)	28.98c (23.50)	35.55b (33.84)	40.28b (41.84)	45.84b (51.50)	48.33b (55.84)	36.11b (37.11)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	38.33f (38.50)	48.23g (56.00)	53.01f (63.84)	59.64f (74.50)	63.77e (80.50)	67.87e (85.84)	52.18f (66.53)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakke leaf powder 5%	23.82b (16.34)	26.90b (20.50)	36.95c (36.17)	41.83c (44.50)	46.03b (51.84)	48.52c (56.17)	36.34c (37.58)
10	Control	51.14g (60.67)	58.90h (73.33)	71.07h (89.50)	83.03h (98.50)	89.56g (100.00)	89.56h (100.00)	69.88h (87.00)
	S.Em. ±	0.27	0.21	0.17	0.23	0.13	0.16	1.78
	CD at 5%	0.77	0.59	0.49	0.63	0.38	0.45	4.99
	YxT							
	S.Em. ±	0.38	0.32	0.26	0.33	0.20	0.24	0.29
	CD at 5%	NS	NS	NS	NS	NS	NS	0.86
	CV %	2.81	1.89	1.31	1.43	0.79	0.91	1.41

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder (16.17%) and it was at par with the treatment of lakke leaf powder 5 per cent with 16.33 per cent grain damage. The maximum per cent of grain damage was observed in tulsi leaf powder 5 per cent (38.50).

4.3.1.1.2 60 DAS

The data of 2007-08 after 60 DAS showed no grain damage due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (20.33%) followed by the treatment of neem leaf powder 5 per cent with 23.67 per cent grain damage. The maximum per cent of grain damage was observed in tulsi leaf powder 5 per cent (55.67) (Table 23).

The data of 2008-09 (Table 24) indicated that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (20.67%) and it was followed by the treatment of neem leaf powder with 23.33 per cent grain damage. The maximum per cent of grain damage was observed in tulsi leaf powder 5 per cent (56.33).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 25) revealed that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was lakke leaf powder 5 per cent (20.50%) and it was followed by the treatment of neem leaf powder 5 per cent (23.50%). The maximum per cent of grain damage was recorded in tulsi leaf powder 5 per cent (56.00).

4.3.1.1.3 90 DAS

The data of 2007-08 after 90 DAS showed no grain damage due

to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (34.00%) and it was at par with the treatment of lakke leaf powder 5 per cent with 36.00 per cent grain damage. The maximum per cent of grain damage was observed in treatment of turmeric powder 5 per cent (65.67) (Table 23).

The data of 2008-09 indicated (Table 24) that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent with 33.67 per cent grain damage stood second and it was followed by the treatment of lakke leaf powder 5 per cent (36.33%). The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (65.33).

The data of pooled for grain damage of two year 2007-08 and 2008-09 (Table 25) revealed that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (33.83%) and it was followed by the treatment of lakke leaf powder 5 per cent with 36.17 per cent grain damage. The maximum per cent of grain damage was observed in turmeric powder 5 per cent (65.50).

4.3.1.1.4 120 DAS

The data of 2007-08 after 120 DAS showed no grain damage due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (42.00%) and it was followed by the treatment of lakke leaf powder 5 per cent with 44.67 per cent grain damage. The maximum per cent of grain damage (87.00) was observed in the

treatment of turmeric powder 5 per cent (Table 23).

The data of 2008-09 indicated that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (41.67%) and it was at par with the treatment of lakke leaf powder 5 per cent with 44.33 per cent grain damage. The maximum per cent of grain damage was observed in turmeric powder 5 per cent (87.00) (Table 24).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 25) revealed that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (41.83%) and it was followed by the treatment of lakke leaf powder 5 per cent with 44.50 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (87.00).

4.3.1.1.5 150 DAS

The data of 2007-08 after 150 DAS showed no grain damage due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (51.67%) and it was at par with the treatment of neem leaf powder 5 per cent with 51.33 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (90.33) (Table 23).

The data of 2008-09 indicated that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (51.67%) and it was at par with the treatment of lakke leaf powder 5 per cent with 52.00 per cent grain damage. The maximum per cent

of grain damage was observed in the treatment of turmeric powder 5 per cent (90.67).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 25) revealed that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (51.50%) and it was at par with the treatment of lakke leaf powder 5 per cent with 51.83 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (90.50).

4.3.1.1.6 180 DAS

The data of 2007-08 after 180 DAS showed no grain damage due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (56.00%) and it was at par with the treatment of lakke leaf powder 5 per cent with 56.00 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (94.33) (Table 23).

Table 24 pertaining to data of 2008-09 indicated that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (55.67%) and it was at par with the treatment of lakke leaf powder 5 per cent with 56.33 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (94.00).

The pooled data of two year for per cent grain damage (Table 25) revealed that there was no grain damage in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf

powder 5 per cent (55.83%) and it was at par with the treatment of lakke leaf powder 5 per cent with 56.17 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of turmeric powder 5 per cent (94.17).

Thus, overall conclusion from the study on evaluation of plant products against *S. oryzae* on sorghum revealed that the plant products viz., sweet flag powder (*Acorus calamus* L.), custard apple seed powder (*Annona squamosa* L.), and Neem seed kernel powder (*Azadirachta indica*, A. juss) were the most effective in controlling of *S. oryzae* infestation. The treatments of neem leaf powder (*Azadirachta indica*, A. juss) and lakke leaf powder (*Vitex negundo* L.) also found effective, while kharanja leaf powder (*Pongamia glabra* L.), adsali leaf powder (*Ahdatoda vasica* L.), Tulsi leaf powder (*Ocimum basilicum* L.) and turmeric powder (*Curcuma longa* L.) were found to be least effective in preventing the pest infestation. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 5).

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. Sunilkumar (2003) also reported the similar results.

4.3.1.2 Per cent weight loss due to *S. oryzae* in sorghum

The data on per cent weight loss after grains treated with various plant products during 2007-08 (Table 26), 2008-09 (Table 27) and pooled data of two year (Table 28) revealed the trends of per cent weight loss at different days after storage as follows.

4.3.1.2.1 30 DAS

The data of 2007-08 after 30 DAS showed no weight loss due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple

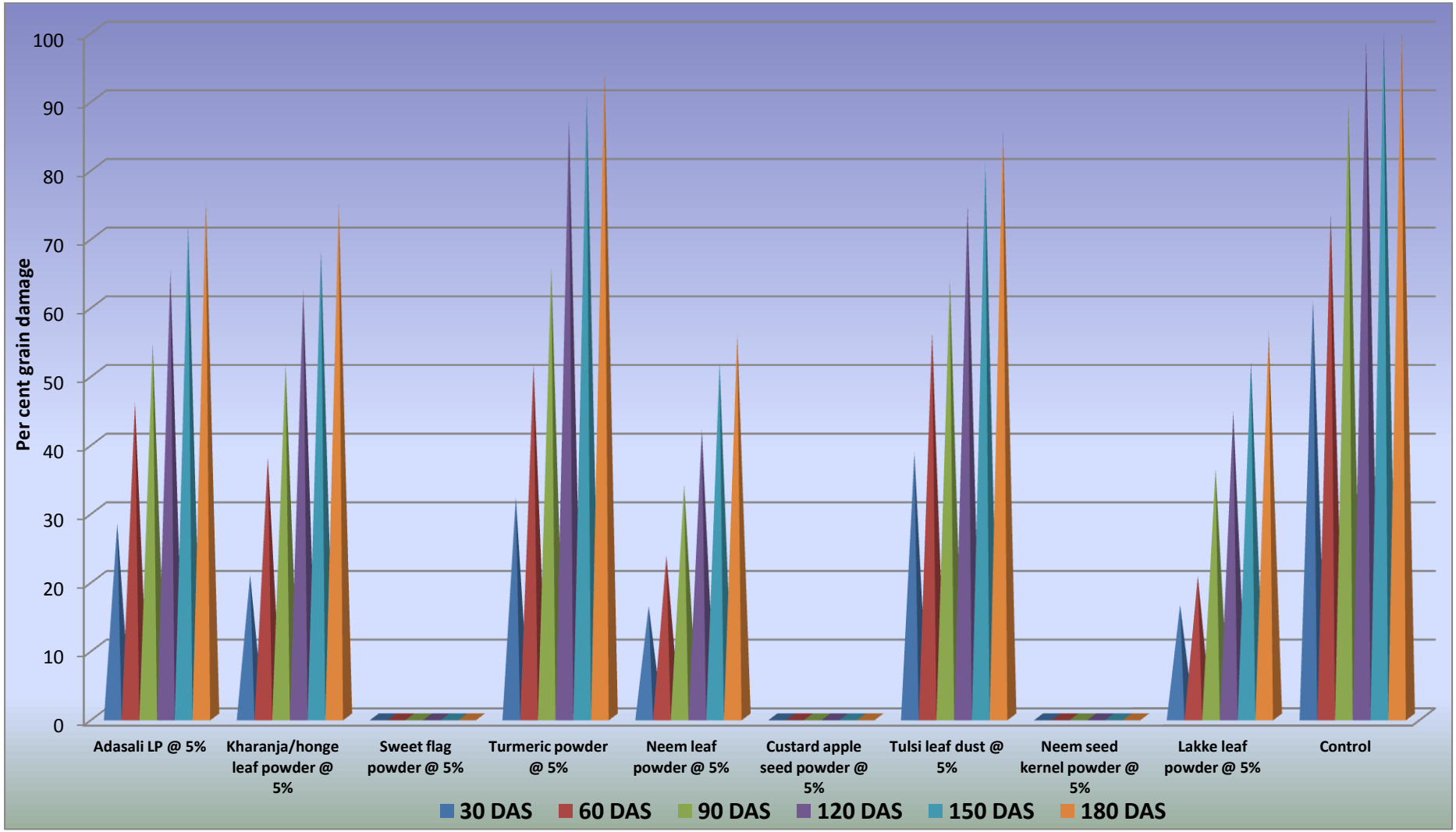


Figure 5: Per cent grain damage due to *S. oryzae* when treated with plant products (Pooled)

Table 26: Per cent weight loss due to *S. oryzae* in sorghum treated with various plant products 2007-08

Sr. No	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Adasali LP 5%	23.34e (15.67)*	35.24e (33.33)	40.80e (42.67)	44.60d (49.33)	45.75d (51.33)	46.89c (53.33)	39.76c (40.94)
2	Kharanja/honge leaf powder 5%	17.46d (9.00)	30.66d (26.00)	38.65d (39.00)	45.00d (50.00)	48.62d (56.33)	52.53e (63.00)	39.58bc (40.56)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	26.78f (20.33)	38.82f (39.33)	47.12g (53.67)	47.87f (55.00)	49.78e (58.33)	52.12de (62.33)	43.97c (48.17)
5	Neem leaf powder 5%	11.54b (4.00)	20.00c (11.67)	27.97b (22.00)	33.21b (30.00)	38.82b (39.33)	41.55b (44.00)	30.13b (25.17)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	31.50g (27.33)	41.38g (43.67)	45.97f (51.67)	46.32e (52.33)	48.62d (56.32)	51.47b (61.23)	44.31c (48.76)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakke leaf powder 5%	12.92c (5.00)	16.74b (8.33)	29.33c (24.00)	34.88c (32.67)	39.06b (39.67)	41.55b (44.00)	30.40b (25.61)
10	Control	44.89h (49.67)	46.32h (52.33)	49.20h (57.33)	52.36g (62.67)	52.53f (63.00)	53.73f (65.00)	49.78d (58.33)
	S.Em. ±	0.28	0.22	0.20	0.18	0.13	0.35	1.86
	CD at 5%	0.83	0.64	0.59	0.53	0.39	1.05	5.31
	CV %	4.95	3.21	2.62	2.10	1.39	3.50	3.30

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 27: Per cent weight loss due to *S. oryzae* in sorghum treated with various plant products 2008-09

Sr. No	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Adasali LP 5%	24.88e (17.67)*	36.45a (35.33)	41.96e (44.67)	45.75d (51.33)	46.89c (53.33)	48.04c (55.33)	40.92c (42.94)
2	Kharanja/honge leaf powder 5%	19.37d (11.00)	31.95d (28.00)	39.82d (41.00)	46.15d (52.00)	49.78d (58.33)	53.73e (65.00)	40.74c (42.56)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	28.18f (22.33)	39.99f (41.33)	48.27g (55.67)	49.02f (57.00)	50.94e (60.33)	53.31e (64.33)	45.11cd (50.17)
5	Neem leaf powder 5%	14.18b (6.00)	21.72c (13.67)	29.33b (24.00)	34.45b (32.00)	39.99b (41.33)	42.71b (46.00)	31.44b (27.17)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	32.77g (29.33)	42.53g (45.67)	47.12f (53.67)	47.47e (54.33)	49.38d (58.32)	52.65d (63.23)	46.46de (50.76)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakke leaf powder 5%	15.34c (7.00)	18.72b (10.33)	30.66c (26.00)	36.09c (34.67)	40.22b (41.67)	42.71b (46.00)	31.69b (27.61)
10	Control	45.97h (51.67)	47.47h (54.33)	50.36h (59.33)	53.55g (64.67)	53.73f (65.00)	54.94f (67.00)	50.94e (60.33)
	S.Em. ±	0.25	0.30	0.19	0.16	0.13	0.15	1.85
	CD at 5%	0.74	0.90	0.57	0.49	0.37	0.42	5.41
	CV %	4.10	2.83	2.38	1.79	1.31	3.33	2.70

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 28: Per cent weight loss due to *S. oryzae* in sorghum treated with various plant products (Pooled of 2007-08 & 2008-09)

Sr. No	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Adasali LP 5%	24.12e (16.67)*	35.85e (34.33)	41.38e (43.67)	45.17d (50.33)	46.32c (52.33)	47.47c (54.33)	40.34c (41.94)
2	Kharanja/honge leaf powder 5%	18.44d (10.00)	31.31d (27.00)	39.23d (40.00)	45.57de (51.00)	49.20d (57.33)	53.13e (64.00)	40.16c (41.56)
3	Sweet flag powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
4	Turmeric powder 5%	27.49f (21.33)	39.41f (40.33)	47.70g (54.67)	48.45f (56.00)	50.36e (59.33)	52.71de (63.33)	44.54d (49.17)
5	Neem leaf powder 5%	12.92b (5.00)	20.88c (12.67)	28.56b (23.00)	33.21b (31.00)	39.41b (40.33)	42.13b (45.00)	30.79b (26.17)
6	Custard apple seed powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
7	Tulsi leaf dust 5%	32.14g (28.33)	41.96g (44.67)	46.55f (52.67)	46.89e (53.33)	49.20d (57.32)	52.06d (62.23)	44.89d (49.76)
8	Neem seed kernel powder 5%	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
9	Lakkeleaf powder 5%	14.18c (6.00)	17.76b (9.33)	30.00c (25.00)	35.49c (33.67)	39.64b (40.67)	42.13b (45.00)	31.05b (26.61)
10	Control	45.40h (50.67)	46.89h (53.33)	49.78h (58.33)	52.95g (63.67)	53.13f (64.00)	54.33f (66.00)	50.36e (59.33)
	S.Em. ±	0.32	0.27	0.24	0.43	0.20	0.24	1.02
	CD at 5%	1.04	0.88	0.76	1.36	0.63	0.68	2.87
	YxT							
	S.Em. ±	0.27	0.21	0.20	0.17	0.13	0.35	0.23
	CD at 5%	0.76	0.60	0.56	0.49	0.37	NS	0.66
	CV %	4.51	3.02	2.50	1.94	1.35	3.42	2.97

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (4.00%) and it was followed by the treatment of lakke leaf powder 5 per cent with 5.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of tulsi leaf powder 5 per cent (27.33) and it was followed by the treatment of turmeric powder 5 per cent (20.33%) (Table 26).

Data presented in Table 27 for 2008-09 indicated that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (6.00%) and it was followed by the treatment of lakke leaf powder 5 per cent with 7.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of
tulsi leaf powder 5 per cent (29.33) and it was followed by the treatment of turmeric powder 5 per cent (22.33%).

The pooled data of two year for per cent weight loss (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (5.00%) and it was followed by the treatment of lakke leaf powder 5 per cent with 6.00 per cent grain damage. The maximum per cent of weight loss was observed in tulsi leaf powder 5 per cent (28.33) and it followed by the turmeric powder 5 per cent (21.33%).

4.3.1.2.2 60 DAS

The data of 2007-08 after 60 DAS showed no weight loss due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (8.33%) and it was followed by the treatment of neem leaf powder 5 per cent with 11.67 per cent weight loss. The

maximum per cent of weight loss was observed in the treatment of tulsi leaf powder 5 per cent (43.67) (Table 26).

Data presented in Table 27 for 2008-09 indicated that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Lakke leaf powder 5 per cent stood second (10.33%) and it was followed by the treatment of neem leaf powder 5 per cent with 13.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of tulsi leaf powder 5 per cent (45.67).

The pooled data of two year (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was lakke leaf powder 5 per cent (9.33%) and it was followed by the treatment of neem leaf powder 5 per cent (12.67%). The maximum per cent of weight loss was recorded in the treatment of tulsi leaf powder 5 per cent (44.67).

4.3.1.2.3 90 DAS

The data of 2007-08 after 90 DAS showed no weight loss due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (22.00%) and it followed by the treatment of lakke leaf powder 5 per cent with 24.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (53.67) (Table 26).

Data presented in Table 27 for 2008-09 indicated that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent with 24.00 per cent weight loss stood second and it was followed by the treatment of lakke leaf powder 5 per cent (26.00%). The

maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (55.67).

The pooled data over two year (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (23.00%) and it followed by the treatment of lakke leaf powder 5 per cent with 25.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (54.67).

4.3.1.2.4 120 DAS

The data of 2007-08 after 120 DAS showed no weight loss due to rice weevil was observed in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (30.00%) and it was at followed by the treatment of lakke leaf powder 5 per cent with 32.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (55.00) (Table 26).

Data presented in Table 27 for 2008-09 indicated that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (32.00%) and it was followed by the treatment of lakke leaf powder 5 per cent with 34.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (57.00).

The pooled data over two year (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (31.00%) and it followed by the treatment of lakke leaf powder 5 per cent with 33.67 per cent

weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (56.00).

4.3.1.2.5 150 DAS

The data of 2007-08 after 150 DAS showed no weight loss due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (39.33%) and it was at par with the treatment of lakke leaf powder 5 per cent with 39.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (58.33) (Table 26).

The data of 2008-09 presented in Table 27 showed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (41.33%) and it was at par with the treatment of lakke leaf powder 5 per cent with 41.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (60.33).

The pooled data over two year for per cent weight loss (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (40.33%) and it was at par with the treatment of lakke leaf powder 5 per cent with 40.67 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (59.33).

4.3.1.2.6 180 DAS

The data of 2007-08 after 180 DAS showed no weight loss due to rice weevil in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf

powder 5 per cent stood second (44.00%) and the treatment of lakke leaf powder 5 per cent with 44.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (62.33) (Table 26).

Data presented in Table 27 for 2008-09 indicated that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. Neem leaf powder 5 per cent stood second (46.00%) and it was at par with the treatment of lakke leaf powder 5 per cent with 46.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (64.33).

The pooled data over two year for per cent weight loss (Table 28) revealed that there was no weight loss in the treatments of sweet flag powder 5 per cent, custard apple seed powder 5 per cent and neem seed kernel powder 5 per cent. While, second best treatment was neem leaf powder 5 per cent (45.00%) and it was at par with the treatment of lakke leaf powder 5 per cent with 45.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of turmeric powder 5 per cent (63.33).

Thus, overall conclusion from the study on per cent of weight loss from sorghum treated with various plant products against *S. oryzae* can be drawn that the plant products *viz*., sweet flag powder, custard apple seed powder, and neem seed kernel powder were the most effective in controlling of *S. oryzae* infestation. The treatment of lakke leaf powder, neem leaf powder and Kharanja leaf powder also found effective, while thus adsali leaf powder, tulsi leaf powder and turmeric powder where found to be least effective in preventing the weight loss due to *S. oryzae*. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 6).

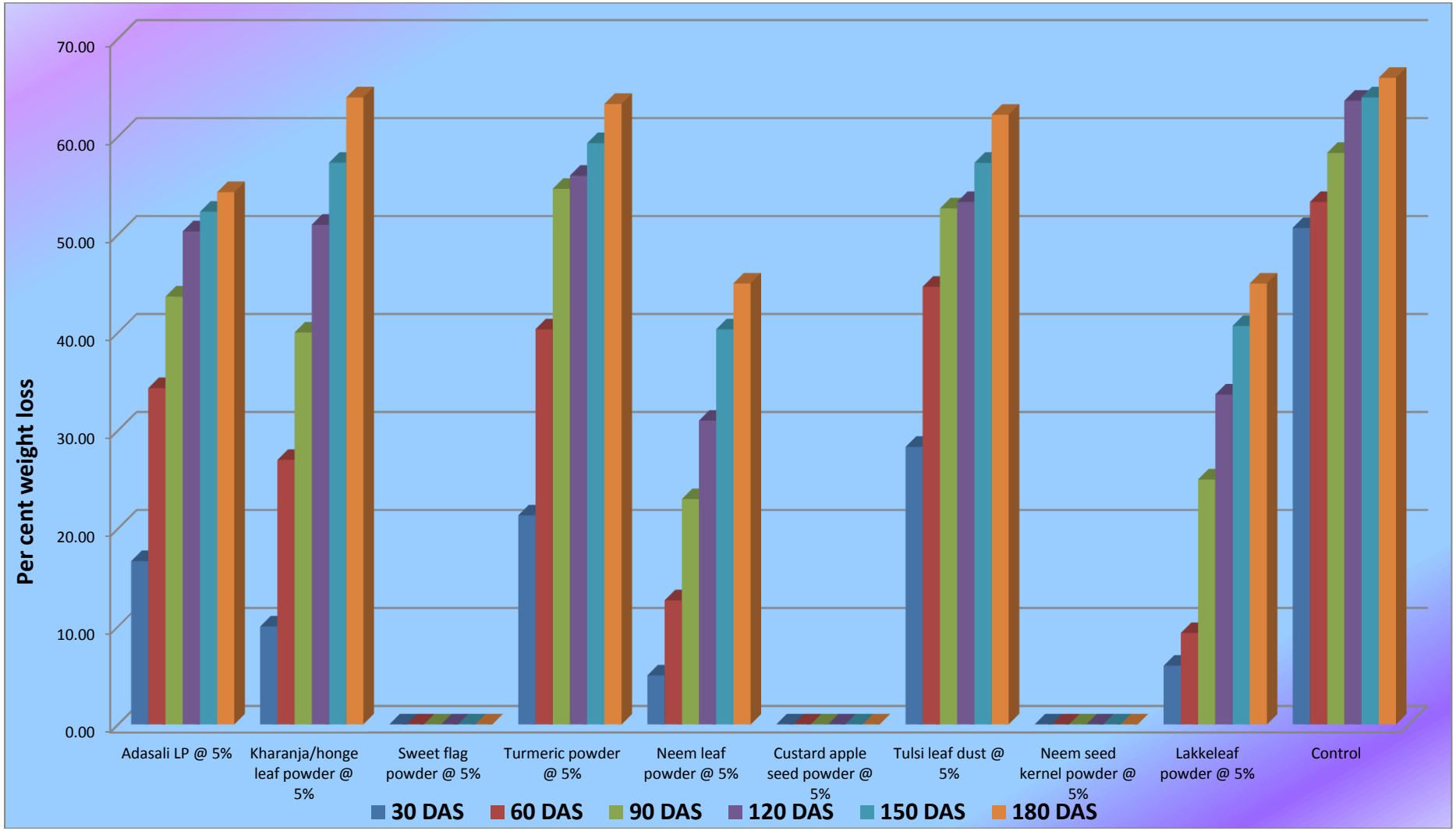


Figure 6: Per cent weight loss due to *S. oryzae* in sorghum treated with various plant products (Pooled)

Thus present finding is in confirmation with Kalasagond (1998) found that sweet flag rhizome powder at 0.6 per cent caused cent per cent mortality of *S. oryzae* and complete protection unto 240 days. Whereas Rama Rao and Sarangi, 1998 reported that Sweet flag powder 5 per cent was found to be most effective grain protectants even up to 45 days after treatment resulting in 100 per cent mortality.

Yevoor (2003) observed that sweet flag powder 2 per cent caused zero per cent grain damage and weight loss and per cent adult mortality of *S. oryzae* up to 60 days after storage in sorghum against *S. oryzae*. 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). Sunilkumar (2003) concluded that custard seed powder at 1 per cent was effective in controlling *S. oryzae* on sorghum grains up to 90 days after storage.

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

4.3.2 Efficacy of various inert materials against *S. oryzae* in sorghum

4.3.2.1 Per cent grain damage due to *S. oryzae* in sorghum treated with inert materials

The data on per cent grain damage after grains treated with various inert materials during 2007-08 (Table 29), 2008-09 (Table 30) and pooled data of two year (Table 31) at different days after storage of sorghum as follows:

Table 29: Grain damage due to *S. oryzae* in sorghum treated with inert materials 2007-08

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	47.42d (54.25)	54.22c (67.00)	60.22d (75.25)	64.35d (81.25)	66.04d (83.50)	70.15d (88.50)	60.52d (74.96)
3	Sawdust 10%	44.69c (49.50)	56.15d (69.00)	58.68d (73.00)	63.61d (80.25)	67.01d (84.75)	73.58e (92.00)	60.62d (74.75)
4	Sand 10%	37.59b (37.25)	51.48b (61.25)	54.62c (66.50)	59.01c (73.50)	61.35c (77.00)	67.45c (85.25)	55.25c (66.79)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	16.63b (8.25)	20.25b (12.00)	22.14b (14.25)	25.62b (18.75)	14.24b (8.88)
6	Control	53.71e (65.00)	58.99e (73.50)	70.87e (89.25)	77.74e (95.50)	84.96e (99.00)	89.56f (100.00)	72.64e (87.04)
	S.Em. ±	0.61	0.38	0.87	0.64	0.93	0.64	2.11
	CD at 5%	1.81	1.13	2.58	1.91	2.76	1.90	6.15
	CV %	3.97	2.05	3.99	2.70	3.70	2.36	3.20

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 30: Grain damage due to *S. oryzae* in sorghum treated with inert materials 2008-09

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	43.41d (47.25)	55.38c (67.75)	60.22e (75.25)	65.10e (82.25)	66.82de (84.50)	71.07d (89.50)	60.33e (74.42)
3	Sawdust 10%	40.32c (41.75)	56.77d (70.00)	58.67de (73.00)	64.52de (81.50)	67.82e (85.75)	74.68e (93.00)	60.45de (74.17)
4	Sand 10%	36.35b (35.50)	52.07b (62.25)	54.62c (66.50)	59.66c (74.50)	62.04c (78.00)	68.28c (86.25)	55.54c (67.17)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	17.18b (8.75)	20.69b (12.50)	21.96b (14.00)	26.35b (19.75)	14.50b (9.17)
6	Control	51.49e (61.25)	59.65e (74.50)	70.87f (89.25)	79.21f (96.50)	88.23f (99.75)	89.56f (100.00)	73.17f (86.88)
	S.Em. ±	0.56	0.36	0.83	0.64	0.82	0.66	2.32
	CD at 5%	1.66	1.07	2.45	1.91	2.43	1.96	6.75
	CV %	3.88	1.92	3.78	2.67	3.19	2.399	3.01

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values..

Table 31: Grain damage due to *S. oryzae* in sorghum treated with inert materials (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	45.41d (50.75)	55.15c (67.38)	60.22d (75.25)	64.72d (81.75)	66.43d (84.00)	70.61d (89.00)	59.43d (74.69)
3	Sawdust 10%	42.46c (45.63)	56.46d (69.50)	58.68d (73.00)	64.07d (80.88)	67.42d (85.25)	74.13e (92.50)	59.44d (74.46)
4	Sand 10%	37.07b (36.38)	51.78b (61.75)	54.62c (66.50)	59.33c (74.00)	61.69c (77.50)	67.87c (85.75)	54.39c (66.98)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	16.91b (8.50)	20.47b (12.25)	22.05b (14.13)	25.98b (19.25)	14.37b (9.02)
6	Control	52.60e (63.13)	59.32e (74.00)	70.87e (89.25)	78.48e (96.00)	86.89e (99.38)	89.56f (100.00)	68.90e (86.96)
	S.Em. ±	0.98	0.25	0.56	0.43	0.62	0.44	1.49
	CD at 5%	3.56	0.72	1.61	1.24	1.77	1.25	4.24
	T X Y							
	S.Em. ±	0.58	0.72	0.85	0.64	0.88	0.65	0.68
	CD at 5%	1.68	NS	NS	NS	NS	NS	2.03
	CV %	3.93	1.99	3.89	2.68	3.45	2.35	3.10

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

4.3.2.1.1 30 DAS

The data of 2007-08 after 30 DAS shows no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Next best treatment was sand 10 per cent with 37.25 per cent grain damage followed by saw dust 10 per cent (49.50%). The highest per cent of grain damage was 54.25 per cent observed in the treatment of cow dung ash 10 per cent. While control recorded 65.00 per cent of grain damage (Table 29).

The data of 2008-09 (Table 30) indicated that there was no grain damage in the treatments kaolinite clay 10 per cent and bentonite 10 per cent. Sand 10 per cent stood second (35.50%) and it was followed by the treatment of saw dust 10 per cent with 41.75 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of cow dung ash 10 per cent (47.25%).

The pooled data for per cent grain damage over two year (Table 31) revealed that there was no grain damage in treatments of kaolinite clay 10 per cent and bentonite 10 per cent. While, second best treatment was sand 10 per cent (36.38%) and it was followed by the treatment of saw dust 10 per cent with 45.63 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of cow dung ash 10 per cent (50.75%) as compared to control (63.13%).

4.3.2.1.2 60 DAS

The data of 2007-08 after 60 DAS showed no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Next best treatment was sand 10 per cent (61.25%) followed by cow dung ash 10 per cent (67.00%). The highest per cent of grain damage was 69.00 per cent observed in the treatment of saw dust 10 per cent. While control recorded 73.50 per cent of grain damage (Table 29).

Table 30 pertaining to data of 2008-09 indicated that there was no grain damage in the treatments of kaolinite clay 10 per cent and bentonite

10 per cent. Sand 10 per cent stood second with 62.25 per cent and it was followed by the treatment of cow dung ash 10 per cent with 67.75 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent (70.00%) as compared to control (74.50%).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 31) revealed that there was no grain damage in treatments of kaolinite clay 10 per cent and bentonite 10 per cent. While, second best treatment was sand 10 per cent (61.75%) and it was followed by the treatment of cow dung ash 10 per cent with 67.38 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent (69.50%) as compared to control (74.00%).

4.3.2.1.3 90 DAS

The data of 2007-08 after 90 DAS showed no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (8.25%). Next best treatment was sand 10 per cent (66.50%) followed by saw dust 10 per cent (73.00%). The highest per cent of grain damage was 75.25 per cent observed in the treatment of cow dung ash 10 per cent. While control recorded 89.25 per cent of grain damage (Table 29).

The data of 2008-09 (Table 30) indicated that there was no grain damage in the treatments kaolinite clay 10 per cent followed by bentonite 10 per cent (8.75%). Sand 10 per cent stood next best treatment with 66.50 per cent and it was followed by the treatment of saw dust 10 per cent with 73.00 per cent grain damage. The highest damage was observed in the treatment of cow dung ash 10 per cent (75.25) as compared to control (89.25%).

The pooled data for per cent grain damage over two year 2007-08 and 2008-09 (Table 31) revealed that there was no grain damage in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (8.50%). The next best treatment was sand 10 per cent (66.50%) and it was followed by the treatment of saw dust 10% per cent with 73.00 per cent grain

damage. The maximum per cent of grain damage was observed in the treatment of cow dung ash 10 per cent (75.25) as compared to control (89.25%).

4.3.2.1.4 120 DAS

The data of 2007-08 after 120 DAS show no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (12.00%). Next best treatment was sand 10 per cent (73.50%) followed by saw dust 10 per cent (80.25%). The highest per cent of grain damage was 81.25 observed in the treatment of cow dung ash 10 per cent. While control recorded 95.50 per cent of grain damage (Table 29).

Table 30 pertaining to data of 2008-09 indicated that there was no grain damage in treatment of kaolinite clay 10 per cent followed by bentonite 10 per cent (12.50%). Sand 10 per cent stood next best treatment with 74.50 per cent and it was followed by the treatment of saw dust 10 per cent with 81.50 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of cow dung ash 10 per cent (82.25) as compared to control (96.50%).

The pooled data for per cent grain damage over two year 2007-08 and 2008-09 (Table 31) revealed that there was no grain damage in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (12.25%). The next best treatment was sand 10 per cent (74.00%) and it was followed by the treatment of saw dust 10 per cent with 80.88 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of cow dung ash 10 per cent (81.75) as compared to control (96.00%).

4.3.2.1.5 150 DAS

The data of 2007-08 depicted in Table 29 show that there was no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (14.25%). Next best treatment was sand 10

per cent (77.00%) followed by cow dung ash 10 per cent (83.50%). The highest per cent of grain damage was observed in the treatment of saw dust 10 per cent (84.75%). While, control recorded 99.00 per cent of grain damage.

The data of 2008-09 depicted in Table 30 showed that there was no grain damage was observed in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (14.00%). Sand 10 per cent stood next best treatment with 78.00 per cent grain damage and it was followed by the treatment of cow dung ash 10 per cent (84.50%). The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent with 85.75 per cent as compared to 99.75 per cent in control.

The pooled data over for per cent grain damage of two year 2007-08 and 2008-09 (Table 31) revealed that there was no grain damage in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (14.13%). Third best treatment was sand 10 per cent with 77.50 per cent grain damage and it was followed by the treatment of cow dung ash 10 per cent (84.00%). The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent with 85.25 per cent over the control (99.38%).

4.3.2.1.6 180 DAS

The data of 2007-08 after 180 DAS showed no grain damage due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (18.75%). Next best treatment was sand 10 per cent (85.25%) followed by cow dung ash 10 per cent (88.50%). The highest per cent of grain damage was 92.00 per cent observed in the treatment of saw dust 10 per cent. While, control recorded 100.00 per cent of grain damage (Table 29).

Table 30 pertaining to data of 2008-09 indicates that there was no grain damage in the treatments kaolinite clay 10 per cent followed by bentonite 10 per cent (20.00%). Sand 10 per cent stood next best treatment

with 86.25 per cent and it was followed by the treatment of cow dung ash 10 per cent with 89.50 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent (93.00) as compared to control (100.00%).

The pooled data for per cent grain damage over two year 2007-08 and 2008-09 (Table 31) revealed that there was no grain damage in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (19.25%). The next best treatment was sand 10 per cent (85.75%) and it was followed by the treatment of cow dung ash 10 per cent with 89.00 per cent grain damage. The maximum per cent of grain damage was observed in the treatment of saw dust 10 per cent (92.50) as compared to control (100.00%).

Thus, overall conclusion from the study on inert materials against *S. oryzae* on sorghum can be drawn that most effective inert materials were kaolinite clay 10 per cent recorded no grain damage and bentonite clay 10 per cent recorded 9.02 per cent grain damage. Whereas, the treatment of sand 10 per cent (66.98%), saw dust 10 per cent (74.46%) and cow dung ash 10 per cent (74.69%) found least effective in preventing the grain damage. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 7).

The present findings are supported by the Yevoor (2003) work stated that kaolinite 10 per cent caused up to 90 per cent mortality of adult at 28 days after release and less per cent grain damage and weight loss up to 90 DAS.

4.3.2.2 Per cent weight loss due to *S. oryzae* in sorghum treated with inert materials

The data on per cent weight loss after grains treated with various inert materials during 2007-08 (Table 32), 2008-09 (Table 33) and pooled data of two year (Table 34) revealed the trends of per cent weight loss at different days after storage of sorghum as follows.

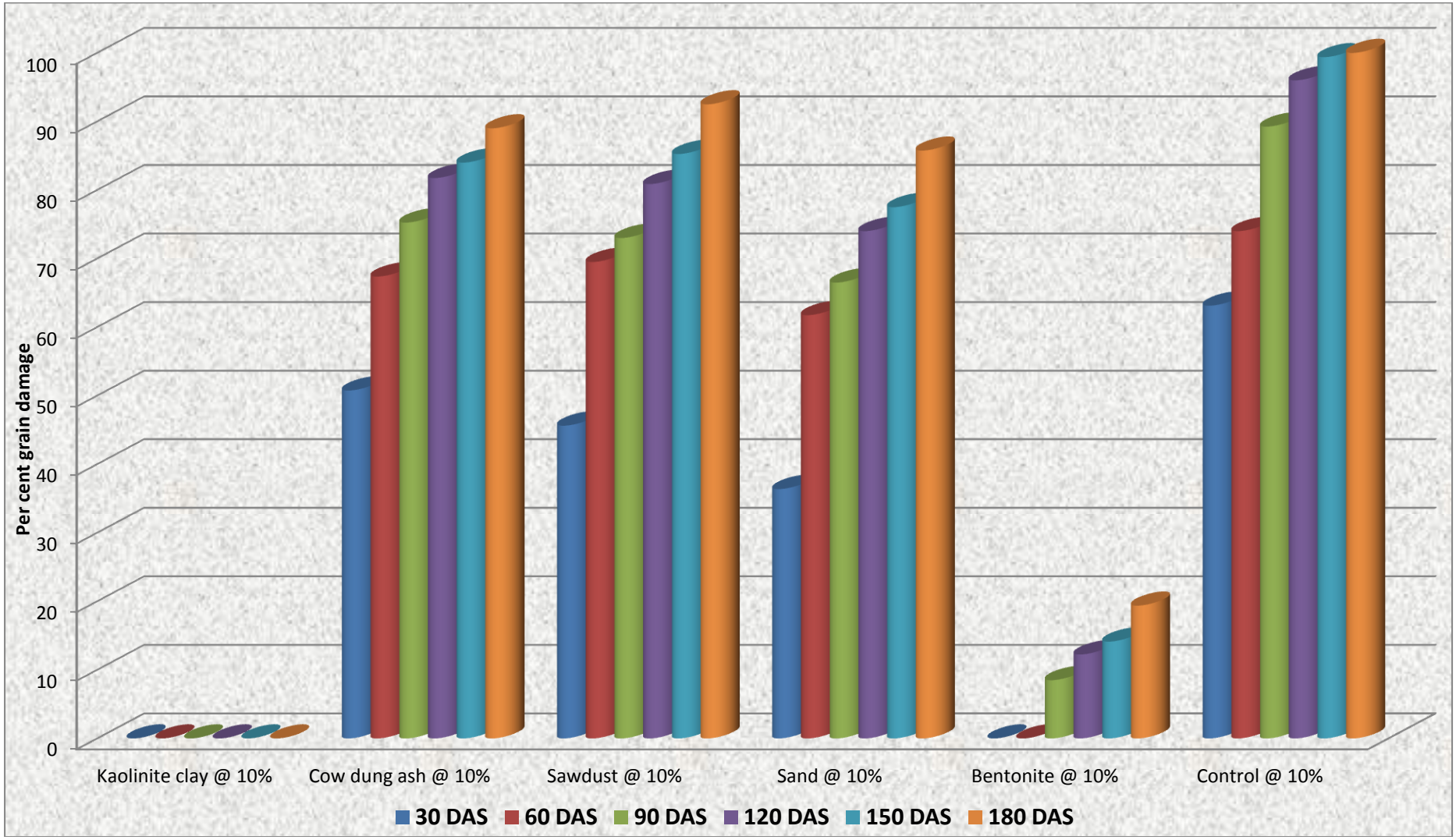


Figure 7: Per cent grain damage due to *S. oryzae* in sorghum treated with inert materials (Pooled)

Table 32: Per cent weight loss due to *S. oryzae* in sorghum treated with inert materials 2007-08

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	18.72d (10.25)	28.56c (23.00)	34.02e (31.25)	37.64d (37.25)	38.94d (39.50)	41.84d (44.50)	33.77d (30.96)
3	Sawdust 10%	13.56c (5.50)	30.00d (25.00)	32.58d (29.00)	37.05d (36.25)	39.70d (40.75)	43.85e (48.00)	33.65d (30.75)
4	Sand 10%	10.47b (3.25)	24.58b (17.25)	28.32c (22.50)	32.90c (29.50)	35.06c (33.00)	39.99c (41.25)	29.67c (24.46)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	10.31b (3.25)	15.89b (7.55)	16.74b (8.33)	19.91b (11.69)	12.05b (5.14)
6	Control	30.66e (26.00)	35.97e (34.50)	45.17f (50.25)	48.73e (56.50)	50.77e (60.00)	51.35f (61.00)	43.85e (48.04)
	S.Em. ±	0.17	0.09	0.20	0.22	0.19	0.20	0.49
	CD at 5%	0.50	0.27	0.58	0.65	0.57	0.59	1.44
	CV %	3.53	1.72	3.55	3.68	3.01	2.66	3.24

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 33: Per cent weight loss due to *S. oryzae* in sorghum treated with inert materials 2008-09

Sr.No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	10.47c (3.25)	29.20c (23.75)	34.02e (31.25)	38.23d (38.25)	39.52d (40.50)	42.42d (45.50)	33.46d (30.42)
3	Sawdust 10%	16.22d (7.75)	30.66d (26.00)	32.58d (29.00)	37.76d (37.50)	40.28d (41.75)	44.43e (49.00)	34.33d (31.83)
4	Sand 10%	7.04b (1.50)	25.33b (18.25)	28.32c (22.50)	33.52c (30.50)	35.67c (34.00)	40.57c (42.25)	29.87c (24.83)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	10.94b (3.65)	15.24b (6.95)	16.22b (7.88)	20.36b (12.15)	12.95b (5.11)
6	Control	28.18e (22.25)	36.57e (35.50)	45.17f (50.25)	49.31e (57.50)	51.24e (60.75)	51.35f (61.00)	43.80e (47.88)
	S.Em. ±	0.16	0.09	0.19	0.21	0.19	0.22	0.50
	CD at 5%	0.48	0.26	0.59	0.63	0.56	0.64	1.45
	CV %	3.24	1.60	3.30	3.50	2.87	2.76	2.97

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 34: Per cent weight loss due to *S. oryzae* in sorghum treated with various inert materials (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Kaolinite clay 10%	0.41a (0.00)*	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)	0.41a (0.00)
2	Cow dung ash 10%	15.12d (6.75)	28.93c (23.38)	34.02e (31.25)	37.94e (37.75)	39.23d (40.00)	42.13d (45.00)	33.65d (30.69)
3	Sawdust 10%	14.89c (6.63)	30.33d (25.50)	32.58d (29.00)	37.41d (36.88)	39.99e (41.25)	44.14e (48.50)	34.02d (31.29)
4	Sand 10%	8.91b (2.38)	24.95b (17.75)	30.33c (22.50)	33.21c (30.00)	35.37c (33.50)	40.28c (41.75)	29.80c (24.65)
5	Bentonite 10%	0.41a (0.00)	0.41a (0.00)	10.63b (3.45)	15.56b (7.25)	16.54b (8.11)	20.18b (11.92)	12.95b (5.12)
6	Control	29.40e (24.13)	36.27e (35.00)	45.17f (50.25)	49.02f (57.00)	50.94f (60.38)	51.35f (61.00)	43.80e (47.96)
	S.Em. ±	0.12	0.14	0.14	0.15	0.13	0.14	0.34
	CD at 5%	0.35	0.51	0.39	0.43	0.38	0.41	0.95
	T X Y							
	S.Em. ±	0.17	0.09	0.19	0.22	0.19	0.21	0.18
	CD at 5%	NS	NS	NS	NS	NS	NS	0.54
	CV %	3.38	1.66	3.43	3.59	2.94	2.71	3.03

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

4.3.2.2.1 30 DAS

Table 32, pertaining to data of 2007-08 indicate that there was no weight loss in treatments kaolinite clay 10 per cent and bentonite 10 per cent. Sand 10 per cent was stood second (3.25%). The maximum per cent of weight loss was observed in cow dung ash 10 per cent (10.25%) and it was at par with the treatment of saw dust 10 per cent (5.50%). Whereas, the control recorded 26.00 per cent weight loss.

The data of 2008-09 after 30 DAS show no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Next best treatment was sand 10 per cent (1.50%) followed by cow dung ash 10 per cent (3.25%). The highest per cent of weight loss was 7.75 per cent observed in the treatment of sawdust 10 per cent. While, control recorded 22.25 per cent of weight loss (Table 33).

The data on pooled for per cent weight loss of two year 2007-08 and 2008-09 (Table 34) revealed that there was no weight loss in treatments of kaolinite clay 10 per cent and bentonite 10 per cent. While, second best treatment was sand 10 per cent (2.38%). The maximum per cent of weight loss was observed in the treatment of cow dung ash 10 per cent (6.75%) and it was at par with the treatment of sawdust 10 per cent (6.63%) as compared to control (24.13%).

4.3.2.2.2 60 DAS

The data of 2007-08 depicted in Table 32 showed that there was no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Next best treatment was sand 10 per cent (17.25%). The highest per cent of weight loss was 25.00 per cent observed in the treatment of saw dust 10 per cent and it was followed by the treatment of cow dung ash 10 per cent (23.00%). While, control recorded 34.50 per cent of weight loss.

The data of 2008-09 presented in Table 33 showed that there

was no weight loss was observed in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Sand 10 per cent stood second with 18.25 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent (26.00%) and it was followed by the treatment of cow dung ash 10 per cent with 23.75 per cent weight loss. While control recorded 35.50 per cent weight loss.

The pooled data for per cent weight loss over two year (Table 34) revealed that there was no weight loss in the treatments of kaolinite clay 10 per cent and bentonite 10 per cent. Second best treatment was sand 10 per cent with 17.75 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent with 25.50 and it was followed by the treatment of cow dung ash 10 per cent having 23.38 per cent weight loss as compared to control (35.00%).

4.3.2.2.3 90 DAS

The data of 2007-08 depicted in Table 32 showed that there was no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (3.25%). Next best treatment was sand 10 per cent (22.50%). The highest per cent of weight loss was observed in the treatment of cow dung ash 10 per cent (31.25%) followed by the treatment of saw dust 10 per cent (29.00%). While, control recorded 50.25 per cent of weight loss.

The data of 2008-09 depicted in Table 33 showed that there was no weight loss was observed in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (3.65%). Sand 10 per cent stood second with 22.50 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of 10 per cent cow dung ash (31.25%) and it was followed by the treatment of saw dust 10 per cent with 29.00 per cent weight loss. While, control recorded 50.25 per cent weight loss.

The pooled data for per cent weight loss over two year 2007-08

and 2008-09 (Table 34) revealed that there was no weight loss in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (3.45%). Second best treatment was sand 10 per cent with 22.50 per cent weight loss. The maximum per cent of weight loss was observed in cow dung ash 10 per cent (31.25%) and it was followed by the treatment of saw dust 10 per cent having 29.00 per cent weight loss as compared to control (50.25%).

4.3.2.2.4 120 DAS

The data of 2007-08 depicted in Table 32 showed that there was no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (7.55%). Next best treatment was sand 10 per cent (29.50%). The highest per cent of weight loss was observed in the treatment of cow dung ash 10 per cent (37.25%) and it was at par with the treatment of saw dust 10 per cent (36.25%). While, control recorded 56.50 per cent of weight loss.

The data of 2008-09 depicted in Table 33 showed that there was no weight loss was observed in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (6.95%). Sand 10 per cent stood second with 30.50 per cent. The maximum per cent of weight loss was observed in the treatment of cow dung ash 10 per cent (38.25%) and it was at par with the treatment of saw dust 10 per cent with 37.50 per cent weight loss. While control recorded 57.50 per cent

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 34) revealed that there was no weight loss in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (7.25%). Second best treatment was sand 10 per cent with 30.00 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of cow dung ash 10 per cent (37.75%) and it was followed by the treatment of saw dust 10 per cent having 36.88 per cent weight loss as compared to control (57.00%).

4.3.2.2.5 150 DAS

The data of 2007-08 depicted in Table 32 showed that there was no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (8.33%). Next best treatment was sand 10 per cent (33.00%). The highest per cent of weight loss was observed in the treatment of saw dust 10 per cent (40.75%) and it was followed by the treatment of cow dung ash 10 per cent (39.50%). While, control recorded 60.00 per cent of weight loss.

The data of 2008-09 depicted in Table 33 showed that there was no weight loss was observed in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (7.88%). Sand 10 per cent stood second with 34.00 per cent. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent (41.75%) and it was followed by the treatment of cow dung ash 10 per cent with 40.50 per cent weight loss. While, control recorded 60.75 per cent weight loss.

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 34) revealed that there was no weight loss in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (8.11%). Second best treatment was sand 10 per cent with 33.50 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent (41.25%) and it was at par with the treatment of cow dung ash 10 per cent having 40.00 per cent weight loss as compared to control (60.38%).

4.3.2.2.6 180 DAS

The data of 2007-08 depicted in Table 32 showed that there was no weight loss due to rice weevil in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (11.69%). Next best treatment was sand 10 per cent with 41.25 per cent. The highest per cent of weight loss was

observed in the treatment of saw dust 10 per cent (48.00%) and it was followed by the treatment of cow dung ash 10 per cent having 44.50 per cent weight loss. While, control recorded 61.00 per cent of weight loss.

The data of 2008-09 depicted in Table 33 showed that there was no weight loss was observed in the treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (12.15%). Sand 10 per cent stood third with 42.25 per cent. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent (49.00%) and it was followed by the treatment of cow dung ash 10 per cent with 45.50 per cent weight loss. While, control recorded 61.00 per cent of weight loss.

The pooled data for per cent weight loss over two year (Table 34) revealed that there was no weight loss in treatments of kaolinite clay 10 per cent followed by bentonite 10 per cent (11.92%). Third best treatment was sand 10 per cent with 41.75 per cent weight loss. The maximum per cent of weight loss was observed in the treatment of saw dust 10 per cent (48.50%) and it was at par with the treatment of cow dung ash 10 per cent having 45.00 per cent weight loss as compared to control (61.00%).

Thus, overall conclusion from the study on inert materials against *S. oryzae* on sorghum can be drawn that most effective inert materials was kaolinite clay 10 per cent recorded no weight loss. While, bentonite clay 10 per cent stood second with 5.12 per cent weight lost. Whereas the treatment of sand 10 per cent (24.65%), cow dung ash 10 per cent (30.69%) and saw dust 10 per cent (31.29%) found least effective in preventing the weight loss. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 8).

Present findings are in confirmation with the findings of Yevoor (2003) who opined that kaolinite 10 per cent caused up to 90 per cent mortality of adult at 28 days after release and less per cent grain damage and weight loss up to 90 DAS.

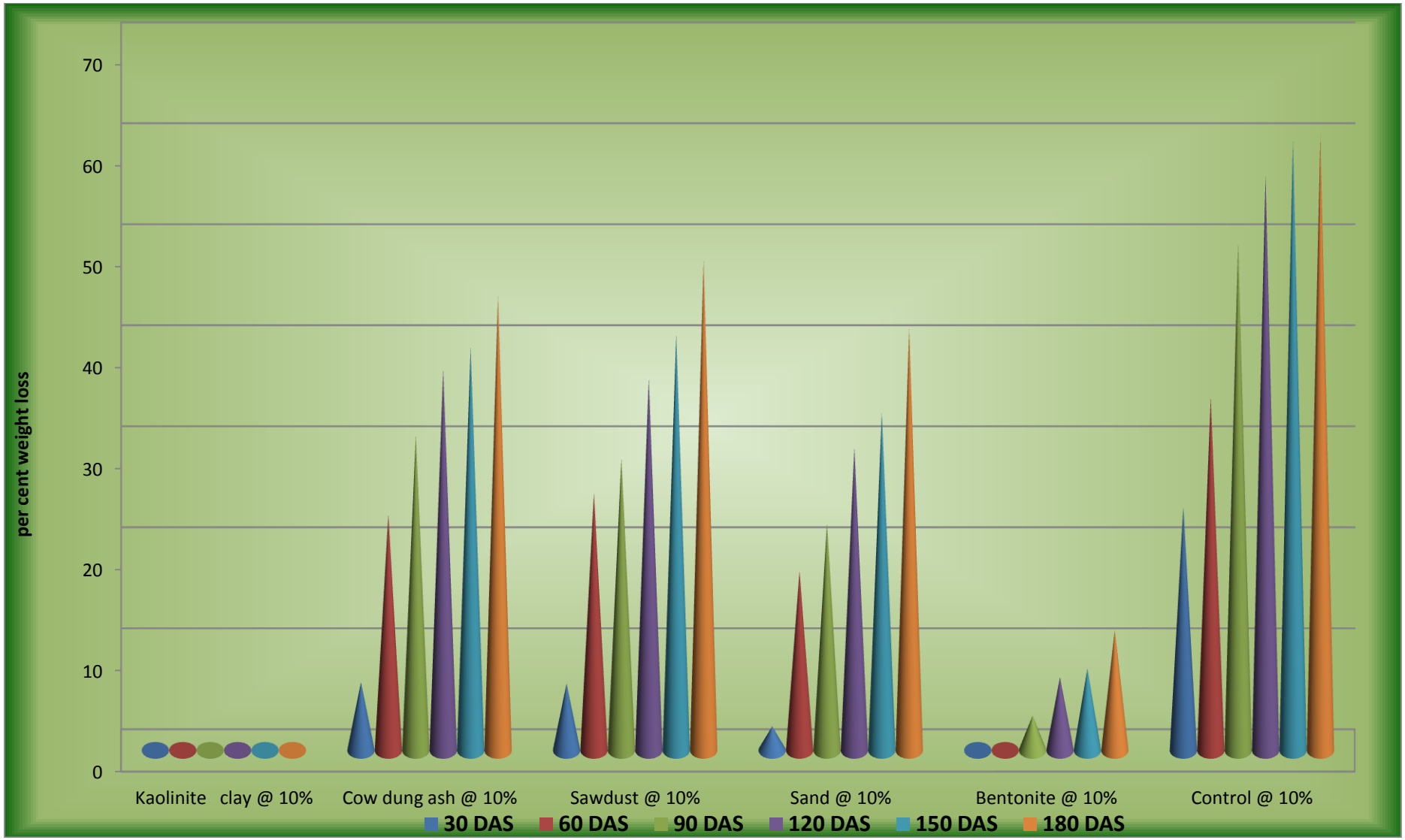


Figure 8: Per cent weight loss due to *S. oryzae* in sorghum treated with various inert materials (Pooled)

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 saw dust 10% 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 up to 180 DAT.

4.3.3. Efficacy of various edible and non edible oils against *S. oryzae* in sorghum

4.3.3.1 Per cent grain damage due to *S. oryzae* in sorghum treated with edible and non edible oils.

The data on per cent grain damage after grains treated with various edible and non edible oils during 2007-08 (Table 35), 2008-09 (Table 36) and pooled data of two year (Table 37) at different days after storage of sorghum as follows.

4.3.3.1.1 30 DAS

The data of 2007-08 depicted in Table 35 showed that there was no grain damage due to rice weevil in all the treatments except control recorded 27.95 per cent of grain damage.

The data of 2008-09 depicted in Table 36 shows that there was no grain damage was observed in grain due to rice weevil in all the treatments except control recorded 23.62 per cent of grain damage. The pooled data over for per cent grain damage of two year 2007-08 and 2008-09 (Table 37) revealed that there was no grain damage in all the treatments was observed. Whereas control record 25.79 per cent of grain damage.

4.3.3.1.2 60 DAS

The data of 2007-08 depicted in Table 35 showed that there was no grain damage due to rice weevil in all the treatments except control recorded 38.34 per cent of grain damage.

Table 35: Grain damage due to *S. oryzae* when treated with edible and non edible oils during 2007-08

Sr.No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	0.41a (0.00)*	0.41a (0.00)	30.43d (25.67)	36.66d (35.67)	41.92d (44.67)	44.79d (49.67)	25.77abcde (25.94)
2	Mustard oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	22.77b (15.00)	29.99b (25.00)	36.05b (34.67)	39.02b (39.67)	21.44ab (19.06)
3	Linseed oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	48.62g (56.33)	54.51g (66.33)	60.87g (76.33)	64.38g (81.33)	38.20h (46.72)
4	Linseed oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	23.56b (16.00)	30.64b (26.00)	36.85b (36.00)	39.80b (41.00)	21.94abc (19.83)
5	Sunflower oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	32.57e (29.00)	38.43e (38.67)	44.22e (48.67)	47.08e (53.67)	27.19bcdef (28.33)
6	Sunflower oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	25.59c (18.67)	32.36c (28.67)	38.43c (38.67)	41.34c (43.67)	23.09abcd (21.61)
7	Groundnut oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	23.56b (16.00)	30.64b (26.00)	36.85b (36.00)	39.80b (41.00)	21.94abc (19.83)
8	Groundnut oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	16.40a (8.00)	24.84a (17.67)	31.72a (27.67)	34.84a (32.67)	18.10a (14.33)
9	Castor oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	39.21f (40.00)	44.79f (49.67)	50.56f (59.67)	53.52f (64.67)	31.48defgh (35.67)
10	Castor oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	32.78e (29.33)	38.83e (39.33)	44.60e (49.33)	47.47e (54.33)	27.41bcdefg (28.72)
11	Control	31.92b (27.95)	38.03b (38.34)	60.20i (75.33)	67.46i (85.33)	77.51i (95.33)	81.84i (98.00)	47.97i (70.05)
	S.Em. ±	0.29	0.27	0.39	0.39	0.41	0.37	2.80
	CD at 5%	0.86	0.79	1.14	1.14	1.20	1.09	7.96
	CV %	15.47	12.27	1.89	1.60	1.45	1.23	1.99

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 36: Grain damage due to *S. oryzae* when treated with edible and non edible oils during 2008-09

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	0.41a (0.00)*	0.41a (0.00)	29.10d (23.67)	35.45d (33.67)	40.77d (42.67)	43.65d (47.67)	24.96bcde (24.61)
2	Mustard oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	21.12b (13.00)	28.64b (23.00)	34.84b (32.67)	37.84b (37.67)	20.54ab (17.72)
3	Linseed oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	57.39h (71.00)	63.89h (80.67)	72.19h (90.67)	77.05h (95.00)	55.70j (56.22)
4	Linseed oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	48.62g (56.33)	54.51g (66.33)	60.87g (76.33)	64.38g (81.33)	38.20h (46.72)
5	Sunflower oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	31.29e (27.00)	37.45e (37.00)	43.07e (46.67)	45.94e (51.67)	26.43bcdef (27.06)
6	Sunflower oil 5.0 ml/ kg	0.41a 0.00	0.41a (0.00)	24.08c (16.65)	31.08c (26.67)	37.25c (36.67)	40.19c (41.67)	22.23abcd (20.28)
7	Groundnut oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	21.96b (14.00)	29.32b (24.00)	35.65b (34.00)	38.63b (39.00)	21.06abc (18.50)
8	Groundnut oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	14.14a (6.00)	23.30a (15.67)	30.42a (25.67)	33.61a (30.67)	17.05a (13.00)
9	Castor oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	38.04f (38.00)	43.83f (48.00)	49.39f (57.67)	52.32f (62.67)	30.73efgh (34.39)
10	Castor oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	31.51e (27.33)	37.65e (37.33)	43.45e (47.33)	46.32e (52.33)	26.62bcdefg (27.39)
11	Control	28.62b (23.62)	35.04b (32.85)	58.89i (73.33)	65.88i (83.33)	75.02i (93.33)	78.43i (96.00)	46.50i (67.08)
	S.Em. ±	0.31	0.28	0.41	0.42	0.40	0.37	2.73
	CD at 5%	0.91	0.82	1.19	1.24	1.17	1.08	7.77
	CV %	18.12	13.61	2.05	1.79	1.45	1.26	2.13

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 37: Grain damage due to *S. oryzae* infestation when treated with edible and non edible oils (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	0.41a (0.00)*	0.41a (0.00)	29.76e (24.67)	36.05d (34.67)	41.34e (43.67)	44.22d (48.67)	25.36d (25.28)
2	Mustard oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	21.94b (14.00)	29.31b (24.00)	35.45b (33.67)	38.43b (38.67)	20.99b (18.39)
3	Linseed oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	57.93h (63.67)	64.63i (73.50)	73.23h (83.50)	78.52h (88.17)	47.24g (51.47)
4	Linseed oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	49.20g (36.17)	55.12h (46.17)	61.55g (56.17)	65.13i (61.17)	38.64i (33.28)
5	Sunflower oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	31.93f (28.00)	37.94e (37.84)	43.64f (47.67)	46.51e (52.67)	26.81e (27.70)
6	Sunflower oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	24.83d (17.66)	31.72c (27.67)	37.84d (37.67)	40.77c (42.67)	22.66c (20.95)
7	Groundnut oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	22.76c (15.00)	29.98b (25.00)	36.25c (35.00)	39.21b (40.00)	21.50b (19.17)
8	Groundnut oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	15.27a (7.00)	24.07a (16.67)	31.07a (26.67)	34.23a (31.67)	17.57a (13.67)
9	Castor oil 2.5 ml/ kg	0.41a (0.00)	0.41a (0.00)	38.62g (39.00)	44.31f (48.84)	49.98g (58.67)	52.92f (63.67)	31.11f (35.03)
10	Castor oil 5.0 ml/ kg	0.41a (0.00)	0.41a (0.00)	32.14f (28.33)	38.24e (38.33)	44.03f (48.33)	46.89e (53.33)	27.02e (28.05)
11	Control	30.27b (25.79)	36.54b (35.60)	59.54i (74.33)	66.67j (84.33)	76.26i (94.33)	80.13g (97.00)	56.85h (68.56)
	S.Em. ±	0.50	0.45	0.26	0.26	0.28	0.40	1.87
	CD at 5%	1.57	1.42	0.75	0.75	0.78	1.27	5.24
	T X Y							
	S.Em. ±	0.30	0.28	0.39	0.41	0.40	0.37	0.36
	CD at 5%	0.86	0.78	NS	NS	NS	1.05	1.01
	CV %	16.74	12.92	1.97	1.70	1.45	1.24	2.06

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

The data of 2008-09 depicted in Table 36 showed that no grain damage was observed due to rice weevil in all the treatments except control (32.85%).

The pooled data over for per cent grain damage of two year 2007-08 and 2008-09 (Table 37) revealed that there was no grain damage in all the treatments was observed. The grain damage in control was recorded as 35.60 per cent.

4.3.3.1.3 90 DAS

The data of 2007-08 depicted in Table 35 showed that there was least grain damage due to rice weevil in groundnut oil 5ml/ kg of seed (8.00). The next best treatment was mustard oil 5 ml/ kg of seed (15.00%) and remained at par with the groundnut oil 2.5 ml/ kg of seed (16.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (56.33). Whereas control recorded 75.33 per cent grain damage.

The data of 2008-09 depicted in Table 36 showed that there was least grain damage in the treatment of groundnut oil 5 ml/ kg of seed (6.00). The next best treatment was mustard oil 5 ml/ kg of seed (13.00%) and remains at par with the groundnut oil 2.5 ml/ kg of seed (14.00%). The maximum grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (71.00). Whereas control recorded 73.33 per cent grain damage.

The pooled data for per cent grain damage over two year 2007-08 and 2008-09 (Table 37) revealed that least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (7.00). The next best treatment was mustard oil 5 ml/ kg of seed (14.00%) followed by the groundnut oil 2.5 ml/ kg of seed (15.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (63.67). Whereas control recorded 74.33 per cent grain damage.

4.3.3.1.4 120 DAS

The data of 2007-08 depicted in Table 35 showed that there was least grain damage due to rice weevil in the treatment of groundnut oil 5 ml/ kg of seed (17.67). The next best treatment was mustard oil 5 ml/ kg of seed (25.00%) and remains at par with the groundnut oil 2.5 ml/ kg of seed (26.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (66.33). Whereas, control recorded 85.33 per cent grain damage.

The data of 2008-09 depicted in Table 36 showed that there was least grain damage in the treatment of groundnut oil 5 ml/ kg of seed (15.67). The next best treatment was mustard oil 5 ml/ kg of seed (23.00%) and remains at par with the groundnut oil 2.5 ml/ kg of seed (24.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (80.67). Whereas control recorded 83.33 per cent grain damage.

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 37) revealed that least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (16.67). The next best treatment was mustard oil 5 ml/ kg of seed (24.00%) and it was at par with the groundnut oil 2.5 ml/ kg of seed (25.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (73.50). Whereas, control recorded 84.33 per cent grain damage.

4.3.3.1.5 150 DAS

The data of 2007-08 depicted in Table 35 showed that there was least per cent of grain damage due to rice weevil was recorded in the treatment of groundnut oil 5 ml/ kg of seed (27.67). The next best treatment was mustard oil 5 ml/ kg of seed (34.67%) and remained at par with the groundnut oil 2.5 ml/ kg of seed (36.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (76.33). Whereas, control recorded 95.33 per cent grain damage.

The data of 2008-09 depicted in Table 36 showed that there was least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (25.67). The next best treatment was mustard oil 5 ml/ kg of seed (32.67%) and remained at par with the groundnut oil 2.5 ml/ kg of seed (34.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (90.67). Whereas control recorded 93.33 per cent grain damage.

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 37) revealed that least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (26.67). The next best treatment was mustard oil 5 ml/ kg of seed (33.67) followed by the groundnut oil 2.5 ml/ kg of seed (35.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (83.50). Whereas control recorded 94.33 per cent grain damage.

4.3.3.1.6 180 DAS

The data of 2007-08 depicted in Table 35 showed that there was least per cent of grain damage due to rice weevil was recorded in the treatment of groundnut oil 5 ml/ kg of seed (32.67). The next best treatment was mustard oil 5 ml/ kg of seed (39.67%) and remains at par with the groundnut oil 2.5 ml/ kg of seed (41.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (81.33). Whereas control recorded 98.00 per cent grain damage.

The data of 2008-09 depicted in Table 36 showed that there was least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (30.67). The next best treatment was mustard oil 5 ml/ kg of seed (37.67%) and remained at par with the groundnut oil 2.5 ml/ kg of seed (39.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (95.00). Whereas control recorded 96.00 per cent grain damage.

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 37) revealed that least per cent of grain damage was recorded in the treatment of groundnut oil 5 ml/ kg of seed (31.67). The next best treatment was mustard oil 5 ml/ kg of seed (38.67%) and it was at par with the groundnut oil 2.5 ml/ kg of seed (40.00%). The maximum per cent of grain damage was recorded in the treatment of linseed 2.5 ml/ kg of seed (88.17). Whereas control recorded 97.00 per cent grain damage.

Thus, overall conclusion from the study on edible oil and non edible oil against *S. oryzae* on sorghum can be drawn that most effective treatments were groundnut oil 5 ml/ kg of seed recorded 13.67 per cent and mustard oil 5 ml/ kg of seed recorded 18.39 per cent grain damage. Whereas the treatment of groundnut oil 2.5 ml/ kg of seed recorded 19.17 per cent grain damage and found least effective in preventing the grain damage. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 9).

The present investigation was supported by the work of Dey and Sarup (1993) who confounded that percentage reduction in the average weevil population was highest in case of soybean oil at 3.30 ml/ kg of grain followed by cotton seed and coconut oils.

4.3.3.2 Per cent weight loss due to *S. oryzae* in sorghum treated with edible and non edible oils

The data on per cent weight loss after grains treated with various edible and non edible oils during 2007-08 (Table 38), 2008-09 (Table 39) and pooled data of two year (Table 40) revealed the trends of per cent weight loss at different days after storage of sorghum as follows.

4.3.3.2.1 30 DAS

The data of 2007-08 depicted in Table 38 showed that there was no significance difference among weight loss due to rice weevil in all the treatments except control recorded 21.35 per cent of weight loss.

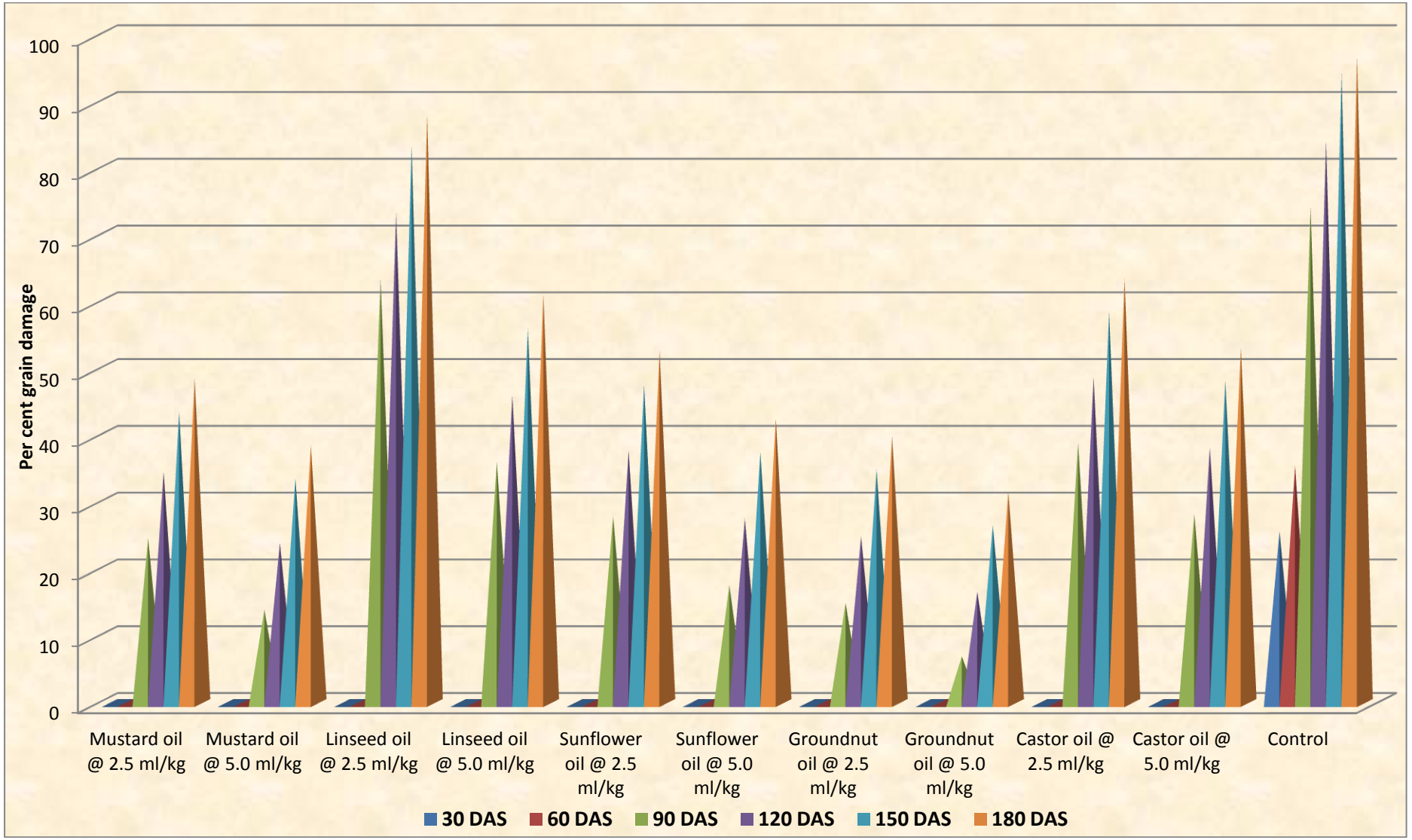


Figure 9: Per cent grain damage due to *S. oryzae* when treated with edible and non edible oils (Pooled)

Table 38: Per cent weight loss due to *S. oryzae* when treated with edible and non edible oils during 2007-2008

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	5.74a (1.00)*	5.74a (2.00)	5.74a (3.00)	40.22g (41.67)	43.11g (46.67)	45.75g (51.33)	29.53b (24.28)
2	Mustard oil 5.0 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	19.09b (10.67)	23.34b (15.67)	27.06b (20.67)	17.26ab (8.84)
3	Linseed oil 2.5 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	40.98g (43.00)	43.85g (48.00)	46.72g (53.00)	30.00b (25.00)
4	Linseed oil 5.0 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	33.02e (29.67)	36.09e (34.67)	39.06e (39.67)	25.33b (18.34)
5	Sunflower oil 2.5 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	37.88f (37.67)	40.80f (42.67)	43.68f (47.67)	28.18b (22.34)
6	Sunflower oil 5.0 ml/ kg	4.79a 0.67	5.74a (2.00)	5.74a (3.00)	28.56d (23.00)	31.95d (28.00)	35.06d (33.00)	22.79ab (14.95)
7	Groundnut oil 2.5 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	25.33c (18.33)	28.56c (23.33)	32.14c (28.33)	20.88ab (12.67)
8	Groundnut oil 5.0 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	14.18a (6.00)	19.37a (11.00)	23.58a (16.00)	14.77a (6.50)
9	Castor oil 2.5 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	32.14e (28.33)	35.24e (33.33)	38.23e (38.33)	24.88b (17.67)
10	Castor oil 5.0 ml/ kg	5.74a (1.00)	5.74a (2.00)	5.74a (3.00)	25.10c (18.00)	28.56c (23.00)	31.95c (28.00)	20.70ab (12.50)
11	Control	27.56b (21.35)	33.83b (30.06)	43.97b (48.23)	47.70h (54.65)	49.78h (58.25)	52.65h (63.21)	42.71c (45.96)
	S.Em. ±	0.61	0.29	0.16	0.70	0.66	0.64	2.99
	CD at 5%	1.79	0.84	0.46	2.06	1.95	1.88	8.49
	CV %	16.29	5.32	2.20	3.38	2.92	2.61	3.92

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 39: Per cent weight loss due to *S. oryzae* when treated with edible and non edible oils during 2008-2009

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	0.41a (0.00)*	5.74a (1.00)	8.13a (2.00)	37.29f (36.67)	40.22cd (41.67)	42.88fg (46.33)	27.49b (21.28)
2	Mustard oil 5.0 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	14.18b (6.00)	19.09ab (10.67)	22.79b (15.00)	13.94ab (5.78)
3	Linseed oil 2.5 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	38.06f (38.00)	40.98d (43.00)	43.85g (48.00)	27.97b (22.00)
4	Linseed oil 5.0 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	29.80d (24.67)	33.02c (29.67)	36.09e (34.67)	23.03b (15.34)
5	Sunflower oil 2.5 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	34.88e (32.67)	37.88cd (37.67)	40.80f (42.67)	26.06b (19.34)
6	Sunflower oil 5.0 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	21.56c (13.45)	25.18b (18.12)	32.14d (28.32)	18.91ab (10.48)
7	Groundnut oil 2.5 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	21.39c (13.33)	25.33b (18.33)	28.86c (23.33)	18.15ab (9.67)
8	Groundnut oil 5.0 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	9.98a (3.00)	14.18a (6.00)	19.37a (11.00)	11.24a (3.83)
9	Castor oil 2.5 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	28.86d (23.33)	30.00bc (25.00)	35.24e (33.33)	22.06b (14.11)
10	Castor oil 5.0 ml/ kg	0.41a (0.00)	5.74a (1.00)	8.13a (2.00)	21.13c (13.00)	25.10b (18.00)	28.56c (23.00)	17.95ab (9.50)
11	Control	26.21b (19.45)	32.01b (28.08)	46.55b (52.67)	47.70g (54.69)	52.89e (63.56)	57.86h (71.71)	44.08c (48.36)
	S.Em. ±	0.27	0.23	0.32	0.75	2.60	0.73	3.21
	CD at 5%	0.79	0.68	0.93	2.21	7.61	2.13	9.11
	CV %	13.19	4.52	5.22	4.01	12.80	3.20	9.26

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 40: Per cent weight loss due to *S. oryzae* when treated with edible and non edible oils (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Mustard oil 2.5 ml/ kg	4.05a (0.50)*	7.04a (1.50)	9.10a (2.50)	38.76g (39.17)	41.67e (44.17)	44.31g (48.83)	28.52c (22.78)
2	Mustard oil 5.0 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	16.74b (8.34)	21.30b (13.17)	24.95b (17.84)	15.68ab (7.31)
3	Linseed oil 2.5 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	39.52g (40.50)	42.42e (45.50)	45.29g (50.50)	29.00c (23.50)
4	Linseed oil 5.0 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	31.44e (27.17)	34.57d (32.17)	37.58e (37.17)	24.20bc (16.84)
5	Sunflower oil 2.5 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	36.39f (35.17)	39.35e (40.17)	42.25f (45.17)	27.13c (20.84)
6	Sunflower oil 5.0 ml/ kg	3.34a (0.34)	7.04a (1.50)	9.10a (2.50)	25.25d (18.23)	28.73c (23.06)	33.65d (30.66)	20.88b (12.71)
7	Groundnut oil 2.5 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	23.42c (15.83)	27.13c (20.83)	30.53c (25.83)	19.55b (11.17)
8	Groundnut oil 5.0 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	12.25a (4.50)	16.95a (8.50)	21.56a (13.50)	13.18a (5.17)
9	Castor oil 2.5 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	30.53e (25.83)	32.71d (29.17)	36.75e (35.83)	23.50bc (15.89)
10	Castor oil 5.0 ml/ kg	4.05a (0.50)	7.04a (1.50)	9.10a (2.50)	23.19c (15.50)	26.92c (20.50)	30.33c (25.50)	19.37b (11.00)
11	Control	26.56b (20.40)	32.65b (29.07)	45.29b (51.46)	47.70h (53.66)	51.30f (60.91)	55.24h (67.46)	43.39d (47.16)
	S.Em. ±	3.64	3.17	0.16	0.49	1.30	0.45	2.12
	CD at 5%	11.49	9.99	0.46	1.39	3.69	1.28	5.95
	T X Y							
	S.Em. ±	0.47	0.26	0.25	0.73	1.89	0.69	0.91
	CD at 5%	1.38	0.75	NS	NS	NS	NS	2.66
	CV %	16.31	4.96	3.78	3.68	8.80	2.90	6.82

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

The data of 2008-09 depicted in Table 39 showed that there was no weight loss was observed in grain in all the treatments except control recorded 19.45 per cent of weight loss.

The pooled data of per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that there was least per cent of weight loss in all the treatments was observed. Whereas, control record 20.40 per cent of weight loss.

4.3.3.2.2 60 DAS

The data of 2007-08 depicted in Table 38 showed that there was no significance difference among weight loss due to rice weevil in all the treatments except control recorded 30.06 per cent of weight loss.

The data of 2008-09 depicted in Table 39 showed that there was no significance difference among weight loss was observed in grain in all the treatments except control recorded 28.08 per cent of weight loss.

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that there was least per cent of weight loss in all the treatments was observed. Whereas control record 29.07 per cent of weight loss.

4.3.3.2.3 90 DAS

The data of 2007-08 depicted in Table 38 showed that there was no significance difference among weight loss due to rice weevil in all the treatments except control recorded 48.23 per cent of weight loss.

The data of 2008-09 depicted in Table 39 showed that there was no significance difference among weight loss in grain in all the treatments except control recorded 52.67 per cent of weight loss.

The data pooled over per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that there was least per cent of weight loss in all the treatments was observed. Whereas control record 51.46 per cent of weight loss.

4.3.3.2.4 120 DAS

The data of 2007-08 depicted in Table 38 showed that there was least per cent of weight loss due to rice weevil was recorded in the treatment of groundnut oil 5 ml/ kg of seed (6.00). The next best treatment was mustard oil 5 ml/ kg of seed (10.67%) and followed by castor oil 5 ml/ kg of seed (18.00%) and it was at par with the groundnut oil 2.5 ml/ kg of seed (18.33%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (43.00) and control recorded 54.65 per cent weight loss.

The data of 2008-09 depicted in Table 39 showed that was least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (3.00). The next best treatment was mustard oil 5 ml/ kg of seed (6.00%) and followed by castor oil 5 ml/ kg of seed (13.00%) and it was at par with the groundnut oil 2.5 ml/ kg of seed (13.33). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (38.00). The control recorded 54.69 per cent weight loss.

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (4.50). The next best treatment was mustard oil 5 ml/ kg of seed (8.34%) and it was at par with the castor oil 5 ml/ kg of seed (15.50%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (40.50) and it is at par with control recorded 53.66 per cent weight loss.

4.3.3.2.5 150 DAS

The data of 2007-08 depicted in Table 38 showed that there was least per cent of weight loss due to rice weevil was recorded in the treatment of groundnut oil 5 ml/ kg of seed (11.00). The next best treatment was mustard oil 5 ml/ kg of seed (15.67%) followed by castor oil 5 ml/ kg of seed (23.00%) and remains at par with the groundnut oil 2.5 ml/ kg of seed

(23.33%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (48.00) and control was recorded 58.25 per cent weight loss.

The data of 2008-09 depicted in Table 39 showed that there was least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (6.00) and remains at par with the treatment of mustard oil 5 ml/ kg of seed (10.67%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (43.00) and control having 63.56 per cent weight loss.

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (8.50). The next best treatment was mustard oil 5 ml/ kg of seed (13.17%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (45.50) and in control 60.91 per cent weight loss.

4.3.3.2.6 180 DAS

The data of 2007-08 depicted in Table 38 showed that there was least per cent of weight loss due to rice weevil was recorded in the treatment of groundnut oil 5 ml/ kg of seed (16.00). The next best treatment was mustard oil 5 ml/ kg of seed (20.67%) followed by castor oil 5 ml/ kg of seed (28.00%) and the groundnut oil 2.5 ml/ kg of seed (28.33%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (53.00) and control was recorded 63.21 per cent weight loss.

The data of 2008-09 depicted in Table 39 showed that there was least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (11.00). The next best treatment was mustard oil 5 ml/ kg of seed (15.00%) followed by the castor oil 5 ml/ kg of seed (23.00%) and the groundnut oil 2.5 ml/ kg of seed (23.33%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (48.00) as

compared to control (71.71%).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 40) revealed that least per cent of weight loss was recorded in the treatment of groundnut oil 5 ml/ kg of seed (13.50). The next best treatment was mustard oil 5 ml/ kg of seed (17.84%) followed by castor oil 5 ml/ kg of seed (25.50%) and the groundnut oil 2.5 ml/ kg of seed (25.83%). The maximum per cent of weight loss was recorded in the treatment of linseed 2.5 ml/ kg of seed (50.50) and at par with control (67.46%).

Thus, overall conclusion from the study on edible oil and non edible oil against *S. oryzae* on sorghum can be drawn that most effective treatments were groundnut oil 5 ml/ kg of seed recorded 5.17 per cent and mustard oil 5 ml/ kg of seed 7.31 per cent weight loss, respectively. Whereas the treatment of groundnut oil 2.5 ml/ kg of seed recorded 11.17 per cent weight loss and found least effective in preventing the weight loss caused by the *S. oryzae*. However, all the treatments gradually lost their effectiveness with the increase in the period of grain storage (Figure 10).

Uttam *et al*. (2002) were tested ten indigenous oils and found that mustard and sesamum oils provided best performance after 5 days of application. Whereas Shukla *et al*. (1992) reported that palm, mustard, soybean, sesamum and groundnut oil cause 90.48 per cent mortality of *S. oryzae.* This is in support with the present findings.

4.3.4. Efficacy of various seed protectants against *S. oryzae* infesting sorghum

4.3.4.1 Per cent grain damage due to *S. oryzae* in sorghum treated with various seed protectants

The data on per cent grain damage after grains treated with various grain protectants during 2007-08 (Table 41), 2008-09 (Table 42) and pooled data of two year (Table 43) revealed the trends of per cent grain damage at different days after storage of sorghum as follows:

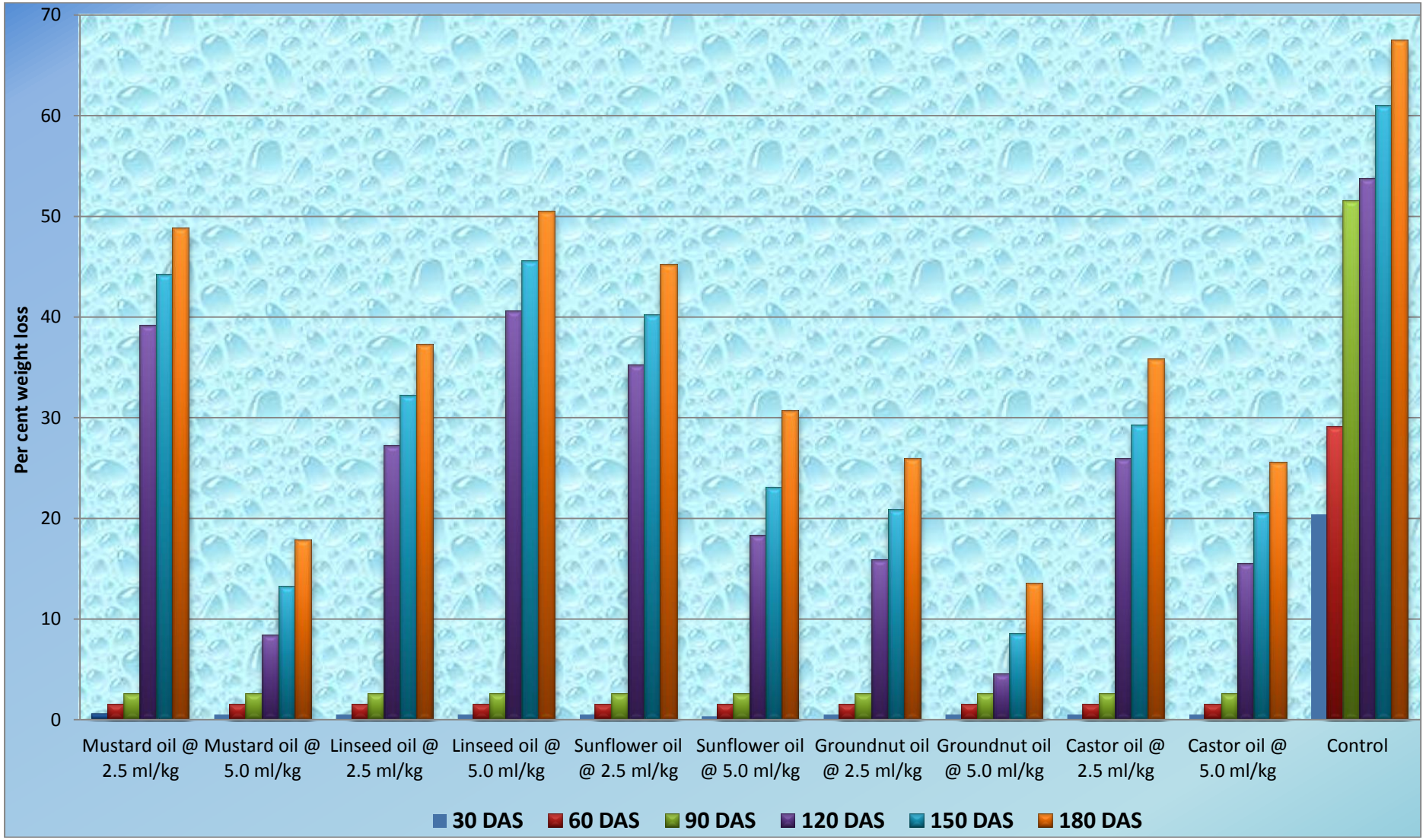


Figure 10: Per cent weight loss due to *S. oryzae* when treated with edible and non edible oils (Pooled)

Table 41: Grain damage due to *S. oryzae* in sorghum treated with seed protectants during 2007-08

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Malathion 0.05%	1.81bc (0.10)*	2.56ab (0.20)	12.23c (4.50)	15.31d (7.00)	18.58d (10.17)	20.84f (12.67)	9.77e (5.77)
2	Chlorpyriphos 0.06%	0.87b (0.03)	2.06a (0.13)	13.13c (5.17)	13.76c (5.67)	17.43c (9.00)	19.20e (10.83)	9.22d (5.14)
3	Cypermethrin 0.005%	0.41a (0.00)	7.40d (1.67)	7.76a (1.83)	9.39ab (2.67)	14.14b (6.00)	15.70c (7.33)	7.32b (3.25)
4	Fenvalerate 0.005%	0.41a (0.00)	5.18c (0.83)	8.08ab (2.00)	9.36a (2.67)	11.99a (4.33)	12.91a (5.00)	6.37a (2.47)
5	Alphamethrin 0.005%	0.87b (0.03)	5.61c (1.00)	9.95ab (3.00)	11.00ab (3.67)	14.76b (6.50)	16.76d (8.33)	7.87c (3.76)
6	Deltamethrin 0.005%	0.41a (0.00)	5.54c (0.97)	9.06ab (2.50)	9.66ab (2.83)	13.55b (5.50)	14.17b (6.00)	6.99b (2.98)
7	Active Azadiractin 0.0125%	0.41a (0.00)	10.20e (3.17)	17.07d (8.67)	21.39e (13.33)	23.30e (15.67)	25.09g (18.00)	12.79f (9.81)
8	Control	41.90d (44.67)	59.54f (74.33)	68.87e (87.00)	89.56f (100.00)	89.56f (100.00)	89.56h (100.00)	66.66g (84.33)
	S.Em. ±	0.33	0.60	0.61	0.59	0.47	0.39	0.16
	CD at 5%	1.00	1.74	1.83	1.76	1.41	1.17	0.48
	CV %	26.66	14.29	8.44	7.03	4.57	3.47	2.90

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 42: Grain damage due to *S. oryzae* in sorghum treated with seed protectants during 2008-09

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**180 DAS**	**Mean**
1	Malathion 0.05%	2.31c (0.17)*	2.96ab (0.27)	12.86d (4.97)	15.87d (7.50)	19.51c (11.17)	21.68f (13.67)	10.20e (6.29)
2	Chlorpyriphos 0.06%	2.06ab (0.13)	2.66a (0.22)	13.97d (5.83)	14.37c (6.17)	18.41c (10.00)	20.10e (11.83)	9.72d (5.70)
3	Cypermethrin 0.005%	0.87a (0.03)	8.45e (2.17)	8.77a (2.33)	10.24ab (3.17)	15.31b (7.00)	16.77c (8.33)	7.96b (3.84)
4	Fenvalerate 0.005%	0.87a (0.03)	6.60c (1.33)	9.06ab (2.50)	10.22a (3.17)	13.34a (5.33)	14.17a (6.00)	7.10a (3.06)
5	Alphamethrin 0.005%	1.34ab (0.07)	6.97cd (1.50)	10.76c (3.50)	11.74ab (4.17)	15.88b (7.50)	17.77d (9.33)	8.48c (4.35)
6	Deltamethrin 0.005%	0.41a (0.00)	6.53cd (1.33)	9.95ab (3.00)	10.49ab (3.33)	14.76b (6.50)	15.53b (7.00)	7.62b (3.53)
7	Active Azadiractin 0.0125%	0.41a (0.00)	11.00f (3.67)	17.58e (9.17)	21.81f (13.83)	24.08d (16.67)	25.83g (19.00)	13.17f (10.39)
8	Control	38.82d (39.33)	60.20g (75.33)	83.45f (98.67)	89.56g (100.00)	89.56e (100.00)	89.56h (100.00)	68.48g (85.56)
	S.Em. ±	0.43	0.53	0.59	0.56	0.45	0.37	0.16
	CD at 5%	1.29	1.58	1.76	1.69	1.33	1.12	0.47
	CV %	28.01	11.51	7.64	6.44	4.08	3.17	2.67

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 43: Grain damage due to *S. oryzae* in sorghum treated with seed protectants (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent grain damage						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Malathion 0.05%	2.06c (0.14)*	2.76a (0.24)	12.54d (4.74)	15.59d (7.25)	19.04f (10.67)	21.26f (13.17)	9.98e (6.03)
2	Chlorpyriphos 0.06%	1.47bc (0.08)	2.36a (0.18)	13.55e (5.50)	14.07c (5.92)	17.92e (9.50)	19.65e (11.33)	9.47d (5.42)
3	Cypermethrin 0.005%	0.64a (0.02)	7.92d (1.92)	8.27a (2.08)	9.81a (2.92)	14.73cd (6.50)	16.24c (7.83)	7.64b (3.54)
4	Fenvalerate 0.005%	0.64a (0.02)	5.89bc (1.08)	8.57a (2.25)	9.79a (2.92)	12.66a (4.83)	13.54a (5.50)	6.73a (2.77)
5	Alphamethrin 0.005%	1.11ab (0.05)	6.29c (1.25)	10.35c (3.25)	11.37b (3.92)	15.32d (7.00)	17.27d (8.83)	8.18c (4.05)
6	Deltamethrin 0.005%	0.41a (0.04)	6.04c (1.15)	9.51bc (2.75)	10.07a (3.08)	14.15bc (6.00)	14.75b (6.50)	7.30b (3.25)
7	Active Azadiractin 0.0125%	0.41a (0.00)	10.60e (3.42)	17.32f (8.92)	21.60e (13.58)	23.69g (16.17)	25.46g (18.50)	12.98f (10.10)
8	Control	40.40d (42.00)	59.87f (74.83)	74.44g (92.84)	89.56f (100.00)	89.56h (100.00)	89.56h (100.00)	67.13g (84.94)
	S.Em. ±	0.26	0.36	0.39	0.37	0.30	0.25	0.11
	CD at 5%	0.75	1.04	1.11	1.06	0.85	0.71	0.30
	T X Y							
	S.Em. ±	0.39	0.55	0.60	0.57	0.46	0.38	0.16
	CD at 5%	NS	NS	NS	NS	NS	NS	NS
	CV %	27.63	12.83	8.03	6.73	4.32	3.32	2.78

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

4.3.4.1.1 30 DAS

The data of 2007-08 depicted in Table 41 showed that there was no grain damage due to rice weevil in the treatments of cypermethrin 0.005 per cent, fenvalerate 0.005 per cent, deltamethrin 0.005 per cent and active azadiractin 0.0125 per cent. All the remaining treatments were statistically at par with each other.

The data of 2008-09 shows that there was no grain damage due to rice weevil in the treatments of cypermethrin 0.005 per cent, fenvalerate 0.005 per cent and deltamethrin 0.005 per cent and active azadiractin 0.0125 per cent. All the remaining treatments were statistically at par with each other (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that that there was no grain damage due to rice weevil in the treatments of cypermethrin 0.005 per cent, fenvalerate 0.005 per cent, deltamethrin 0.005 per cent and active azadiractin 0.0125 per cent followed by chlorpyirophos 0.06 per cent (0.08) and malathion 0.05 per cent (0.14) as compared to control (42.00%).

4.3.4.1.2 60 DAS

The data of 2007-08 depicted in Table 41 showed that the treatments of Chlorpyirophos 0.06 per cent recorded least grain damage (0.13%) and it was at par with malathion 0.05 per cent (0.20%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (3.17) as compared to control (74.33%).

The data of 2008-09 showed that there was least per cent of grain damage was recorded in the treatment of chlorpyirophos 0.06 per cent (0.22) and it was at par with malathion 0.05 per cent (0.27%). The highest grain damage was observed in the treatment of active azadiractin 0.0125 per cent (3.67) as compared to control with 75.33 per cent grain damage (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that there was least damage was observed in the treatments of chlorpyriphos 0.06 per cent (0.18%) and malathion 0.05 per cent (0.24%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (3.42) as compared to control (74.83%).

4.3.4.1.3 90 DAS

The data of 2007-08 depicted in Table 41 showed that the treatments of cypermethrin 0.005 per cent recorded least per cent grain damage (1.83) and it was at par with fenvalerate 0.005 per cent (2.00%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (8.67) as compared to control (87.00%).

The data of 2008-09 showed that there was least per cent of grain damage was recorded in the treatment of cypermethrin 0.005 per cent (2.33) and it was at par with fenvalerate 0.005 per cent (2.50%) and deltamethrin 0.005 per cent (3.00%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (9.17) as compared to control with 98.67 per cent grain damage (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that there was least per cent of grain damage was recorded in the treatment of cypermethrin 0.005 per cent (2.08) and it was at par with fenvalerate 0.005 per cent (2.25%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (8.92) as compared to control with 92.84 per cent grain damage.

4.3.4.1.4 120 DAS

The data of 2007-08 depicted in Table 41 showed that the treatments of fenvalerate 0.005 per cent recorded least per cent grain damage (2.67) and it was at par with cypermethrin 0.005 per cent (2.67%), deltamethrin 0.05% per cent (2.83%) and alphamethrin 0.005 per cent (3.67%). The maximum per cent of grain damage was observed in the

treatment of active azadiractin 0.0125 per cent (13.33) as compared to control (100.00%).

The data of 2008-09 showed that there was least percent of grain damage was recorded in the treatment of cypermethrin 0.005 per cent (2.33) and it was at par with fenvalerate 0.005 per cent (3.17%), deltamethrin 0.005 per cent (3.33%) and alphamethrin 0.005 per cent (4.17%).The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (13.83) as compared to control with 100 per cent grain damage (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that there was least per cent of grain damage was recorded in the treatment of fenvalerate 0.005 per cent (2.92) and it was at par with cypermethrin 0.005 per cent (2.92%) and deltamethrin 0.005 per cent (3.08%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (13.58) as compared to control with 100 per cent grain damage.

4.3.4.1.5 150 DAS

The data of 2007-08 depicted in Table 41 showed that the treatment with fenvalerate 0.005 per cent recorded the least grain damage (4.33%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (15.67) as compared to control (100.00%).

The data of 2008-09 showed that there was least percent of grain damage was recorded in the treatment of fenvalerate 0.005 per cent (5.33). The maximum grain damage was observed in the treatment of active azadiractin 0.0125 per cent (16.67) as compared to control with 100.00 per cent grain damage (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that the treatment of fenvalerate 0.005 per

cent was recorded leas per cent of damage (4.83). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (16.17) as compared to control with 100.00 per cent grain damage.

4.3.4.1.6 180 DAS

The data of 2007-08 depicted in Table 41 showed that the treatment fenvalerate 0.005 per cent recorded the least grain damage (5.00%) followed by deltamethrin 0.05 per cent (6.00%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (18.00) as compared to control (100.00%).

The data of 2008-09 showed that there was least percent of grain damage was recorded in the treatment of fenvalerate 0.005 per cent (6.00) followed by deltamethrin 0.005 per cent (7.00%). The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (19.00) as compared to control with 100.00 per cent grain damage (Table 42).

The pooled data for per cent grain damage of two year 2007-08 and 2008-09 (Table 43) revealed that the treatment of fenvalerate 0.005 per cent (5.50) followed by deltamethrin 0.005 per cent (6.50%).The maximum per cent of grain damage was observed in the treatment of active azadiractin 0.0125 per cent (18.50) as compared to control with 100.00 per cent grain damage.

Thus, overall conclusion from the study on seed protectants against *S. oryzae* on sorghum can be drawn that most effective treatments were fenvalerate 0.005 per cent (2.77%) followed by deltamethrin 0.005 per cent (3.25%) and cypermethrin 0.005 per cent (3.54%) were most effective and recorded the lowest grain damage against *S. oryzae*. The treatment of alphamethrin 0.005 per cent and the chlorpyriphos 0.06 per cent were also

found effective. However, all the treatments gradually lost their effectiveness with the increase in period of grain storage (Figure 11).

Yadav (1997) reported that application of deltamethrin on jute bag prior to storage of wheat gave excellent protection against the major storage insect pest. Whereas Srinivasachryulu and Yadav (1997) evaluated six chemicals under laboratory conditions and found that fluvalinate and malathion were less toxic insecticides while deltamethrin was most toxic to *S. zeamais*.

Thus present finding is more or less in confirmation with the findings of the various scientists in the past.

4.3.4.2 Per cent weight loss due to *S. oryzae* in sorghum treated with various seed protectants.

The data on per cent weight loss after grains treated with various seed protectants during 2007-08 (Table 44), 2008-09 (Table 45) and pooled data of two years (Table 46) revealed the trends of per cent weight loss at different days after storage of sorghum as follows:

4.3.4.2.1 30 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of fenvalerate 0.005 per cent (0.08) and cypermethrin 0.005 per cent (0.08%) and it was at par with active azadiractin 0.0125 per cent (0.17%) as compared to control (10.00%).

The data of 2008-09 showed that there was least weight loss due to rice weevil in the treatments of fenvalerate 0.005 per cent (0.42) and it was at par with cypermethrin 0.005 per cent (0.75%) as compared to control 6.33 per cent weight loss (Table 45).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 46) revealed that that there was least weight loss in the treatments of fenvalerate 0.005 per cent (0.25%) and it was at par with cypermethrin 0.005 per cent (0.42%). The maximum per cent of weight loss

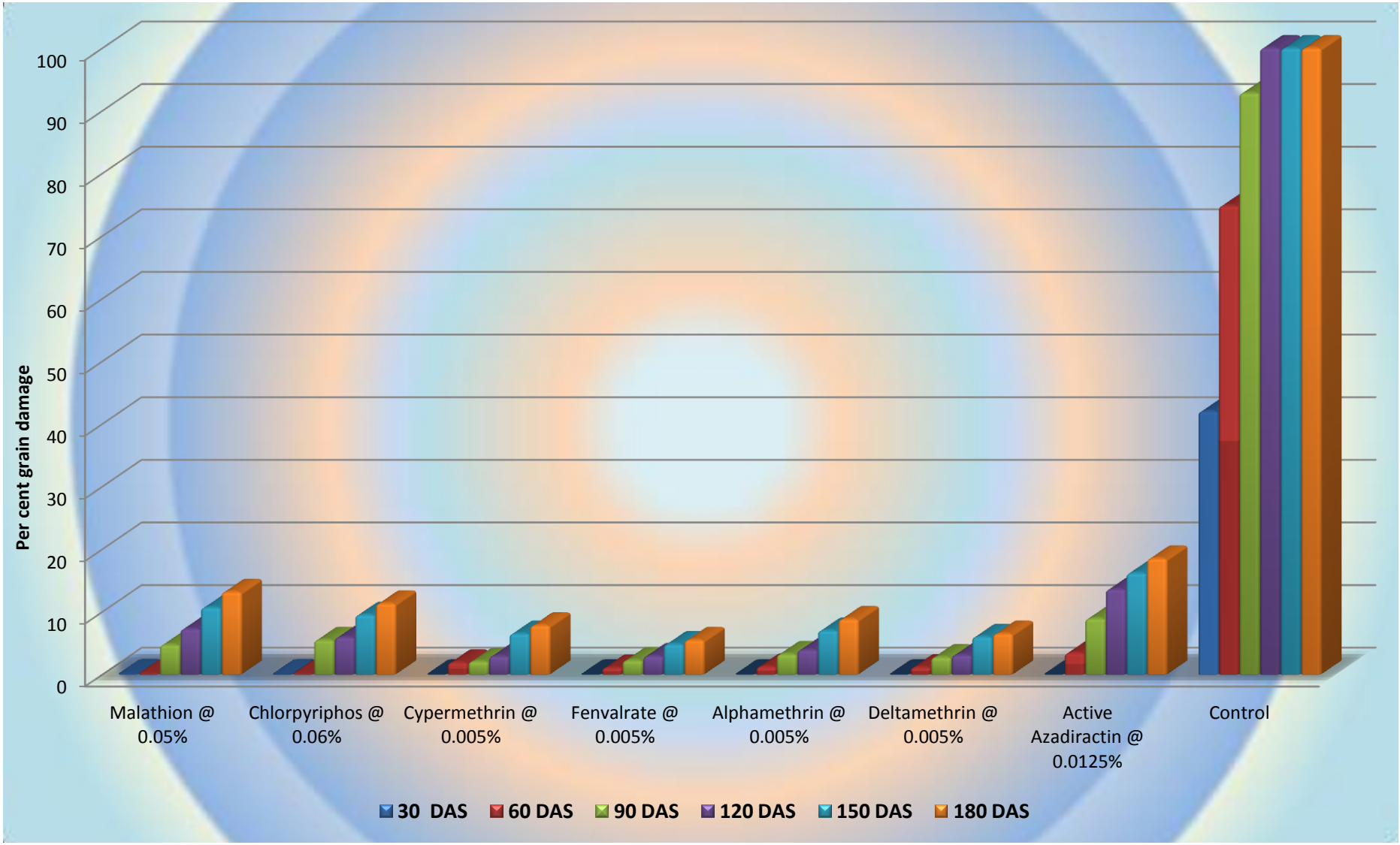


Figure 11: Per cent grain damage due to *S. oryzae* in sorghum treated with seed protectants (Pooled)

Table 44: Per cent weight loss due to *S. oryzae* in sorghum treated with seed protectants during 2007-2008

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Malathion 0.05%	3.66bc (0.42)*	8.08ab (2.00)	13.09c (5.17)	18.41d (10.00)	20.25d (12.00)	22.24d (14.33)	11.03d (7.32)
2	Chlorpyriphos 0.06%	3.66bc (0.42)	6.53a (1.33)	10.24a (3.17)	16.77c (8.33)	18.42c (10.00)	20.40c (12.17)	9.89c (5.90)
3	Cypermethrin 0.005%	1.22a (0.08)	9.06b (2.50)	11.99bc (4.33)	15.31bc (7.00)	16.06b (7.67)	17.45b (9.00)	9.18b (5.10)
4	Fenvalerate 0.005%	1.22a (0.08)	7.40ab (1.67)	12.69bc (4.83)	14.57b (6.33)	14.96ab (6.67)	15.52ab (7.17)	8.58ab (4.46)
5	Alphamethrin 0.005%	4.05c (0.50)	7.72ab (1.83)	12.69bc (4.83)	14.76bc (6.50)	14.76ab (6.50)	18.26b (9.83)	9.10bc (5.00)
6	Deltamethrin 0.005%	5.61c (1.00)	6.97ab (1.50)	11.27ab (3.83)	13.13a (5.17)	14.17a (6.00)	16.07ab (7.67)	8.32a (4.20)
7	Active Azadiractin 0.0125%	1.62ab (0.17)	13.11c (5.17)	18.41d (10.00)	20.55e (12.33)	23.56e (16.00)	26.55e (20.00)	13.73e (10.61)
8	Control	18.44d (10.00)	42.30d (45.31)	46.89e (53.33)	52.71f (63.33)	52.71f (63.33)	52.71f (63.33)	44.89d (49.77)
	S.Em. ±	0.74	0.60	0.48	0.44	0.39	0.34	0.18
	CD at 5%	2.21	1.81	1.44	1.26	1.16	1.03	0.54
	CV %	30.68	10.33	5.81	4.18	3.50	2.78	2.88

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 45: Per cent weight loss due to *S. oryzae* in sorghum treated with seed protectants during 2008-2009

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Malathion 0.05%	5.96abc (1.08)*	9.95a (3.00)	14.34c (6.17)	19.35d (11.00)	21.12d (13.00)	23.04d (15.33)	11.73d (8.26)
2	Chlorpyriphos 0.06%	6.83bc (1.42)	9.88a (3.00)	11.77a (4.17)	17.78c (9.33)	19.35c (11.00)	21.26c (13.17)	10.79c (7.01)
3	Cypermethrin 0.005%	4.19ab (0.75)	10.76a (3.50)	13.33bc (5.33)	16.40b (8.00)	17.11b (8.67)	18.43b (10.00)	10.01b (6.04)
4	Fenvalerate 0.005%	2.41a (0.42)	9.39a (2.67)	13.97bc (5.83)	15.70b (7.33)	16.07ab (7.67)	16.60a (8.17)	9.41a (5.35)
5	Alphamethrin 0.005%	7.03bc (1.50)	9.66a (2.83)	13.97bc (5.83)	15.51ab (7.17)	15.89a (7.50)	19.20b (10.83)	9.92b (5.94)
6	Deltamethrin 0.005%	8.08c (2.00)	9.06a (2.50)	12.68ab (4.83)	14.37a (6.17)	15.34a (7.00)	17.11a (8.67)	9.27a (5.19)
7	Active Azadiractin 0.0125%	7.03bc (1.50)	14.36b (6.17)	19.35d (11.00)	21.41e (13.33)	24.33e (17.00)	27.26e (21.00)	13.97e (11.67)
8	Control	14.54d (6.33)	41.55c (44.00)	52.71e (63.33)	54.63f (66.50)	54.63f (66.50)	54.63f (66.50)	46.26f (52.19)
	S.Em. ±	1.03	0.57	0.44	0.43	0.37	0.33	0.17
	CD at 5%	3.08	1.70	1.33	1.27	1.12	1.00	0.50
	CV %	25.87	8.21	4.97	3.99	3.23	2.60	2.47

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

Table 46: Per cent weight loss due to *S. oryzae* in treated with seed protectants (Pooled of 2007-08 & 2008-09)

Sr. No.	Treatments	Per cent weight loss						
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	180 DAS	Mean
1	Malathion 0.05%	4.33b (0.75)*	9.02a (2.50)	13.71d (5.67)	18.88d (10.50)	20.68e (12.50)	22.64e (14.83)	11.38d (7.79)
2	Chlorpyriphos 0.06%	5.24c (0.92)	8.21a (2.17)	11.00a (3.67))	17.27c (8.83)	18.89d (10.50)	20.83d (12.67)	10.34c (6.46)
3	Cypermethrin 0.005%	2.71a (0.42)	9.91b (3.00)	12.66bc (4.83)	15.86b (7.50)	16.58c (8.17)	17.94b (9.50)	9.60bc (5.57)
4	Fenvalerate 0.005%	1.82a (0.25)	8.39a (2.17)	13.33cd (5.33)	15.14b (6.83)	15.51b (7.17)	16.06a (7.67)	9.00ab (4.90)
5	Alphamethrin 0.005%	5.54c (1.00)	8.69a (2.33)	13.33cd (5.33)	15.14b (6.84)	15.33ab (7.00)	18.73c (10.33)	9.51b (5.47)
6	Deltamethrin 0.005%	6.85d (1.50)	8.01a (2.00)	11.97b (4.33)	13.75a (5.67)	14.75a (6.50)	16.59ab (8.17)	8.79a (4.70)
7	Active Azadiractin 0.0125%	4.81b (0.84)	13.73c (5.67)	18.88e (10.50)	20.98e (12.83)	23.95f (16.50)	26.90f (20.50)	13.64e (11.14)
8	Control	16.64e (8.17)	41.96d (44.66)	49.78f (58.33)	53.67f (64.92)	53.67g (64.92)	53.67g (64.92)	45.67f (50.98)
	S.Em. ±	0.64	0.41	0.30	0.27	0.25	0.22	0.12
	CD at 5%	1.82	1.16	0.86	0.78	0.71	0.63	0.33
	T X Y							
	S.Em. ±	0.89	0.59	0.46	0.42	0.78	0.34	0.17
	CD at 5%	NS	NS	NS	NS	NS	NS	NS
	CV %	28.06	9.18	5.38	4.08	3.36	2.69	2.67

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

was observed in active azadiractin 0.0125 per cent (0.84) as compared to control (8.17%).

4.3.4.2.2 60 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of chlorpyriphos 0.06 per cent (1.33%) and it was at par with deltamethrin 0.005 per cent (1.50%). The maximum per cent of weight loss was noticed in active azadiractin 0.0125 per cent (5.17) as compared to control (45.31%).

The data of 2008-09 showed that there was least weight loss due to rice weevil in the treatment of deltamethrin (2.50%), fenvalerate 0.005 per cent per cent (2.67%), alphamethrin 0.005 per cent (2.83%), chlorpyriphos 0.06 per cent (3.00%) and malathion 0.05 per cent (3.00%) as compared to control 44.00 per cent weight loss (Table 45).

The pooled data for per cent weight loss of the two year 2007-08 and 2008-09 (Table 46) revealed that there was least weight loss in the treatments of deltamethrin 0.005 per cent (2.00%), chlorpyriphos 0.06 per cent (2.17%), fenvalerate 0.005 per cent (2.17%), alphamethrin 0.005 per cent (2.33%) as compared to control 44.66 per cent weight loss.

4.3.4.2.3 90 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of chlorpyriphos 0.06 per cent (3.17%) and it was at par with deltamethrin 0.005 per cent (3.83%). The maximum per cent of weight loss was noticed in active azadiractin 0.0125 per cent (10.00) as compared to control (53.33%).

The data of 2008-09 showed less weight loss found due to rice weevil in the treatments of chlorpyriphos 0.06 per cent (4.17%) and it was at par with deltamethrin 0.005 per cent (4.83%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (11.00) compared to control 63.33 per cent weight loss (Table 45).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 46) revealed that there was least weight loss in the treatments of chlorpyriphos 0.06 per cent (3.67%) followed by deltamethrin 0.005 per cent (4.33%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (10.50) compared to control 58.33 per cent weight loss.

4.3.4.2.4 120 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of deltamethrin 0.005 per cent (5.17%). The maximum per cent of weight loss was noticed in active azadiractin 0.0125 per cent (12.33) as compared to control (63.33%).

The data of 2008-09 showed least weight loss due to rice weevil in the treatments of deltamethrin 0.005 per cent (6.17%) and it was at par with alphamethrin 0.005 per cent (7.17%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (13.33) compared to control (66.50%) (Table 45).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 46) revealed that there was least weight loss in the treatment of deltamethrin 0.005 per cent (5.67%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (12.83) compared to control (64.92%).

4.3.4.2.5 150 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of deltamethrin 0.005 per cent (6.00%) and it was at par with alphamethrin 0.005 per cent (6.50%) and fenvalerate 0.005 per cent (6.67%). The maximum per cent of weight loss was noticed in active azadiractin 0.0125 per cent (16.00) as compared to control (63.33%).

The data of 2008-09 showed lowest weight loss due to rice

weevil in the treatment of deltamethrin 0.005 per cent (7.00%) and it was at par with alphamethrin 0.005 per cent (7.50%) and fenvalerate 0.005 per cent (7.67%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (17.00) compared to control (66.50%) (Table 45).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 46) revealed that there was least weight loss in the treatment of deltamethrin 0.005 per cent (6.50%) and it was at par with alphamethrin 0.005 per cent (7.00%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (16.50) compared to control (64.92%).

4.3.4.2.6 180 DAS

The data of 2007-08 depicted in Table 44 showed that there was least weight loss due to rice weevil in the treatments of fenvalerate 0.005 per cent (7.17%) it was at par with deltamethrin 0.005 per cent (7.67%). The maximum per cent of weight loss was noticed in active azadiractin 0.0125 per cent (20.00) as compared to control (63.33%).

The data of 2008-09 showed least weight loss due to rice weevil in the treatments of fenvalerate 0.005 per cent (8.17%) and it was at par with deltamethrin 0.005 per cent (8.67%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (21.00) compared to control (66.50%) (Table 45).

The pooled data for per cent weight loss of two year 2007-08 and 2008-09 (Table 46) revealed that there was least weight loss in the treatments of fenvalerate 0.005 per cent (7.67%) it was at par with deltamethrin 0.005 per cent (8.17%). The maximum per cent of weight loss was recorded in active azadiractin 0.0125 per cent (20.50) compared to control (64.92%).

Thus, overall conclusion from the study on weight loss caused by *S. oryzae* in sorghum treated with seed protectants can be drawn that most

effective treatments were deltamethrin 0.005 per cent (4.70%) and it was at par with fenvalerate 0.005 per cent (4.90%). The next best treatment was alphamethrin 0.005 per cent (5.47%) and cypermethrin 0.005 per cent (5.57%). The treatment of chlorpyriphos 0.06 per cent was also found effective. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage (Figure 12).

The present finding is in confirmation with Rani (1997) who stated that a single application of deltamethrin prevented storage insect infestation up to 20 months. While Dharm Singh and Yadav (1998) tested five insecticides as seed protectants of wheat seed against *S. oryzae* and deltamethrin (3 ppm dust) was found most effective and protected seeds for up to nine months.

4.4 Suitability of different host foods of *S. oryzae*

Eight different commodities were studied in laboratory for their susceptibility in host of *S. oryzae*. The commodities were evaluated on the basis of susceptibility index. The results obtained are presented in Table 47.

From the Table 47, it can be clearly seen that out of eight commodities tested, the pest could developed only on four commodities *viz*., maize, wheat, sorghum and paddy. The average number of adult emerged in these commodities range from 41 to 59.

The data on susceptibility index indicated that highest susceptibility index was recorded for paddy (4.48) followed by sorghum (3.57). Susceptibility index for maize was 3.13 and it was at par with wheat having susceptibility index 3.10. The remaining four commodities *viz*., coriander, cumin, chilli and fenugreek had low susceptibility index. So that it is proved least suitable to *S. oryzae* as host.

Thus, from the above results it can be concluded that the cereals were more suitable host among the different commodities tested. The order

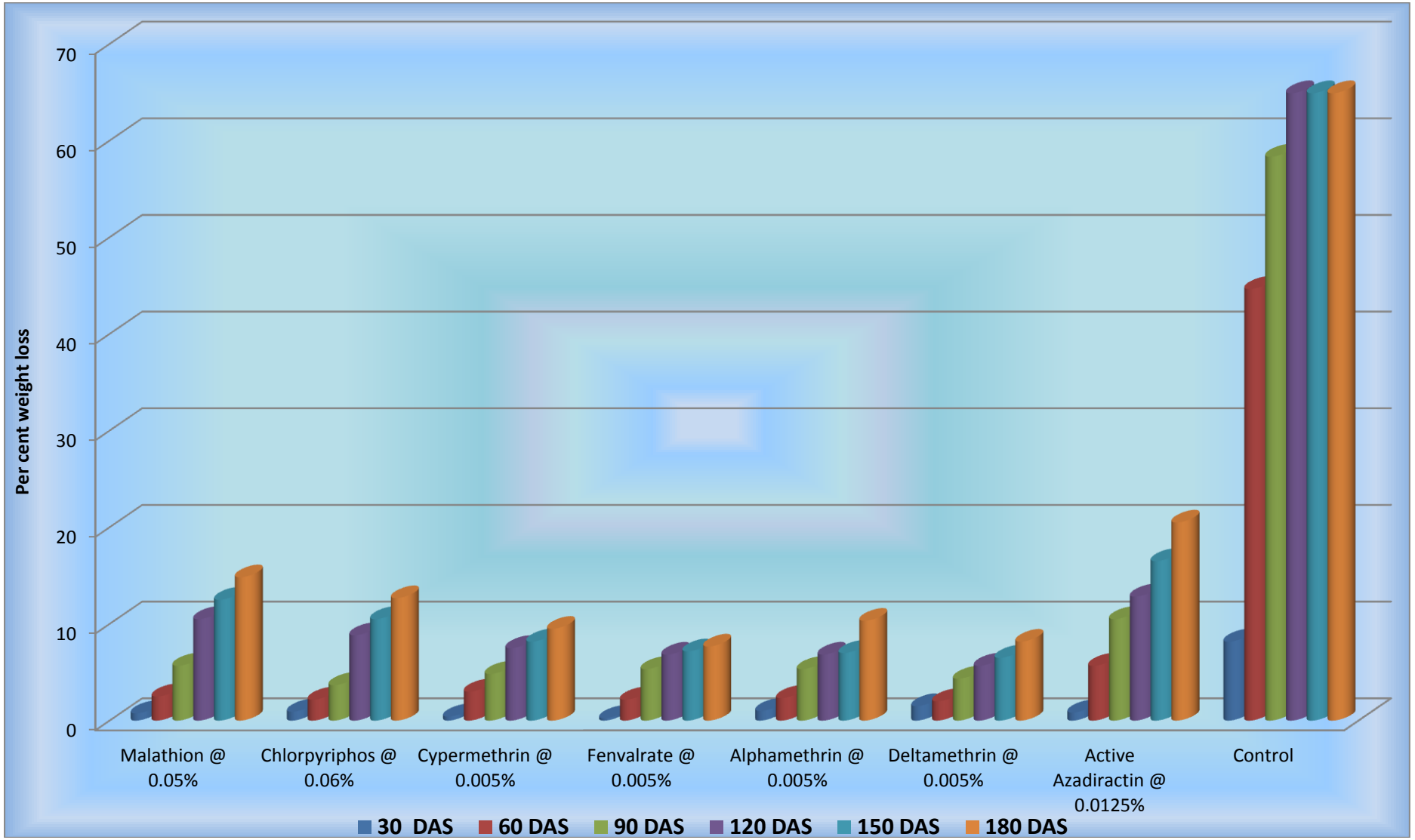


Figure 12: Per cent weight loss due to *S. oryzae* in sorghum treated with seed protectants (Pooled)

of host suitability of different commodities was paddy> sorghum> maize> wheat> coriander> cumin> chilli> fenugreek.

According to Jacob (1992), under laboratory condition development period was shorter and the emergent adult's weights were greater on wheat when tested with five hosts for host plant resistance study. The variation in results is due to difference in place, host and environmental condition.

Table 47: Host preference of *S. oryzae*

Sr. No.	Host	Per cent damage	No. of adult emerged	Susceptible index
1	Maize	58.04 b (72.00)*	41.00	3.13
2	Wheat	58.26 b (72.33)	46.00	3.10
3	Sorghum	64.90 c (82.00)	57.33	3.57
4	Coriander	0.41a (0.00)	0.00	1.00
5	Cumin	0.41a (0.00)	0.00	1.00
6	Chilli	0.41a (0.00)	0.00	1.00
7	Fenugreek	0.41a (0.00)	0.00	1.00
8	Paddy	69.16d (87.33)	59.00	4.48
	S.Em. ±	0.63	0.82	0.12
	CD at 5%	1.90	2.47	0.37
	CV %	0.48	5.39	8.92

* Figures in the parentheses are original values and those outside the parentheses are arcsine transformed values.

V. SUMMARY AND CONCLUSION

The studies on "Biology and management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum" were carried out on the biology, varietal screening, management and host preference of rice weevil under laboratory conditions during 2007-08 and 2008-09 at the Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat state. The results obtained are summarized here:

5.1 Biology of rice weevil, *S. oryzae*

The biological study of the *S. oryzae* on sorghum was carried out under laboratory conditions.

5.1.1 Egg

Eggs were laid inside the cavity of grain, oval in shape with one end pointed and other end being round. Freshly laid eggs were translucent and white and became opaque before hatching. The length of egg varied from 0.35 to 0.39 mm with an average of 0.37 ± 0.01 mm and the breadth varied from 0.15 to 0.19 mm with an average of 0.17 ± 0.01 mm. The incubation period varied from 3.78 to 6.12 day with an average of 4.87 ± 0.31 day at 25.20 to 31.55°C temperature and 77.10 to 87.50 per cent relative humidity. The hatching percentage of eggs varied from 66.00 to 82.00 per cent with an average of 74.95 ± 5.50 per cent.

5.1.2 Larva

Grub was apodous, short, stout, yellowish white and brown colored head. Three moults and four instars were observed under laboratory conditions. The body length of first instar larvae measured from 0.26 to 0.33 mm with an average of 0.30 ± 0.02 mm and breadth from 0.09 to 0.11 mm with an average of 0.10 ± 0.01 mm. Duration of first instar larvae was 5.50 to 7.00 day with an average of 6.17 ± 0.53 at 24.80 to 31.40°C temperature and

75.50 to 85.10 per cent relative humidity. The second instar larva was larger than first instar larva. The length of second instar larvae ranged from 0.42 to 0.48 mm with an average of 0.44 ± 0.02 mm and breadth from 0.14 to 0.16 mm with an average of 0.15 ± 0.01 mm. The duration of second instar larvae ranged from 6.00 to 7.50 day with an average of 6.60 ± 0.56 day at 24.50 to 32.60°C temperature and 80.70 to 91.10 per cent relative humidity. The third instar larva was bigger in size than the earlier instars. The body length of third instar larvae ranged from 4.50 to 9.85 mm with an average of 6.17 ± 1.27 mm and breadth from 1.50 to 3.28 mm with an average of 2.06 ± 0.43 mm. The duration of third instar larvae ranged from 7.50 to 9.50 day with an average of 8.42 ± 0.57 day at 25.30 to 31.40°C temperature and 91.00 to 92.50 per cent relative humidity. The body length of fourth instar larvae ranged from 1.25 to 1.45 mm with an average of 1.39 ± 0.05 mm and breadth from 0.42 to 0.48 mm with an average of 0.46 ± 0.02 mm. The duration of fourth instar larvae ranged from 4.50 to 6.50 day with an average of 5.20 ± 0.57 day at 23.00 to 31.80°C temperature and 81.40 to 89.00 per cent relative humidity. The total larval period varied from 24.50 to 28.50 day with an average of 26.39 ± 1.24 day.

5.1.3 Pupa

Pupa was white to yellowish white; excrete with clearly visible head thorax and abdomen. Pupa measured 3.25 to 3.50 mm in length with an average of 3.34 ± 0.09 mm and the width measured 1.63 to 1.75 mm with average of 1.67 ± 0.04 mm. Pupal period occupied 6 to 7 day with an average of 6.82 ± 0.24 day at 25.20 to 36.40°C temperature and 68.50 to 88.10 per cent relative humidity. Pupation took place in larval tunnel inside pupal case.

5.1.4 Adult

Newly emerged adults were reddish brown which become black at the time of hatching. Adults were elongated, sub-cylindrical with four orange colored patches on elytra. Male and female adults look alike

externally 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. Male measured 3.15 to 3.45 mm in length with an average of 3.32 ± 0.10 mm and 1.26 to 1.38 mm width with an average of 1.33 ± 0.04 mm. While, female measured 3.50 to 3.75 mm in length with an average of 3.62 ± 0.10 mm and 1.40 mm to 1.50 mm width with an average of 1.45 ± 0.04 mm.

5.1.5 Pre-oviposition, oviposition and post-oviposition periods

During present study, pre-oviposition, oviposition and post-oviposition periods varied from 3 to 7 (Av. 4.95 ± 0.89), 33 to 61 (Av. 52.21 ± 8.16) and 18 to 37 (Av. 29.81 ± 4.52) days, respectively at 23.80 to 34.90°C temperature and 63.80 to 92.00 per cent relative humidity.

5.1.6 Fecundity

The fecundity of rice weevil ranged from 122 to 265 with an average of 163.87 ± 27.37 eggs per female during its entire life cycle.

5.1.7 Adults longevity

In case of adult longevity with food, adult females survived for 81 to 101 day with an average of 86.98 ± 6.84 day while males survived for 55 to 60 day with an average of 57.75 ± 1.84 day at 25.60 to 38.40°C temperature and 65.20 to 88.50 per cent relative humidity. Whereas, without food adult females survived for only 8 to 11 day with an average of 9.50 ± 0.87 day but males survived for 5 to 7 day with an average of 5.40 ± 0.56 day at 19.60 to 31.00°C temperature and 67.50 to 79.50 per cent relative humidity.

5.1.8 Sex ratio

The sex ratio of male: female of *S. oryzae* was 1:1.15. The females were more emerged as compared to the males.

5.1.9 Total life cycle

The total life cycle of males of *S. oryzae* ranged from 91.45 to 99.96 (Av. 98.81 ± 2.33) day with food, while without food it ranged from

40.94 to 45.89 (Av. 43.47 ± 1.29) day. The total life cycle of female with food ranged from 117.89 to 140.96 (Av. 125.06 ± 5.24) day, while in case of without food it ranged from 44.50 to 50.46 (Av. 47.57 ± 1.58) day.

5.2 Screening of different varieties of sorghum against *S. oryzae*

Twelve sorghum genotypes were tested for their influence on some biological aspects of the pest. The observations on per cent grain damage, per cent weight loss, germination percentage and adult emergence were taken into consideration to decide the susceptibility of sorghum genotypes to *S. oryzae.*

5.2.1 Developmental period and growth index

The grub period on different genotypes of sorghum varied from 24.05 to 27.97 day. Grub period was shorter on genotype DJ 6514 (24.05 day) which was at par with SR 666 (24.17 day) followed by SR 1905 (24.43 day) and SR 2460 (24.47 day) which was at par with each other. The longer grub duration ranged from 27.80 to 27.97 day was recorded on genotypes ICSV 700, IS 6566, 168 II 108 and SR 770. These genotypes were found at par with each other in view of grub duration.

The pupal period ranged from 5.13 to 8.92 day on different genotypes of sorghum. The longer pupal period ranging from 8.72 to 8.92 on genotypes IS 6566, ICSV 700, 168 II 108 and SR 770 which were at par with each other. The lowest pupal period of 5.13 day was recorded on genotype SR 1905.

The growth index was the highest in genotype DJ 6514 (2.05) which was at par with SR 666 (2.04), SR 2460 (2.00) and SR 1905 (1.95) which were found significantly higher over rest of the genotypes. The genotype SR 770 was found to be less suitable for *S. oryzae* as it showed the lowest growth index (1.17) and was at par with IS 6566 (1.18), ICSV 700 (1.20) and 168 II 108 (1.25). The remaining genotypes were having intermediate growth index.

Thus, on the basis of growth index, it can be concluded that the genotypes DJ 6514, SR 666, SR 2460 and SR 1905 were more suitable for *S. oryzae*, whereas SR 770, IS 6566, ICSV 700 and 168 II 108 were less suitable for it.

5.2.2 Sex ratio

The observation revealed that the sex ratio (male: female) ranged from 1:0.95 to 1:1.31 among different genotypes. Proportion of female was higher than male in almost all the genotypes except in SR 666 and GJ 36 and equal in IS 2312. So it can be concluded that the sex ratio of *S. oryzae* was influenced by genotype.

5.2.3 Longevity of adult

The longevity of male and female were lowest on 168 II 108 and SR 1905 genotypes, whereas highest longevity was on genotype IS 2312.

5.2.4 Susceptibility index

The lowest number of adults were emerged in genotype IS 2312 (18.00 adult) and which was at par with GJ 38 (18.67 adult), GJ 36 (19.00) and SR 2804 (19.67) respectively, which was significantly superior over rest of the genotypes. This was followed by ICSV 700 (26.00 adult), IS 6566 (26.33 adult), SR 770 (26.67 adult) and 168 II 108 (27.33 adult) which were at par with each other. The highest number of adults were emerged in genotype SR 1905 (45.67 adult) which remained at par with SR 666 (42.33 adult) followed by SR 2460 (38.67 adult) and DJ 6514 (38.00 adult) and at par with each other. The highest susceptible index was found on genotypes SR 666 (15.33) which was at par SR 1905 (14.67), whereas the lowest susceptible index was found on genotypes SR 770 (3.67).

5.2.5 Per cent grain damage

5.2.5.1. 30 DAS

At 30 days after storage, sorghum genotype 168 II 108 recorded significantly minimum grain damage of 21.33 per cent which was at par with

ICSV 700 (23.00%) and SR 770 (21.67%) followed by IS 6566 (26.67%).

5.2.5.2 60 DAS

At 60 days after storage, significantly minimum of 50.33 per cent damaged grains were noticed in IS 6566 (50.33%) followed by 168 II 108 (53.33%), ICSV 700 (53.67%) and SR 770 (53.67%) and remained at par with each other.

5.2.5.3 90 DAS

At 90 DAS, significantly minimum per cent of damaged grains was observed in GJ 36 (90.00%) followed by IS 2312 (91.00%), GJ 38 (92.33%), IS 6566 (92.67%), SR 770 (93.33%), and 168 II 108 (93.67%) and remained at par with each other.

5.2.5.4 120 DAS

The hundred per cent grain damage was found in all the genotypes after 120 days of storage. There was no difference among various genotypes of sorghum.

5.2.5.5 150 DAS

The hundred per cent grain damage was found in all the genotypes after 150 days of storage. There was no difference among the various genotypes of sorghum.

5.2.5.6 180 DAS

The hundred per cent grain damage was found in all the genotypes after 180 days of storage. There was no difference among various genotypes of sorghum.

The mean per cent grain damage data indicated that the most susceptible genotypes was DJ 6514 with 87.61 per cent grain damage, while 168 II 108 was the most resistance sorghum genotype (78.06%).The remaining genotypes were intermediate and did not find any significant difference.

5.2.6 Per cent weight loss

5.2.6.1 30 DAS

At 30 days after storage, sorghum genotype 168 II 108 recorded significantly minimum of 16.33 per cent weight loss and it was at par with SR 770 (16.67%) and ICSV 700 (18.00%).

5.2.6.2 60 DAS

At 60 days after storage, significantly minimum of 40.33 per cent weight loss observed in IS 6566 and it was at par with ICSV 700 (43.67%) and SR 770 (43.67%).

5.2.6.3 90 DAS

At 90 days after storage, sorghum genotype IS 6566 recorded significantly minimum of 45.33 per cent weight loss was observed and it was at par with 168 II 108 (48.33%), SR 770 (48.67%), ICSV 700 (48.68%) and SR 2804 (50.33%).

5.2.6.4 120 DAS

Total weight loss was observed non significantly in all the different sorghum genotypes at 120 days after storage.

5.2.6.5 150 DAS

Total weight loss was observed non significantly in all the different sorghum genotypes at 150 days after storage.

5.2.6.6 180 DAS

Total weight loss was observed non significantly in all the different sorghum genotypes at 180 days after storage.

The mean per cent weight loss data indicated that the most susceptible genotypes was DJ 6514 with 61.11 per cent weight loss, while, IS 6566 was the most resistance sorghum genotype and found 48.38 per cent weight loss. The remaining genotypes were reacting intermediate and found no significant difference.

5.2.7 Population build up

5.2.7.1 30 DAS

Less number of adults were observed in SR 770 (61.00 adult) and remained at par with 168 II 108 (61.67 adult), ICSV 700 (62.67 adult) and IS 6566 (63.33 adult) at 30 days after storage when five pairs of weevils were released at the begining of storage.

5.2.7.2 60 DAS

The population build up was less in SR 770 (217.33 adult) which was at par with 168 II 108 (218.33 adult), ICSV 700 (219.00 adult) and IS 6566 (219.33 adult).

5.2.7.3 90 DAS

Population of live insects was minimum in SR 770 (370.00) and remained at par with ICSV 700 (371.33 adult), 168 II 108 (371.33 adult) and IS 6566 (372.00 adult).

5.2.7.4 120 DAS

Emergence of adults was significantly minimum was observed SR 770 (521.67 adult) and at par with ICSV 700 (523.33 adult), 168 II 108 (523.67 adult) and IS 6566 (524.00 adult).

5.2.7.5 150 DAS

Population build up was minimum in SR 770 (724.67) and it was at par with ICSV 700 (726 adult), IS 6566 (726.33 adult) and 168 II 108 (726.33 adult).

5.2.7.6 180 DAS

There were least number of adults emerged in SR 770 (930.00 adult). This was at par with the IS 6566 (930.33 adult), ISCV 700 (931.00 adult) and 168 II 108 (932.33 adult).

The mean population buildup in different sorghum genotypes, the data indicated that the highest population buildup of *S. oryzae* was found in susceptible genotype is DJ 6514 with 547.56 adult and it was at par with

SR 666 (542.22 adult). The most resistant sorghum genotype was SR 770 (470.78 adult).

5.2.8 Per cent seed germination in sorghum damaged by *S. oryzae*

5.2.8.1 30 DAS

At 30 days after storage, SR 770 maintained maximum germination per cent (62.67) followed by ICSV 700 (61.00%) and it was at par with IS 6566 (59.00%).

5.2.8.2 60 DAS

The maximum germination was observed in ICSV 700 (34.33%) and it was at par with SR 770 (34.00%) and 168 II 108 (31.33%).

5.2.8.3 90 DAS

The genotypes DJ 6514 and SR 2460 were recorded zero per cent germination after 90 days after storage. While, other genotypes were also recorded very low per cent of germination.

5.2.8.4 120 DAS

After 120 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

5.2.8.5 150 DAS

After 150 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

5.2.8.6 180 DAS

After 180 days of storage of sorghum, zero per cent germination was observed in all the genotypes.

The mean per cent germination in different sorghum genotypes data indicated that the lowest per cent of germination in different sorghum genotypes was found in susceptible genotype was DJ 6514 (5.06) and it was at par with SR 1905 (7.17%), SR 666 (7.45%) and SR 2460 (8.17%). The highest per cent of germination was found in sorghum genotype SR 770 (16.39).

5.2.9 Bio chemical parameters of sorghum genotypes

The observations on the major biochemical plant constituents such as total nitrogen, crude protein and tannin content of twelve sorghum genotypes presented as below.

5.2.9.1 Total nitrogen

The total nitrogen per cent varied from 2.18 to 3.51 and it was found maximum in genotype DJ 6514 (3.51%). While, the minimum total nitrogen per cent found in genotype SR 2804 (2.18) and it was at par with SR 1905 (2.46%).

The interaction effect between nitrogen content and population build up was found non significant and had no significant effect on population build up of the *S. oryzae.*

5.2.9.2 Crude protein

Crude protein per cent varied from 13.64 to 21.94. Sorghum genotype DJ 6514 had maximum per cent of crude protein (21.94) and it remained at par with IS 6566 (21.01%).

The correlation between crude protein and population build up showed negative but non significant (-0.34). Therefore the data indicating no effect of crude protein on population build up of *S. oryzae* on different genotypes of sorghum.

5.2.9.3 Tannin

The highest tannin content was recorded in SR 770 (0.32%) and it was at par with IS 6566 (0.27), ICSV 700 (0.29) and 168 II 108 (0.29%). The correlation effect was negatively significant indicating negative relationship between population build up and content of tannin per cent of the different genotypes of sorghum.

5.3 Eco friendly approaches for the management of rice weevil in sorghum

5.3.1 Efficacy of various plant products against *S. oryzae* in sorghum

5.3.1.1 Per cent grain damage in sorghum by *S. oryzae*

The overall conclusion from the study on evaluation of plant products against *S. oryzae* on sorghum revealed that the plant products *viz*., sweet flag powder, custard apple seed powder and neem seed kernel powder were the most effective in controlling of *S. oryzae* infestation. The treatments of neem leaf powder and lakke leaf powder also found effective, while kharanja leaf powder, adsali leaf powder, tulsi leaf powder and turmeric powder were found to be least effective in preventing the pest infestation. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage.

5.3.1.2 Per cent weight loss due to *S. oryzae* in sorghum

In the study on per cent of weight loss from sorghum treated with various plant products against *S. oryzae* can be drawn that the plant products *viz*., sweet flag powder, custard apple seed powder and neem seed kernel powder were the most effective in controlling of *S. oryzae* infestation. The treatment of lakke leaf powder, neem leaf powder and Kharanja leaf powder also found effective, while thus adsali leaf powder, tulsi leaf powder and turmeric powder where found to be least effective in preventing the weight loss due to *S oryzae*. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage.

5.3.2 Efficacy of various inert materials against *S. oryzae* in sorghum

5.3.2.1 Per cent grain loss due to *S. oryzae* in sorghum treated with inert materials

The overall conclusion from the study on inert materials against

S. oryzae on sorghum can be drawn that most effective inert materials were kaolinite clay 10 per cent recorded no grain damage and bentonite clay 10 per cent (9.02%). Whereas, the treatment of sand 10 per cent (66.98%), saw dust 10 per cent (74.46%) and cow dung ash 10 per cent (74.69%) found least effective in preventing the grain damage. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage.

5.3.2.2 Per cent weight loss due to *S. oryzae* in sorghum treated with inert materials

The overall conclusion from the study on inert materials against *S. oryzae* on sorghum can be drawn that most effective inert materials was kaolinite clay 10 per cent recorded no weight loss. While, bentonite clay 10 per cent stood second with 5.12 per cent weight lost. Whereas the treatment of sand 10 per cent (24.65%), cow dung ash 10 per cent (30.69%) and saw dust 10 per cent (31.29%) found least effective in preventing the weight loss. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage.

5.3.3. Efficacy of various edible and non edible oils against *S. oryzae* in sorghum

5.3.3.1 Per cent grain damage due to *S. oryzae* in sorghum treated with edible and non edible oils

The overall conclusion from the study on edible oil and non edible oil against *S. oryzae* on sorghum can be drawn that most effective treatments were groundnut oil 5 ml/ kg of seed recorded 13.67 per cent and mustard oil 5 ml/ kg of seed recorded 18.39 per cent grain damage. Whereas the treatment of groundnut oil 2.5 ml/ kg of seed recorded 19.17 per cent grain damage and found least effective in preventing the grain damage. However, all the treatments gradually lost their effectiveness with the increase the period of grain storage.

5.3.3.2 Per cent weight loss due to *S. oryzae* in sorghum treated with edible and non edible oils

The overall conclusion from the study on edible oil and non edible oil against *S. oryzae* on sorghum can be drawn that most effective treatments were groundnut oil 5 ml/ kg of seed recorded 5.17 per cent and mustard oil 5 ml/ kg of seed 7.31 per cent weight loss, respectively. Whereas the treatment of groundnut oil 2.5 ml/ kg of seed recorded 11.17 per cent weight loss and found least effective in preventing the weight loss caused by the *S. oryzae*. However, all the treatments gradually lost their effectiveness with the increase in the period of grain storage.

5.3.4. Efficacy of various seed protectants against *S. oryzae* infesting sorghum

5.3.4.1 Per cent grain damage due to *S. oryzae* in sorghum treated with various seed protectants

The overall conclusion from the study on seed protectants against *S. oryzae* on sorghum can be drawn that most effective treatments were fenvalerate 0.005 per cent (2.77%) followed by deltamethrin 0.005 per cent (3.25%) and cypermethrin 0.005 per cent (3.54%) were most effective and recorded the least grain damage against *S. oryzae*. The treatment of alphamethrin 0.005 per cent and the chlorpyriphos 0.06 per cent were also found effective. However, all the treatments gradually lost their effectiveness with the increase in the period of grain storage.

5.3.4.2 Per cent weight loss due to *S. oryzae* in sorghum treated with various seed protectants

The overall conclusion from the study on weight loss caused by *S. oryzae* in sorghum treated with seed protectants can be drawn that most effective treatments were fenvalerate 0.005 per cent (2.77%), followed by deltamethrin 0.005 per cent (3.25%) and cypermethrin 0.005 per cent (3.54%) were most effective and recorded the least grain damage against *S.*

oryzae. The treatment of alphamethrin 0.005 per cent and the chlorpyriphos 0.06 per cent were also found effective. However, all the treatments gradually lost their effectiveness with the increase in the period of grain storage.

5.4 Suitability of different host foods of *S. oryzae*

Eight different commodities were studied in laboratory for their susceptibility in host of *S. oryzae*. The commodities were evaluated on the basis of susceptibility index. It can be clearly seen that out of eight commodities tested, the pest could developed only on four commodities *viz*., maize, wheat, sorghum and paddy. The average number of adult emerged in these commodities range from 41 to 59. The data on susceptibility index indicated that highest (4.48) susceptibility index was recorded for paddy followed by sorghum (3.57).

Thus, from the above results it can be concluded that the cereals were more suitable host among the different commodities tested. The order of host suitability of different commodities was paddy> sorghum> maize> wheat> coriander> cumin> chilli> fenugreek.

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*original not seen

Appendix I: Meteorological parameters recorded at MSRS, Surat

Month	STW	Max.Temp. (ºC)	Min. Temp. (ºC)	Morn. RH(%)	Eve. RH (%)
July-07	27	32.70 ± 1.70	25.30 ± 1.20	91.50 ± 3.60	88.10 ± 7.40
	28	33.30 ± 1.10	26.70 ± 1.30	67.10 ± 4.40	81.40 ± 5.90
	29	33.00 ± 1.00	25.50 ± 0.50	86.80 ± 3.20	75.50 ± 7.40
	30	32.30 ± 0.70	26.30 ± 0.50	86.80 ± 4.40	77.70 ± 7.10
	31	31.55 ± 0.80	25.20 ± 0.70	87.50 ± 4.55	77.10 ± 7.40
August-07	32	31.40 ± 0.40	24.80 ± 0.30	85.10 ± 1.10	75.50 ± 2.10
	33	32.60 ± 1.00	24.50 ± 0.50	91.10 ± 3.70	80.70 ± 3.30
	34	32.20 ± 1.30	26.60 ± 1.20	85.00 ± 2.90	75.50 ± 7.20
	35	31.40 ± 1.60	25.30 ± 2.00	92.50 ± 6.30	91.00 ± 8.40
September-07	36	30.60 ± 2.50	25.20 ± 1.30	91.80 ± 2.70	88.00 ± 4.30
	37	31.80 ± 1.10	23.00 ± 0.40	89.00 ± 2.80	81.40 ± 5.30
	38	33.40 ± 0.50	23.80 ± 0.80	88.70 ± 2.30	72.00 ± 4.60
	39	36.40 ± 0.90	25.20 ± 0.50	88.10 ± 3.10	68.50 ± 2.40
October-07	40	38.40 ± 2.90	25.60 ± 1.90	88.80 ± 8.50	65.20 ± 7.90
	41	33.70 ± 2.10	24.60 ± 1.20	91.10 ± 3.20	74.20 ± 8.60
	42	34.90 ± 0.50	23.80 ± 1.40	92.00 ± 4.30	63.80 ± 3.50
	43	33.60 ± 0.90	24.20 ± 0.90	86.80 ± 8.90	54.10 ± 1.30
	44	34.80 ± 0.70	22.00 ± 0.75	83.00 ± 7.85	58.00 ± 2.15
November-07	45	34.70 ± 0.34	24.20 ± 0.55	85.00 ± 8.86	75.00 ± 7.88
	46	35.20 ± 6.78	23.40 ± 2.43	89.00 ± 9.03	70.00 ± 9.77
	47	32.30 ± 3.28	23.40 ± 1.19	90.50 ± 8.13	77.70 ± 9.03
	48	32.60 ± 0.80	21.80 ± 0.24	85.00 ± 9.55	67.40 ± 6.36
December-07	49	31.00 ± 0.33	19.60 ± 1.32	79.50 ± 8.36	67.50 ± 4.65
	50	29.50 ± 0.60	12.50 ± 1.33	83.10 ± 8.34	50.70 ± 2.30
	51	30.60 ± 1.49	10.90 ± 2.19	81.20 ± 9.24	34.70 ± 7.91
	52	35.00 ± 1.55	15.10 ± 3.13	81.00 ± 9.21	36.50 ± 8.14

C E R T I F I C A T E

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis for rendering reference service in a library or documentation centre.



Place: Navsari **(G. R. Bhanderi)**

Date: 24/12/2012