Losses caused by rodents to economic field crops and fruit trees

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REVIEW ARTICLE
ON
LOSSES CAUSED BY RODENTS TO ECONOMIC FIELD CROPS AND FRUIT TREES.

BY

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I- Introduction

Rodents are a key mammalian group, which are highly successful in many environments throughout the world. They constitute more than 42% of the known mammalian species. In many instances rodents provide major benefits to the environment as bio-engineers. However, of major importance is the 5-10% of rodent species that cause significant losses to agricultural crops in many regions of the world **(Rao and Bai, 2004)**.

Types of rodent pests in Egypt and World

Approximately 4000 rodent species are divided on the basis of their anatomy into three well-defined groups, or suborders, and more than 30 families**.**

1-The Sciuromorpha, or squirrel like rodents, include the various species of squirrel, chipmunk, prairie dog, pocket gopher and pocket mouse.

2-The Hystricomorpha, or porcupine like rodents, include the porcupine, , nutria (coypu) and agouti.

3-The Myomorpha, or mouse like rodents, it is the largest rodent group. It includes a great variety of mouse and rat species, as well as species of vole, muskrat, gerbil and jerboa. **(Hoogostraal,1963), (Osborn and Helmy, 1980), (Meehan, 1984), (Wilson and Reeder, 1993) and (Chopra *et al*., 1996).**

Whilst a majority of rats and mice thrive in the natural environments, some species have adapted to the human settlements, causing nuisance to the human populations.

The major harms caused by these commensally rodents include:

1-Economic losses and illnesses caused by their consumption and contamination of economic field crops (pre- and post-harvest) and fruit trees.

2-Economic and property losses caused by their burrowing and gnawing habits.

3-Fire hazards resulted from their gnawing on electric wires and cables.

4-Potential health risks to humans as they are hosts or vectors of various kinds of communicable diseases.

Most of the economic losses caused by rodents occur in cereal crops **(Kami, 1966)**, **(Brooks and Barnes, 1972) and** (**Bertolino, 2005)** although significant damage occurs annually in both sugar cane and macadamia orchards**,** (**Ramsey and Wilson, 2000).**

This review aiming to describe:

1**-losses caused by rodents to economic field crops.**

a- Pre-harvest losses.

b - Post-harvest losses: extent of the problem.

2- Losses caused by rodents to economic fruit trees.

II-Losses caused by rodents to economic field crops.

A- Pre-harvest losses

A-a- Cereal crops

The severity varies with season, location and ecosystem. Among the field crops, rice is the most vulnerable crop to rodents. Rodents do not spare any variety and they attack all stages of the crop during all seasons (**Sridhara, 1992)**.

A- a-1- Rice crop

The assessment of damage caused by rodent to rice was carried- out as the following technique. Three fields were selected, each was a feddan area. 15 samples were selected diagonally and were determined by using wooden frame (100 x 100 cm). In each sample, the numbers of damaged and undamaged tillers (The Cut Tiller Count method) inside the frame were counted, and the percentage of damage was calculated according to **Hamelink (1981)** and **Poche *et al*., (1982)** as follows:

$$\% \text{ Damage} = \frac{\text{Number of damaged tillers}}{\text{Total tillers counted}} \times 100$$

In India, Prakash *et al.*, (1986) found that the damage to the paddy tillers was significantly ($P<0.01$) more in the centre of the paddy fields than at the rice periphery and middle zone. The damage to the paddy tillers were (8.62% to 9.5%), (8.43% to 9%), (5.75% to 6.23%) and (5.75% to 6.5%) in Nadia, Hooghly, North 24-Parganas and Burdwan districts respectively, while was 13.86% at the State of Punjab **Chopra and Parshad (1986)**.

Rice damage at different stages, by rodents has been estimated to be 10%. The severity varies with season, location and ecosystem. Among the field crops, rice is the most vulnerable crop to rodents. Rodents do not spare any variety and they attack all stages of the crop during all seasons. In addition to tiller cutting, they also hoard ripened panicles inside their burrows. They have tremendous hoarding capacity especially in *Bandicota bengalensis* and *Mus meltada*. Hoarding by *Bandicota bengalensis* was observed in the farm at the time of harvest. Maximum damage to nurseries takes place when the seeds are just germinated. At this stage, the nurseries are drained out and the rodents run freely inside the bed spoiling all germinated seed. Later, they also cut the seedlings 1-2 inches above the water level. Sometimes the rodents pull out the transplanted seedlings and create gaps in the main field. Generally, their activity is confined to inside field leaving 2-4 meters on all sides of the field. In the initial stage, damage appears in patches and after some time, all these small patches become into one big patch. Damage increases with the onset of panicle initiation and continues up to panicle emergence (**Sridhara, 1992).**

Analysis of the information available on the damage and economic losses caused by rodents in rice, wheat, sugarcane, maize, pearl millet, sorghum, oil seed, legume and horticulture and forestry and rural and urban dwellings and storage facilities clearly shows that chronic damage ranging from 2% to 15% persists throughout the country and severe damage, sometimes even up to 100% loss of the field crop, is not rare (**Parshad, 1999).**

Santra *et al*., (2001) estimated the damage caused by Indian house rat *Rattus rattus* (Linnaeus); brown or sewer rat, *Rattus norvegicus* (Berkenhout), house mouse *Mus musculus* Linnaeus, and Large bandicoot rat *Bandicota indica* Bechstein, in three districts of West Bengal. House rat, *Rattus rattus* (Linnaeus) was the most dominant rodents which caused excessive damage on field and stored crops at West Bengal. The damages made by these rodents were approximately 5-6% paddy in the field and 7% in the stores; 6-7% wheat in the field) and 1-8% other crops.

In Madagascar, the most important rodent pest is the roof rat *(Rattus rattus).* The impact of the rat on rice crops was studied in the region of Lake Alaotra, the principal rice-producing region of Madagascar. Evaluation of rodent damage was conducted in 591 parcels just before harvesting. The average damage value was low (on average less than 1%) and the average losses per hectare were also low at less than 100 kg paddy rice/ha. Differences were significant, depending on the locality and the presence of good refuge habitat for rats around the rice field. The rice variety and agronomic practices did not influence the damage levels (**Salvioni, 1991).**

In Indonesia, rodents are the most important pre-harvest pests in economic terms, causing on average at least 15% annual losses of rice (**Geddes, 1992).**

Rodent damage to rice can be measured at several stages of crop growth. In West Java, monocultures of lowland irrigated rice, cumulative damage to rice during the dry season was 54% at the primordial stage and 32% at the booting stage, but only 16% at the ripening stage. In deep water rice systems, *B.bengalensis* and *B.indica* can cause significant damage to pre-flood rice as well as non-rice crops. More damage occurs at the rice stem elongation stage through stem cutting and biting opening the leaf sheath **(Singleton and Petch, 1994)**.

Rice yield can be estimated by farmers directly or by quadrate samples, the former being on average 20% lower than the actual yield. Integrated rodent management increased rice yields more when rats were common, in both dry and wet season crops. For every 1% increase in tiller damage by rats, there was a decrease of 58 kg/ha in rice yield. The benefit-to-cost ratio for all seasons and years averaged 25:1 but varied considerably from year to year between a low of −2:1 to a high of 63:1 (**Singleton *et al*., 2004).**

Surveys **in Bangladesh** have found that rats attack 37% of fields at the beginning of the flood period, rising to 52% at harvest when rats cut the panicles for storage in their burrows. Yield loss assessments have been shown to vary widely temporally and spatially. There is limited economic assessment of the effect of rats on rain-fed deepwater rice. However, studies over two years in Bangladesh which assessed actual yield loss caused by rats during the entire growth period showed losses ranging from 32% to 67%. These studies also showed that damage during elongation was more severe than that suffered during ripening (**Aplin *et al*., 2004).**

In common with most of Asia, Bangladesh farmers routinely plant 2 rows of rice for the rats for every 8 rows sown, pre-harvest losses ranging from 5-17% (**Belmain and Shafali, 2008)** and (**Meerburg *et al*., 2008) .**

A survey of 350 farmers was conducted in the lowland rain fed agricultural system **of central Myanmar (Burma)** to examine the importance of rodents, farmers' perception of the causes of yield loss, and their beliefs as to why they undertake rodent management. Farmers grew monsoon rice, summer rice and mungbeans with the major constraints upon production identified as pests (29.4% of respondents), followed by insufficient water (19.4%). The main pests were insects (48.6%), followed by rats (40.9%); however, farmers thought that rats caused most damage to their crops (47.7% of respondents; insects 30.3%), and were the most important pest to control. Farmers estimated that rodents caused 13% yield loss. Rodents were clearly identified as a significant problem by farmers **(Brown *etal*., 2008).**

A- a- 2- Wheat crop

Alfonso (1968) mentioned that, as wheat heads mature rats feed on the base of the young pencil shoot and completely bite off the stem and feed on the grain, Figures (1 and 2).

Fig.(1): Wildlife biologist Rachel Labador is surrounded by rat-damaged wheat fields (see the bare, brownish patch) in Banaue, Philippines.

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Fig. (2): Damage caused by rats to wheat crop.

The assessment of damage in wheat crop follows the same steps previously mentioned with rice crop.

In Egypt, Abdel-Gawad *et al*., (1982) estimated the damage caused by *A. niloticus* (Des.) in wheat field. They found that the maximum attack by this rat was more predominant during the milky and paste stage and the damage decreased gradually towards the center of the field.

Abdel-Karim (1991) studied the damage caused by *Arvicanthis niloticus* (Des.) in wheat fields at Sharkia governorate. The rat attacks wheat plants all over the growing season. The signs of infestation started to appear during the second week of December but wheat plants subjected to relatively high damage during milky and pasty (dough) stages in March and April.

In Minia governorate **Asran (1991)** and in Fayoum governorate **Asran *et al*., (1991)** found that the damage by rodent species in wheat crop started at the early growth stage and increased during the milky and dough growth stages, this was supported by **Keshta (1996)** in Qena, Beni Suef and Kalubia governorates and **Abdel-Hamid (1997)** in Fayoum governorate and **El-Nashar (1998)** in Minia and Sohag governorates.

Losses to wheat crop due to large jird, *Meriones shawi isis* (Thomas) were about 2.46 Ardab/Fed., by and decreased to 1.03 Ardab/Fed., during 2001 and 2002 agriculture seasons, respectively, using live trap method. However, there was no damage with the use of crashing burrows method in Behria governorate **(Metwally *et al*., 2009).**

In Kano, northern Nigeria, The damage and yield loss caused by two rodent species, *Arvicanthis niloticus* and *Mastomys* (*Praomys*) *natalensis*, in cereal crops in fields from August, 1990 to April, 1992 were investigated. In premature crops, damage increased from tiller stages to the dough stages. Statistically significant differences in the percentages of damage (yield loss) in mature rice (4.8% in 1990 and 12.6% in 1991) and in wheat (30.0% in 1991 and 21.7% in 1992) were found. Severe yield losses in wheat, compared to low and moderate levels in rice (grown for the most part during the rains), were probably a result of greater consumption of the wheat, grown entirely by irrigation during the dry season when other rodent food sources were less abundant. The results showed significant effects of developmental stage of the crop, year of cultivation, and their interactions on the magnitude of crop damage (**Rabiu and Rose, 2004).**

In Bangladesh, **Poche *et al.*, (1982)** studied wheat yield reduction by the lesser bandicoot rat, *B. Bengalensis*. The damage caused by this rat on mature wheat was 12.1% or 77000 tons of grain destroyed before harvest and 17% of the damaged tillers were removed; whereas, 83% of them were cut near the ground level.

In southern Australia, Plagues of house mice, *Mus domesticus* can cause severe economic damage to grain crops when their populations peak at sowing of winter-growing crops in autumn. Mice damage crops by locating and digging out newly sowed seeds. If damage is high, farmers have to re-sow their crop. A trial was conducted to examine the effect of increasing sowing depth of short and long coleoptiles wheat. Crops were sown at 30, 50 and 70 mm and the germination rate and number of mouse diggings was compared in an open field and a mouse-proof enclosure (fenced site). The effective loss at emergence on the open field compared to the fenced site was 10–18% for wheat, (**Brown *et al*., 2003) and (Brown, 2005).**

A- a- 3-Maize crop

Everard (1966) found that rodents damage was to all growth stages of the maize and was more prominent in the peripheral areas of the field than in the center. Stem debris, remains of ears, and stilt roots of erect plant. Lodged heads of maize or naturally growing grass were damaged, but the rat never cut down the maize plants, Figure (3).

Fig.(3): Damage caused by rodent on maize crops.

The assessment of damage caused by rodent **t**o maize were carried- out as the following technique. Four maize plots each of 2 feddans were selected. In each plots, ten samples (each containing 30 maize plants) were randomly chosen and checked to estimate the degree of damage in their ears according to **Hamelink (1981)** ,as follows:-

$$\% \text{ Damage ears} = \frac{i\,I \times S_1 + i\,II \times S_2 + \ldots\, ir \times S}{N} \times 100$$

Where: I = damage incidence expressed by the number of damage ears per severity class (I= 0%, II = 25%, III = 50%, IV = 75% and V= 100% grain missing). S = Damage severity for each class (i = 1, 2, 3, etc.). N = Total number of sampled ears. R= repetition.

In Egypt, Abdel-Gawad *et al.,* (1982) estimated the damage caused by *A. niloticus* (Des.) in sorghum and maize fields. Concerning damage in maize and sorghum in the harvest stage, the most damage was clear in corncob of the maize and in the stem top of sorghum. The damage was concentrated beside the border and decreased toward the center of the field in both maize and sorghum.

Abdel-Karim (1991) studies the damage caused by *Arvicanthis niloticus* (Des.), in maize fields at Sharkia governorate. He found that the rats attack maize plants at the beginning of germination and continued till harvest time but high rate of infestation was noticed during two stages of growth, the first one was early in the season from the second week of June till the end of June while the second period was during the second week of August.

In Minia governorate **Asran (1991)** prescribed the damage by *Arvicanthis niloticus* (Des.) in maize crop during the milky and dough growth stages, this was supported by **Keshta (1996)** in kalubia, Beni-suef and Qena governorates; **Abdel-Hamid (1997**) in Fayoum governorate; **El-Nashar (1998)** in Minia governorate and **Ahmed (2001)** in Sohag governorate**.**

Losses to maize crop by large jird *Meriones shawi isis* (Thomas) were about 2 Ardab/Fed., and decreased to 0.9 Ardab/Fed., during 2001 and 2002 agriculture seasons, respectively in Behria governorate (**Metwally *et al*., 2009).**

In Tanzania, It is not unusual for maize damage to exceed 80% in certain cropping seasons and locations **(Mwanjabe and Leirs, 1997).**

A total yield loss of 48% of maize, sorghum, paddy, and pulses that were in production during the 1989/90 crop season was attributed to seed depredation by *Mastomys natalensis* rat (**Mwanjabe *et al*., 2002).**

Rodents cause an estimated pre-harvest loss of 15% of the annual maize crop (**Makundi *et al*., 1991)**.

Damage due to rodents causes an estimated annual yield loss of 5–15% of maize (corn), corresponding to about $45 million, and food which could feed about 2 million people, (**Leirs, 2003**; Tables 1, 2 and 3).

The actual rodents damage to maize fields at the planting and seedling stages in 15 fields, each 0.5 ha in size, in Morogoro, was established at the seedling stage. The heterogeneous distribution of damage in some plots caused variations in the accuracy of the estimates between plots, but a sampling interval of five rows consistently produced estimates with a variance of less than 10% (**Mulungu *et al*., 2007)**.

In parts of South America, native rodents cause crop damage varying between 5–90% of total production (**Rodriquez, 1993).**

A-b- Sugar crops

Rodents may damage sugar cane and sugar beet from the time of planting through harvesting, and cause additional damage waste by contamination, **Abdel-Gawad (1974),Abdel-Gawad *et al*., (1982), Ali and Farghal (1995), Brodie and Webster(1997) , Engeman *et al*., (1998)** and **Zhang and Zhang (1999)**.

A-b-1- Sugar cane crop

The assessment of damage caused by rodent on sugar cane was carried-out as the following technique. The stalks were carefully examined to determine the percentage of rodents damage. The percentage of damage was calculated using the following equation:

$$\% \text{ Damage} = \frac{\text{Total numbers of damaged internodes}}{\text{Mean number of internodes in stalk x 30}} \times 100$$

In Egypt, Rat infestation reduced the juice solid contents from 12.38% to 11.64% in the top internodes, and from 18.78% to 15.655 in the bottom ones (**El-Deeb *et al*., 1989).** The damage of the Nile grass rat *Arvicanthis niloticus* (Des.), to sugar cane in Upper Egypt were 20 to 40 % reduction in yield and 30 % in final sucrose in the infested stalks of sugar cane. The bottom infestation percentage was higher than in the top ones that may be related to high sucrose content in the bottom internodes than in the top one (**Abazaid, 1990)**.The infestation percentage in the plant cane was less than in first and second rattoons. The percentage of rodents damage for four sugar cane varieties,G.T.54-9, G.95-19, G.95-21 and Ph8013 were higher during first season than second season **(Bakri and Al-Gendy, 2009)**,Figure (4)**.**

The annual loss in sugar cane crops caused by the Nile grass rat *Arvicanthis niloticus* **(**Des.**)** was estimated to be about 5-8% by weight. The proportions of rat damaged mill able stalk averaged 23.99 % and of dead stalks (due to damage) 7.17 % in no baited fields while in baited fields, rat damaged mill able stalks averaged 13.53 % and dead stalks 3.85 % **(Porquez and Barredo, 1978).**

The extent of crop loss by the rodent has been estimated to the tone of 165 crores of rupees annually in sugar cane, wheat and paddy in the state of Punjab alone **(Anonymous, 1987).**

The Queensland sugar, industry has recently implemented a comprehensive integrated pest management (IPM) system to minimize crop losses from two active rodent species, *Rattus sordidus* (canfield rat) and *Melomy burtoni* (climbing rat). These species inflicted approximately $25M of damage in a major outbreak in the 1999-2000 seasons **(Hunt *et al*., 2004)**.

A- b-2- Sugar beet crop

The assessment of damage caused by rodent on sugar beet was carried-out as the following technique. The roots were carefully examined to determine the rodents damage percentage, using the following equation:

$$\text{Damage \%} = \frac{\text{Weight of damaged roots in kg.}}{\text{Total weight of roots in kg.}} \times 100$$

In Egypt, The rodents damage was concentrated at the upper part of root, where the sucrose was high (**Ali and Farghal 1994).** Losses to sugar beet by rats were about (47.33 and 39.33kg.) and (51.54 and 43.33 kg.) during each cultivation season respectively **(Bakri and Al-Gendy, 2009),** Figure (5).

Sugar beet field **in North California** was affected by approximately 27% of all roots examined and account of for a 9% loss in the total production **(Salmon *et al* ., 1984).**

Fig.(4): Damage caused by rodent to sugar cane crop.

Fig.(5): Damage caused by rodent to sugar beet crop.

B- Post-harvest losses: extent of the problem

After harvest the crop attains its highest value, taking into account all the costs of producing it, processing, (packaging), storage and distribution prior to consumption and contaminated of stored foods. The actual values of the losses caused by rats vary by crop, variety, year, geographical location, pest species involved, length and method of storage and climate **(Gratz, 1990).**

The assessment of damage caused by rodent on Storage crops was carried- out as the following technique. **Caliboso and Teter (1983)** suggested that a constant estimate of the population density is needed to assess losses due to rodent. This could be obtained through trapping or by rougher methods such as counting of trails._**Zippin (1958)** found useful method in estimating population density in the warehouse. This method based on the average body weight of *Mus* sp. (161 g.), *Rattus mindanensis* (160 g.), and *Rattus norvegicus* (330 g.), and the daily intake of food constituted 95% of the total diet. Thus, the daily loss can be computed by the following formula:

$$L_R = (Pd_1 \times di_1) + (Pd_2 \times Di_2) + (Pd_3 \times Di_3).$$

Where: Pd_1=Population density of species 1 (n). Di_1 = Daily intake of species(g).

Consumption and contaminated (urine and droppings) of stored crops.

In Egypt, The estimated annual losses caused by rodents alone are about 4-10% in weight of stored grains, and the rate of damage to bags is between 10-26% **(El-Lakwah,1984).**

Results of investigations carried out during 1989/1991 in stores of the Kalyubia region showed that loss in weight of cereal grains is from 0.03-0.77% and for pulses 1.41-2.81% **(El-Lakwah *et al.,* 1993).**

High loss values are obtained when wheat is heavy rodent attack. Wheat storage period is between 4-8 months (The longer the storage period the higher the losses). The losses caused by handling and transport reveal that quantities lost under the stack are from 8-46kgs/ stack with a mean value of 30.8 kg. The total quantity of wheat loss (in the various shounas of Principal Bank for Development and Agricultural Credit), were 18769.6 tons during the storage period 1993/94, and its economic value is equivalent to 9.8 million Egyptian Pounds **(El-Lakwah and Laborious, 1995).**

In one survey of corn in a **Midwestern state**, 76% of about 1,000 grain samples were contaminated with rodent droppings. Mouse droppings outnumbered rat droppings twelve to one. A house mouse produces about 36,000 droppings in a year's time. Mouse infestations are so widespread that droppings and hairs often end up in many types of food commodities intended for human use. Certain levels of rodent contamination are grounds for condemning food commodities. Structural damage caused by rodents can be expensive (**WFP, 2008).**

In Philippine, the major species affecting food storage are the Norway rat, *Rattus norvegicus*, the common rice field rat, *Rattus rattus mindanensis,* and the house mouse, *Mus musculus*. Surveys conducted in small warehouses in the Philippines indicated losses of 40 to 210 kg of grains in each (**Rubio, 1971).**

In Nueva Ecija (Central Luzon), Aganon (1981) reported that the annual grain loss per warehouse due to rodent contamination and spillage was estimated at 1.92 to 2.93 cavans.

I**n Bangladesh,** rodents weighing more than 50 grams consume 15%. Interviewing farmers on rodent damage inside houses provided an estimated loss equivalent to US $ 29.50 for a six month period (**Bruggers, 1983).**

At 10.5 million households the annual losses are estimated at US $ 620 million for the entire country in houses only (**Mian *et al*., 1984).**

Two national strategic multi-media rodent control campaigns were organised and analysed in detail. Net profits were calculated at US $ 800,000 for each campaign, based on a single crop and season (**Adhikarya and Posamentier, 1987).**

The rodent population estimated in the farmers' households averaged 8·3 mice and 2·0 rats per household**.** These rodents were estimated to consume and hoard about 53 kg. of rice per farm family per year (**Mian *et al*., 1987).**

Farmer estimates of rice lost during storage to rodents ranged from 5 to 40%, with an average of 13% (±0.02 sem) estimated loss. Trials were developed to repeatedly measure rodent impacts on stored rice and concluded that losses could be as high as 5% of the total amount of grain stored by a household. Losses to rodents over a three month period per household grain store were typically 35kg; rodent losses over a year would be enough to feed an additional person's dietary intake per household. A further 2.5% of rice was partially eaten by rodents, significantly affecting its nutritional value, and contamination with rodent feces could be as high as 300 droppings per kg. (**Aplin *et al*., 2004).**

5-10% of stored grain was lost to rodents over each 3-month storage period (each household losing ˜200kg/year). Contamination with urine and feces was also severe (200 > 1,500 droppings/ kg.) by **Belmain and Shafali (2008).**

Losses of rice **in the Philippines** were reduced from US $ 36 million to US $ 3.5 million with the advent of organised rat control programs according to **Sumangil (1990).**

In Pakistan, Ahmad *et al*., (1995) estimated the annual grain losses/shop due to rats consumption, contamination, spillage, and wastage to be 740kg/shop**.** The annual losses would approximately about 0.3% of the estimated 1225 million mt that move through the markets yearly. Post harvest losses present one of the main problems not only in rice but also in all grain production. Losses in food crops, occurring during harvesting, threshing, drying, storage, transportation…etc have been estimated to be between 30 and 40% of all food crops in developing countries. If post harvest losses are reduced, the world supply can be increased by 30-40 % without cultivating additional hectares of land or increasing any additional expenditure on seed, fertilizer, irrigation and plant protection measure to grow the crop.

Rodents damaged entire upland after harvests in one of the poorest countries in **Southeast Asia**. 74% of the interviewed households reported losses between 50 and 100%, 100% rice losses were common. Maize harvest was also severely damaged with 43% of households reporting yields of less than 50% of expected production. Widespread damage was similarly reported for Job's tears, sesame, and cassava. These losses are a major livelihood shock for rural households who rely on their own production as a source of food and income (**WFP, 2009).**

The economic losses caused by insects usually do not exceed 5-10%, he stated, but losses caused by rodents and birds can range from 5% to more than 50% **(Fachrudin, 2009),** Figure (6)**.**

Fig.(6): Stored rice contaminated with rodent feces.

III-Losses caused by rodents to fruit trees.

The common commensal pests are *Rattus rattus* and *M. musculus* throughout the country including the islands. *R. rattus* along with squirrels, *Funambulus palmarum* and *F. tristriatus* are serious pests of plantation crops such as coconut and oil palm in the southern peninsula. *F. pennanti* is abundant in orchards and gardens in the north and central plains and sub-mountain regions **(Parshad, 1999)** and (**Chakravarthy, 2004).**

The fruit trees were carefully examined to determine the rodents damage percentage, using the following equation:

$$\text{Damage \%} = \frac{\text{Weight of damaged fruit in kg.}}{\text{Total weight of fruit in kg.}} \times 100$$

The amount of damage caused by rats (*Rattus argentivente*, *Ratus tiomanicus* and *Ratus diardil*) to oil palm areas on Malaysian is difficult to estimate. In nurseries, rats have been known to chew the stem base of young seedlings to feed on the tender bud tissues found there. Such incidences are prevalent in field nurseries situated near forest areas or those situated in new clearings with secondary forests nearby. Young palms planted out in the field are not exempt from rodent attacks. If the attack is severe, the young palms die due to collapsed fronds which have been attacked at the base by the rats. Other than that, it has been estimated that severe rat damage could cause between 20% to 30% damage among the new plantings and the total fresh fruit bunch yield during the first twelve months after maturity was 20% lower than those from palms with no damage. If attacks are not that severe, the fronds that have been attacked are removed to allow new fronds to grow, however the palm remains stunted for some time. In such incidences, preventive measures need to be carried out to ensure that subsequent attacks do not occur on the same young palms which have already been weakened by earlier attacks. Mature palms with ripe and unripe fruits alike are also subject to rodent attacks. In the case of fruits being attacked, rodents gnaw to reach the kernel inside. Crop losses caused by rats feeding on the mesocarp of the fruit has been estimated to be in the region of 5% of the oil yield - and in severe cases, can rise to between 7 to 10% of total oil production, about 165kg of oil per hectare per year **(Chung and Balasubramaniam, 2000).**

During the 18 years of the trial about 43% of the trees on M.9 and B.9 rootstocks were lost, mainly because of poor anchorage, while only 12% of those with M.9 and B.9 inter-stocks were lost, mainly because of rodent damage **(Czynczyk, 1986).**

The secretive, nocturnal nature of rats means that they often go unnoticed in a neighborhood until dooryard citrus and other fruit starts to ripen. They then make their presence known with a vengeance. In citrus and papaya the characteristic damage is a circular hole about the size of a quarter or half dollar and the whole fruit hollowed out, Figures (7 and 8). They remove whole fruits from blueberries, figs, grapes, strawberries, Surinam cherry, loquat, and dates, so the damage is less noticeable or birds are blamed for the missing fruit. Estimates of damage caused by *Rattus rattus* to macadamia nut crops were determined from several Australian macadamia orchards during the 1995/1996 growing season. Both the extent and pattern of crop damage were associated with the type of adjacent non-crop habitat. Orchards adjacent to large, temporally stable, structurally complex habitats experienced high levels of rodent damage (mean 9.9%). Front row trees adjacent to these stable habitats showed significantly higher damage than trees further into the orchard, suggesting an interaction between the crop and non-crop habitats. Orchards adjacent to highly modified grasslands and other orchard blocks exhibited the lowest levels of damage (mean 0.8%), with the damage in these areas being uniformly distributed **(White *et al*., 1997), (Horskins *et al*., 1998)** and **(Horskins and Wilson, 1999).**

Habitat manipulation was used as a management strategy for the control of rodent (*Rattus rattus*) damage in Australian macadamia orchard systems. The total cost of the habitat manipulation was $AUD 292 per site. Manipulation resulted in a reduction in damage of 65% within the associated orchards. This reduction in rodent damage resulted in a saving of $AUD 980 per site. Therefore habitat manipulation was cost-effective and is a viable strategy for the control of rodent damage in Australian macadamia orchard systems **(White *et al*., 1998).**

Over a 3-yr period, orchard trees adjacent to the restored habitat received 50% less rodent damage than trees adjacent to non-manipulated habitats. A cost–benefit analysis (based on both contractor and farm rates) of the damage reduction obtained after the initial manipulation indicated a break-even point (based on farm rates and a nut in shell price of $2.80/kg.). After break-even, this represents an economic benefit to growers that will result in an additional return of approximately $4500 per annum per km of orchard frontage **(Ward *et al*., 2003)**.

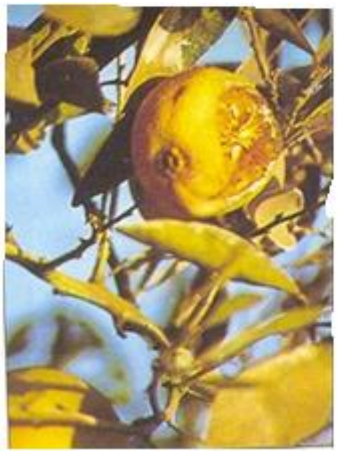

Fig.(7): Roof rat damage to oranges.

A

Weeds around trunk

B

Injury inside weed area

Fig.(8): Damage due to mice (properly referred to as "voles" but growers simply call them "mice"), is most serious when their normal food supply is limited. Mouse injury to fruit trees mostly consists of girdling of trunk and roots and sometimes root pruning (A and B).

Table (1): Major agricultural rodent pest problems for food crops in selected regions, their importance as food competitors with people, and methods of control being applied in Africa.

Rodents species	Region	Major crop(s)	Estimated damage	Pest status	Main control	Notes
Mastomys spp	Sub-Saharan Africa outside central rainforest block	All cereals, groundnut, tubers	Tanzania: 5–15% of harvest annually; outbreaks >80% Nigeria: maize 42%; rice at seedling stage 11% during an outbreak; sorghum 10–90% Senegal: rice >80% during an outbreak Kenya 2.3–75% (mean 11.5%)	Very high	Rodenticide	See overview in Fiedler(1988)
Arvicanthis spp	Sub-Saharan Africa South to Zambia	All cereals, groundnut, tubers, vegetables	Same as Mastomys; in areas where both occur, it is difficult to distinguish damage by different species	Very high		
Meriones shawi	Northern Africa	Cereals, vegetables	Morocco: 40–70% losses	Very high during outbreaks		
Tatera spp	Eastern Africa	Cereals, tubers		Low		
Taterillus spp	West Africa, Sahel	Groundnut	Senegal: 10%	Low, high during outbreaks		
Rattus rattus	Madagascar, locally in Africa	Maize, rice				
Thryonomys sp		Rice	Nigeria: rice average 5%	Moderate	Hunting, traps	
Rhabdomys pumilio	Eastern and southern Africa	Cereals		Moderate		
Cricetomys gambianus	Sub-Saharan Africa	Cereals, root crops, fruits vegetables cacao			Traps	
Mole rats (Heterocephalus) spp, Tachyorctes spp, Cryptomys spp)	Eastern and Southern Africa	Root crops, Vegetables		Very high	Traps	
Squirrels (Xerus spp)	Semi-arid sub-Saharan Africa	Maize, coconut, groundnut	Kenya: 9.7% of planted maize, 5.4% of maize cobs	High		
Porcupines	Sub-Saharan Africa	Maize, coconut		High		

Table (2): Major agricultural rodent pest problems for food crops in selected regions, their importance as food competitors with people, and methods of control being applied in Asia and Australia.

Rodents species	Region	Major crop(s)	Estimated damage	Pest status	Main control	Notes
Asia						
Rattus argentiventer R losea	South east Asia	Rice	Indonesia: 10–20% Malaysia: 2–5% Vietnam: >10% to>500,000 ha Thailand: 6% lowland, 7% upland	Very high	Rodenticide physical, control, fumigation, bounty system	Impacts on rice production see Singleton(2003); grasslands and non- rice cereals in China see Zhong *et al.* (1999) and Zhang *et al*. (1999)
Bandicota bengalensis B indica, Mus spp	South east Asia	Rice, sorghum, tuber crops	Laos: upland crops10–15%; up to 100% in outbreak years Cambodia: patchy, no data Philippines: (patchy) 1–10%; up to 40% at district level	High High Moderate	Rodenticide, physical control	
Microtus brandti, Meriones unguiculatus, Mysopalax baileyi	South Asia	All cereals and tuber crops	India and Bangladesh: 5–10%, some years >50% at district level	Very high	Rodenticide, physical control	
Cricetulus spp,	China	Grasslands	Inner Mongolia: 15–44% Quinghai-Tibet: 370 000 km^2 badly affected	Very high	Rodenticide	
Microtus spp ***Rattus spp, Myospalax fontanieri***		All cereals, vegetables	15 million metric tons (5–10%)	Very high	Rodenticide, physical control	
Australia						
Mus domesticus		All cereals	Outbreaks: 5–30% of harvest at regional level; non-outbreak <2%	Very high	Rodenticide	Impacts on cereal crops see Caughley *et al.* (1994);
Rattus sordidus		Sugarcane	US$1–2 million annually (2–5%)	Moderate	Rodenticide habitat modification	impacts on sugar crops see Whisson (1996);
Rattus rattus		Macadamia nuts	Up to US$1–2 million annually (30%)	Moderate	Rodenticide	Impacts on macadamia nuts see White *et al*.(1997).

Table (3): Major agricultural rodent pest problems for food crops in selected regions, their importance as food competitors with people, and methods of control being applied in Europe, South and North America.

Rodents species	Region	Major crop(s)	Estimated damage	Pest status	Main control	Notes
Europe						
Apodemus spp	Northwest Europe	Cereals, non-cereals		Moderate		See Lund(1998)
Microtus agrestis	Northwest Europe	Forestry, orchards	Forestry, orchards	Low		
Microtus arvalis	Northwest Europe	Horticulture, pastures, cereals during outbreaks	pastures, cereals during outbreaks	Moderate, high		
Arvicola terrestris	Northwest Europe	Tubers, vegetables, orchards	Tubers, vegetables,	Moderate		
South America						
Holochilus spp	Argentina, Brazil, Uruguay Venezuela	Rice, sugarcane, maize	Outbreaks: 20%	High	Rodenticide	See Rodriguez (1993)
Akodon spp	Bolivia, Peru	Cereals, rice,	Outbreaks: 10–90%	Very high	Rodenticide	
Calomys spp	Argentina Bolivia,	Cereals, maize	Outbreaks: 10–90%	High	Rodenticide	
Oligoryzomys spp, Phyllotis	Argentina, Chile, Peru	Fruits, maize, sugarcane	Outbreaks: 12–20%	High	Rodenticide	
Sigmodon spp	Colombia, Venezuela, Peru	Alfalfa, rangelands				
Zygodontomys spp	Venezuela, Colombia	Forage crops				
North America						
Microtus spp	Eastern US	Orchards, vegetables,		High	Rodenticide	See Marsh(1988)
Geomys sp, Thomomys sp				High	Rodenticide	
Spermophilus spp	Western US			High	Rodenticide	

Less detailed data is provided for Europe and North America to give a global overview. Other species may be much more important locally as pest species. Regional variation in crop choice and climate may affect a species' relevance as a pest. Damage figures are rarely available and methods of assessment are unstandardized. In most cases, more than one species in a genus are involved in pest problems, but not all species in a genus are necessarily pests. See [supplementary information on Frontiers website] for references and further details.

IV- Discussion of the article

1 - Rodents prefer grain crops and sugar crops for its palatability and its high caloric content **(Al-Gendy,1999) and (Ramsey and Wilson, 2000)**.

2 - Climbing rats and some rodents, prefer palm and fruit trees when its available in the appropriate environment for survival and breeding **(White *et al*., 1997), (Horskins *et al*., 1998), (Horskins and Wilson 1999)**.

3 – No losses have been reported in rice crop in Egypt, due to the diversity of food in summer and autumn seasons and to the existence of alternatives to high-calorie contents in garbage and waste of homes and restaurants **(Al-Gendy, 2005**).

4 - In many countries have not registered losses in rice, wheat and sugar crops as they are applying a good control program to eliminate rodents and reduce their numbers.

5 - Developing countries are recording centimes higher losses in the main crops necessary for population daily nutrition because of the wide spread slums that provide shelter and habitat for rodents from which to attack fields. Moreover the lack of support for the application of control program to eliminate rodents.

V-The recommendations of the article

1- Paying more attention towards reduction of losses caused by rodents both pre-and post-harvest which can provide and safe on amount of food sufficient enough to feed an additional person for each family all over the world **(Aplin *et al*., 2004).**

2- Reducing post-harvest losses will results in 30% to 40% increase in production without cultivating extra lands or increase in expenditures on seed, fertilizer and irrigation **(Ahmad *et al*., 1995),** and about 280 million people suffering malnutrition can benefit **(Meerburg *et al*., 2008)**.

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