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Management of maize using trap barrier system for house mouse (*Mus musculus* Linn.) depredations in Faisalabad and Jhang, Pakistan

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Abstract
The house mouse (*Mus musculus* Linn.) of the order 'rodentia' and family 'muridae', inhabits wide range of habitats. Of its main inhabited habitations, well moisture canal irrigated cropland-ecosystems, man-made relatively old buildings and stored grain structures are included. This paper describes information about the depredatory patterns exhibited by the house mouse for the maize, incorporated with the trap barrier system (TBS) in the sampled sub-habitats of Faisalabad and Jhang, Pakistan. Both of them belong to Central Punjab, Pakistan, where predominant agricultural activities are extended throughout the year. For one acre plots of each, the house mouse damage was intensively high during the years (2012) and (2013) in controlled conditions 109.6±4.20; 151.8±4.07; 99.11±4.37 and 137.1±5.00, while in the barrier treated conditions, there was a significant decline for rodent depredations 56.89±2.97; 66.58±3.01; 50.33±2.37 and 66.35±3.37. Trap success ratios (TSRs) indicated that, through the application of trap barrier system in both the habitats, there was a considerable decline in the population of house mouse, and prove beneficial for other economically important crops', for not only inhibiting the house mouse damage proportions, but for maintenance of crop sustainability.

Keywords: Management, crops, rodents; trap barrier system, agro-ecosystems

1. Introduction
Impact of rodents on variety of agricultural crops has been detrimental throughout the world [1, 2]. Damage appears to augment with their sufficiently large population influx among the cultivations and indoor situations [3, 4]. The house mouse (*Mus musculus* Linn.) remains a serious destructive vertebrate pest in urban and sub-urban situations causing widespread damage to crops, stored grains and houses [5-7]. Importantly, long term effects of the house mouse damage remain after the eradication of invasive rodents, due to longer periods of survival [8]. Unquestionably, the house mouse potential for triggering damage has been detected on variety of vegetation with sufficient moisture and lower the crop production among various habitats throughout the world [8, 9].
Diversity of rodents reported among large cultivation besides non-cultivated localities brings about substantial depredations and resulting economic losses [10-12]. Occurrence of ample food reserves closer to their burrows, therefore, do not require large foraging distance, and enables to revisit the food sites repeatedly. Many of them are also carriers of serious communicable diseases among domestic animals, livestock and humans [13-15]. Although the induction of multiple cropping systems (MCS) has benefitted majority of farmers in South Asian regions, but has also resulted in hazardous impacts' on agriculture like the advent of large populations of the vertebrate pests [16]. Predominantly, agro-ecosystems of Punjab, (Pakistan) have been productive, sufficing major agricultural proportions of the country [17], but lately, have been severely affected by undesirable activities of rodents' and birds', consequently lowering the crop production [18, 19].
The community based trap barrier system (CTBS) aimed at inhibiting rodent depredations with eco-friendly methods through the participation of farmers. It has been extensively practiced in Australia, Indonesia, Philippines, Vietnam and major parts of China, where encouraging results indicate its overall effectiveness to the farmers and sustainable agriculture [20-23]. A significant aspect of the trap barrier system (TBS) is that, the crop protection occurs in ecologically acceptable manner, as the entire crop is wrapped in poly-ethylene sheets, held together with wooden bamboos, at sufficient height of about (50 cm) from soil.

The barrier system is equipped with the ample moat water comprising multiple channels for movements of rats and mice. Occurrence of inlets mainly towards the four corners of the crop locations comprises with four types of traps viz. steel jar, single, double and multiple capture, containing rodent attractive baits of grains, nuts, vegetable and fruits, to effectively entrap the marauding rodents [24-28]. Present studies were largely based on the sustainable integrated method (SIM), to reduce rodent damage without interfering with the ecosystem sustainability [29]. Mainly, three major agricultural predicaments, namely, to assess ecological status of different vertebrate pest among various habitats, to determine the impacts of physical and biotic factors, responsible for rise and fall of the rodent populations regarding different agricultural landscapes, and finally, to ascertain about population gains or losses for vertebrate pests relative to set of crops [30].

1.1 Hypothesis: Present studies hypothesized that, impact of trap barrier system would significantly reduce the depredations of the house mouse on maize in the various sub-habitats of the two major habitats, and better the crop yield and economics.

1.2 Aims and objectives

To assess the relative depredatory impacts of *Mus musculus* (Linn.) for maize for various sub-habitats in both Faisalabad and Jhang in controlled and trap barrier induced conditions, and to determine the predicted crop damage as collated from the house mouse damage patterns.

2. Materials and Methods

Present studies to determine the impact of house mouse (*Mus musculus* Linn.) on maize (*Zea mays* L.) were extended for 24 months in both Faisalabad and Jhang. Both of them occur in region of Central Punjab (Pakistan) at latitude 31°.33 north, longitude 72°.33 east and latitude 30°.31, and north longitude 73°.74 east respectively. This region is characterized with variety of agricultural and horticultural croplands and is mainly canal irrigated. It has forest and roadside plantations in both rural and urban conditions. Of the important crops here include wheat (*Triticum aestivum*), maize *(Zea mays*), rice (*Oryza sativa*), cotton (*Gossypium hirsutum*) brassica (*Brassica campestris*), canola (*Brassica naphus*), sugarcane (*Saccharum officinarum*), sunflower (*Helianthus annuus*), sorghum and millet. Various fruit orchards likes' citrus, guava, mango, dates pomegranate and mulberry are also frequent in fairly large proportions, with variety of old and tall trees since independence, providing suitable burrows, roosts and nests for rodents and birds. Overall, there exists enriched floral diversity and the dearth of food does not remain limiting factor, fostering sufficiently large populations of amphibians, reptiles, birds, small and large mammals, mostly as pests are also present in fairly good numbers [31].

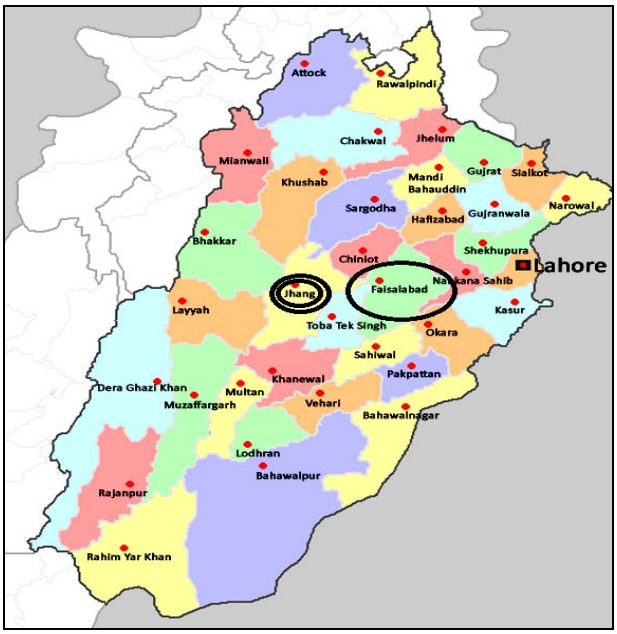

Fig 1: Study area(s) of present work in Faisalabad and Jhang.

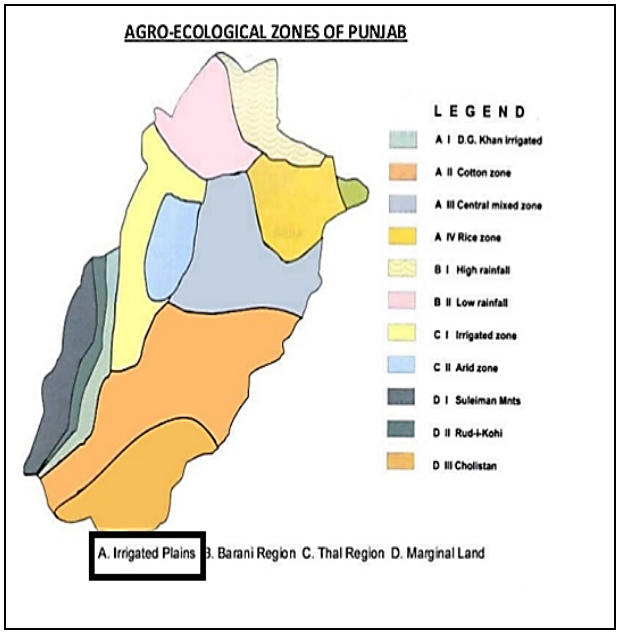

Fig 2: Agro-ecological zones of Punjab, Pakistan

Both the major habitats (Faisalabad and Jhang) are considered as the main agricultural hub of Pakistan. The croplands, forest plantations and roadside plantations are closely equipped with canal irrigation systems of three main canals (Jhang, Gogera and Rakh branches), with various water tributaries. Observations were made among two main sub-habitats, namely, the student farms and agricultural extension, (University of Agriculture) and the postgraduate agricultural research station, with sufficient number of crops. Similarly, the sub-habitats of Jhang comprised village 476, village korian, massan and maddoki respectively. Studies were conducted for two years (2013 and 2014) consecutively on maize under the controlled and barrier installed conditions to ascertain the foraging and feeding variations.

Suitable baits of the whole bread which was immersed in vegetable oil, were provided as baits in the four types of traps viz. steel jar, McGill mouse trap, double and multiple capture traps. A total of 16 such traps were placed in the entire maize field (four each at the corners). They were critically examined the nest morning regarding the capture of house mouse. Number of mice were manually numbered using their taxonomic key from the variety of sub-habitats. They were paper-tagged displaying their numerical numbers entrapped per sub-habitat. Trap success ratios (TSRs') were recorded from every sub-habitat in the study sites with the formula:

$$\frac{\text{No. of rodents captured}}{\text{Trap nights}}$$

$$\frac{\text{\% age damaged tillers x 100}}{\text{Total no. tillers counted}}$$

Assessment of crop damage by *Mus musculus* (Linn.) with respect to wheat was extended by equally splitting into three halves of the fields among all the sub-habitats [32]. Estimation of rodent damage was ascertained by the 1x1 m^2 transect lines drawn diagonally in the controlled and treated conditions of maize. Use of manual counts was done at each stage on the basis of the intact and damaged wheat plants on various growth crop stages. Proportions of damage for each wheat frame were calculated according to [33]:

2.1 Statistical analysis

The data was statistically analyzed using a micro-computer with analysis of variance, Randomized Complete Randomized Designed and means were compared for statistical differences with Tukey's student Newman-Keul test, with correlation and regression analysis to describe the results [34].

3. Results and Discussion

Table 1: Relative abundance recorded for house mouse (*Mus musculus* Linn.) at each growth stage of *Zea mays o*f in the sub-habitats of Faisalabad in years (2013 and 2014).

Habitat I Faisalabad	Wheat growth stages	Stage duration (weeks)	Trap nights	Relative abundance of house mouse	
Years				Control	Treated
2013	Germination	2	32	1244.00	602.00
				38.88	18.81
	Tillering	4	64	1715.00	809.00
				26.80	12.64
	Flowering	10	160	4006.00	2031.00
				25.04	12.69
	Ripening	4	64	1800.00	1109.00
				28.13	17.33
	Total	20	320	8765.00	4551.00
	Average			27.39	14.22
2014	Germination	2	32	1121.00	639.00
				35.03	19.97
	Tillering	4	64	1490.00	773.00
				23.28	12.08
	Flowering	10	160	3670.00	1862.00
				22.94	11.64
	Ripening	4	64	2348.00	752.00
				36.69	11.75
	Total	20	320	8629.00	4026.00
	Average			26.97	12.58

Table 2: Occurrence of abundance of house mouse for various growth stage of wheat among the sampled sub-habitats of Jhang in years (2013 and 2014).

Habitat II Jhang	Maize growth stages	Stage duration (weeks)	Trap nights	Relative abundance of house mouse	
Years				Control	
2013	Germination	2	32	1400.00	692.00
				43.75	21.60
	Tillering	4	64	2321.00	1159.00
				36.27	18.11
	Flowering	10	160	6005.00	2359.00
				37.53	14.74
	Ripening	4	64	2418.00	1116.00
				37.78	17.44
	Total	20	320	12144.00	5326.00
	Average			37.95	16.64
2014	Germination	2	32	1295.00	460.00
				40.47	14.38
	Tillering	4	64	2124.00	922.00
				33.19	14.41
	Flowering	10	160	5721.00	2953.00
				35.76	18.46
	Ripening	4	64	1829.00	973.00
				28.58	15.20
	Total	20	320	10969.00	5308.00
	Average			34.28	16.59

Table 3: Percentage of *Mus musculus* (Linn.) damage record for maize at the three corners of field (left, middle and right) under controlled and barrier induced conditions from the four sub-habitats of district Faisalabad (2013 and 2013).

Site I			District Faisalabad							
			Control				Treated			
Years	Maize growth stages	Duration each stage in (weeks)	Left side (55rows)	Middle side (70 rows)	Right side (55 rows)	Total	Left side (55 rows)	Middle side (70rows)	Right side (55 rows)	Total
Year (2013)	Germination	2	15.08	13.58	16.17	44.83	8.17	7.67	7.25	23.08
	% damage		10.19	9.18	10.92	30.29	5.52	5.18	4.90	15.60
	Tillering	4	112.08	83.17	84.33	279.58	59.25	47.25	44.42	150.92
	% damage		32.02	23.76	24.10	79.88	16.93	13.50	12.69	43.12
	Flowering	10	126.33	95.33	105.08	326.75	51.33	46.83	44.58	142.75
	% damage		36.10	27.24	29.24	92.57	14.67	13.38	12.74	40.79
	Ripening	4	140.33	111.08	105.42	356.83	64.67	44.58	40.92	150.17
	% damage		40.10	31.74	30.12	101.95	18.48	12.74	11.69	42.90
	(Overall Average)	20	98.46	75.79	77.75	252.00	45.85	36.58	34.29	116.73
	(Overall % damage)		29.60	22.97	23.59	76.17	13.80	11.19	10.50	35.60
Year (2014)	Germination	2	12.50	11.33	15.50	39.33	7.50	6.58	6.67	20.75
	% damage		8.45	7.66	10.47	26.58	5.07	4.45	4.50	14.02
	Tillering	4	63.67	66.67	50.25	180.58	38.33	29.08	30.15	97.57
	% damage		18.19	19.05	14.36	51.60	10.95	8.31	8.61	27.88
	Flowering	10	83.08	87.25	78.33	248.67	41.17	52.50	40.47	134.14
	% damage		23.74	18.18	22.38	64.30	11.76	10.94	11.56	34.26
	Ripening	4	90.67	82.83	85.17	258.67	49.83	46.67	27.71	124.21
	% damage		25.90	17.26	17.74	60.90	14.24	9.72	7.92	31.88
	(Overall Average)	20	62.48	62.02	57.31	181.81	34.21	33.71	26.25	94.17
	(Overall % damage)		19.07	15.53	16.29	50.84	10.50	8.35	8.149	27.01

Table 4: Incidence of house mouse damage incurred to maize for growth stages recorded in Jhang. Observations are combined together for various sub-habitats in (2013 and 2014).

Site II			District Jhang							
			Control				Treated			
Years	Maize growth stages	Duration each stage in (weeks)	Left side (55 rows)	Middle side (70 rows)	Right side (55 rows)	Total	Left side (55 rows)	Middle side (70rows)	Right side (55 rows)	Total
Year (2013)	Germination	2	16.25	14.00	17.25	47.50	9.08	7.92	8.17	25.17
	% damage		10.98	9.46	11.66	32.09	6.14	5.35	5.52	17.00
	Tillering	4	146.67	138.67	143.17	428.50	66.92	54.33	58.33	179.58
	% damage		41.90	39.62	40.90	122.43	19.12	15.52	16.67	51.31
	Flowering	10	157.25	127.83	127.71	412.79	75.00	68.17	66.92	210.08
	% damage		44.93	36.52	36.49	117.94	21.43	19.48	19.12	60.02
	Ripening	4	148.75	139.83	126.92	415.50	74.33	68.25	62.17	204.75
	% damage		42.50	39.95	36.26	118.71	21.24	19.50	17.76	58.50
	(Overall Average)	20	117.23	105.08	103.76	326.07	56.33	49.67	48.90	154.90
	(Overall % damage)		35.08	31.39	31.33	97.79	16.98	14.97	14.77	46.71
Year (2014)	Germination	2	14.50	12.25	16.00	42.75	8.33	7.25	7.67	23.25
	% damage		9.80	8.28	10.81	28.89	5.63	4.90	5.18	15.71
	Tillering	4	127.75	93.42	94.50	315.67	56.50	50.00	25.44	131.94
	% damage		36.50	26.69	27.00	90.19	16.14	14.29	5.30	35.73
	Flowering	10	100.25	85.33	92.00	277.58	52.75	46.63	44.17	143.54
	% damage		20.89	24.38	26.29	71.55	10.99	13.32	9.20	33.51
	Ripening	4	92.75	94.75	90.25	277.75	39.33	49.58	32.33	121.25
	% damage		19.32	27.07	18.80	65.20	8.19	14.17	6.74	29.10
	(Overall Average)	20	83.81	71.44	73.19	228.44	39.23	38.36	27.40	105.00
	(Overall % damage)		21.63	21.61	20.72	63.96	10.24	11.67	6.60	28.51

Data of the present study indicates that during various growth stages of maize during (2013 and 2014) the house mouse remained in fairly high proportions in controlled conditions. Maximum abundance was recorded on the flowering stage (10 weeks) wherein 160 trap nights resulted in capture of approximately (4000) house mice, while they remained least (1244) on the germination stage. Nonetheless, following the application of (TBS), the population abundance declined considerably for all four growth stages (Table 1). Situation did not presented sufficient deviations for the mouse

populations in Jhang, where yet again, during the prolonged flowering stage, maximum mouse population was entrapped. Seemingly, this major habitat provided slightly higher house mouse abundance as compared to Faisalabad in controlled conditions.

Implications of trap barrier system throughout the sub-habitats, nevertheless, reduced the rodent populations' abundance, to the ecologically acceptable limitations (Table 2). Present studies proved to be effective point indicators for effectiveness of the (TBS) to decrease house mouse infestations on maize on all growth stages, but with elevated intensity for the flowering stage (lasted for 10 weeks), resulting in maximum capture. Similar studies on house mouse damage to wheat have been reported by [35] who reported that house mouse remained one of the trivial vertebrate pests to cause significant depredations to variety of growth stages of wheat at differential growth stages and, therefore, resulted in serious economic losses. Although, not significant relative abundance occurred between both the major habitats, but slightly enhanced damage proportions in Jhang were possibly attributed to the more affluent ecological circumstances which facilitated in the house mouse destruction of wheat. It may also be anticipated that increase and decrease among rodent pests is closely linked to their reproductive ecology. Undoubtedly, majority of them possess short gestation periods and except in the coldest and hottest months of the year, continue to breed, wherein most of the remaining temperature fluctuations, are well endured by them [36]. Effectiveness of trap barrier was also determined regarding the (maize) crop damage for both the habitats. For convenience, the crop was equally sub-divided into three sections viz. left, middle and right [30] to assess the damage precisely. In both the major sampled habitats, percentage of *Mus musculus* (Linn.) depredations did not represent larger deviations among themselves, with considerable decline of house mouse in the barrier induced environments.

The house mouse, invariably considered as highly opportunistic and prolific breeder, occurs throughout the croplands in fairly large proportions, causing intensive damage on all important crops in Pakistan. It nibbles through fast and not only depredates crops but also causes significant economic losses. Additionally, variety of rodents consider several crops as their safe heavens to find ample protection against their predators. Of these, sugarcane which remains available for about eight to ten months appears most preferred crop [37-39]. An important aspect of the success of various vertebrate pests is attributed to the occurrence of multiple-cropping systems throughout the region of Punjab. Although it provides relative facilitated access to the farmers for improving their cultivations over a relatively small area (12 acres), but provides opportunities to them to freely feed without considerable loss of energy. It remains pertinent that similarities of results with present studies are comparable to [40-43]. In the inception of management methods (with TBS), numerical decline of *Mus musculus* (Linn.) not only inhibited its less crop abundance, but also its damage proportions as were recorded under controlled conditions. Moreover, it was also important to know that majority of the burrows established were well inside the wheat crop, and provided convenient damage patterns to the house mouse than located at a distance.

4. Conclusions

From the present study, it was concluded that, undeniably all rodents in the suitable ecological conditions, remain economically significant vertebrate pests to variety of agricultural crops. They destroy them and are responsible for considerable economic losses. The region of Punjab, Pakistan, where canal irrigation system remains the main source for crops, occurrence of sufficient moisture provides sufficient opportunities to them in wheat, rice, sugarcane and maize based agro-ecosystems. Farmer's attitude, knowledge and perceptions possibly focus on reliance with traditional management measures of rodent pests, but lately, this has resulted in far less dividends as anticipated, which results in more destruction of crops and economic losses. Not only the crop sowing and mature periods perhaps would reduce such damage, but induction of useful and environmentally safe ecologically based rodent management measures (trap barrier system) promises more reliable and safe control programs, and after its watchful implications throughout the region of Punjab, with the astringent possibility to minimize the rodent menace, and to improve sustainable agricultural practices.

5. References

1. McConkey KR, Drake DR, Meehan HJ, Parson N. Husking stations provide evidence of seed predation by introduced rodents in Tongan rain forests. Biol. Conserv., 2003; 109:221-225.
2. Hoque MM, Sanchez FF, Benigno EA. Rodent problems in selected countries in South-East Asia and islands in the Pacific. In: Prakash, I., ed., Rodent pest manage. Baton Rouge, CRC Press, 1988, 85-99.
3. Quick GR. Rodents and Rice. Report and proceedings of an expert panel meeting on rice rodent control. Manila, Phil. Int. Rice Res. Institute. 1990, 132**.**
4. DeGraaf G. The rodents of southern Africa. Pretoria, Butters worth. 1981, 267.
5. Gratz N. The burden of rodent-borne diseases in Africa south of the Sahara. Belg. J Zool., 1997; 127:71-84.
6. Fiedler LA. Rodent pest management in Eastern Africa. Rome, FAO (Food and Agriculture Organization of the United Nations). Plant Prod. Prot., 1994; 83:123.
7. Glisman SR. Multiple cropping systems a basis for developing and alternative agriculture. Environ. Studies Univ. Calif. USA. 1979, 70-82**.**
8. Khan HA, Ahmad S, Javed M, Rehman K. Roost composition and damage assessment of rose ring parakeet (*Psittacula Kamari*) on maiz and sunflower in agroecosystem of central Punjab, Pakistan. Int. J Agric Biol. 2011; 14:149-152.
9. Ahmad S, Khan HA, Javed M, Rehman K. Management of Maize and Sunflower against the Depredations of Rose-ringed Parakeet (*Psittacula krameri*) using Mechanical Repellents in an Agro-ecosystem. Int. J Agric. Biol. 2012; 14:286-290.
10. Singleton GR, Sudarmaji, Suriapermana S. An experimental field study to evaluate a trap barrier system and fumigation for controlling the rice field rat, *Rattus argentiventer,* in rice crops in West Java. Crop Prot. 1998; 17:55-64.
11. Towns DR, Broome KG. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. New Zeal. J Zool. 2003; 30:377-398.
12. Singleton GR, Sudarmaji, Jacob J, Krebs CJ. Integrated management to reduce rodent damage to lowland rice crops in Indonesia. Agric. Ecol. Environ., 2005; 107:75-82.
13. Brown PR, Tuan NP, Singleton GR, Tuat NV, Tan TQ, Hoa LT. Impact of village-level rodent control practices

on rodent populations and rice crops in Vietnam. In: G. R. Singleton, L. A. Hinds, C. J. Krebs and D. M. Spratt, (Eds.). Rats, mice and people: Rodent Biol. Manag. ACIAR. Res. Monograph. ACT, Canberra Aust., 2003; 197-202.
14. Brown PR. Short- and long-term demographic changes in house mouse populations after control in dryland farming systems in Australia. Wildlife Res. 2006; 33:457.
15. Leung LKP, Singleton GR, Sudarmaji Rahmini. Ecologically-based population management of the rice-field rat in Indonesia. In: Singleton GR, Hinds LA, Leirs H, Zhang Z (Eds.). Ecologically-based management of rodent pests. ACIAR, Canberra, ACT, Aus., 1999, 305-324.
16. Singleton GR, Sudarmaji, Brown PR. Comparison of different sizes of physical barriers or controlling the impact of the rice field rat, *Rattus argentivente*, in rice crops in Indonesia. Crop Port., 2003; 22:7-13.
17. Lam YM. Rice as a trap crop for the rice field rat in Malaysia. In proc. 13th vertebrate press Confr. A. C. Crabb and R. E. Marsh (Eds.). 1988, 123-128**.**
18. Ylonen H, Jacob J, Davies MJ, Singleton GR. Predation risk habitat selection of Australia house mice *Mus domesticus* during an incipient plague: desperate behavior due to food depletion. Oikos. 2002; 99:284-234.
19. Stenseth NC, Leirs H, Mercelis S. Comparing strategies for controlling an African pest rodent: an empirically based theoretical study. J Appl. Ecol. 2001; 38:1020-1031.
20. Rhodes H, Makundi A, Bekele, Leirs H, Massawe AW, Rwamugira W *et al*. Farmer's perceptions of rodents as crop pests: Knowledge, attitudes and practices in rodent pest management in Tanzania and Ethiopia. Belg. J Zool. 2005; 135:153-157.
21. Palis FG, Singleton G, Sumaldeand Z, Hossain M. The social and cultural dimensions of rodent pest management. Integr. Zool. 2007; 2:174-183.
22. Wood BJ, Fee CG. A critical review of the development of rat control in Malaysian agriculture since the 1960s. Crop Prot. 2003; 22:445-461.
23. Florencia GP, Morin S, Chien HV, Chi TN. Socio-cultural and economic assessment of CTBS (community trap barrier system) adoption in South Vietnam. Omonrice. 2005; 13:85-89.
24. Lam YM, Supaad MA, Chang PM, Mohamed MS, Goh CS, Radzi H. An innovative approach for protecting rice against severe rat depredation. Proceedings of the 3rd International Conference on Plant Protection in the Tropics, Getting Highlands, Malaysia, 1990, 1-23.
25. Singleton GR, Petch DA. A review of the biology and management of rodent pests in Southeast Asia. Canberra, Australian Centre for International Agricultural Research, Tech. Reports. 1994, 65.
26. Brown PR, Tuan NP, Singleton GR, Ha PTT P, Hoa PT, Hue DT *et al*. Ecologically based management of rodents in the real world applied to a mixed agro-ecosystem in Vietnam. Bull. Ecol. Soc. America. 2006; 16:2000-2010.
27. Taber LD, Sheri AN, Ahmad MS. Mammals of the Lyallpur region-west Pakistan. J Mammal, 1967; 48:392-407.
28. Palis FG, Sumalde Z, Hossain M. Assessment of rodent control projects in Vietnam: adaptation and Impact. ACIAR, Australia. 2004.
29. Cowan DP, Quy RJ, Lambert MS. Ecological properties on the management of commensal rodents. ACIAR, Australia. 2003.
30. Crabb AC, Morois JJ, Salmon TP. Evaluation of fields sampling techniques for estimation of birds' damage in pistachio orchard. Proc.16th Vert. Pest Conf., 1994, 335-345.
31. Gebhart K, Anderson AM, Kirkpatrick KN, Shwiff SA. A review and synthesis of bird and rodent damage estimates to select California crops. Crop Prot. 2011; 30:1109-1116.
32. Steel RGD, Torrie JH, Dinkey DA. Principles and procedures of statistics, 2nd Ed., McGraw Hill Book Co., Singapore. 1996.
33. Buckle AP. Rodent control methods: CAB Int. Wallingford, Oxon, England, 1994, 127-133.
34. Brown PR, Tuan NP, Singleton GR, Hoa PT, Hue DT, Tan TQ *et al*. Ecologically based management of rodents in the real world: application to mixed agro-ecosystems in Vietnam. Ecol. Appl., 2006; 16:2000-2010.
35. Mess A. Placental evolution within the supra-ordinal clades of eutheria with the perspective of alternative animal models for human placentation. Adv. In Biol., 2014, 21.
36. Beg MA, Khan AA, Begum F. Rodent problem in sugarcane fields of Central Punjab. Pak. J Agric. Sci., 1979; 16:105-110.
37. Smiet AC, Khokhar AR, Fulk GW. Geographical distribution and variation of *Bandicota bengalensis* in Pakistan. Pak. J Zool. 1978; 10:43-47.
38. Khan AA. Rodent damage in Punjab rice fields. Int. Rice News Let. 1987; 12:25-26.
39. Leung LKP, Singleton GR, Sudarmani I. Ecologically based field rodent management in Indonesia. ACIAR Publication, Canberra, Australia, 1999, 305-318.
40. Leung LKP, Sudarmaji I. Managing rodent pests based on trap barrier system. Ecol. Let., 1999; 3:102-105.
41. Aplin KP, Brown PR, Jacobs J, Krebs CJ, Singleton GR. Field methods of rodent studies in Asia and the Indo-Pacific. ACIAR Monograph, 2003; 100:1-223.
42. Belmain SR, Meyer AN, Timberine R, Penicela L. Managing rodent pests in household and stored grains through intensive trapping. ACIAR Monograph. 2003, 440-445.
43. Belmain SR, Dlamini N, Eiseb S, Kirsten F, Mahlaba T, Makundi R. The ECORAT Project: Developing ecologically based rodent management for southern Africa. Int. Pest Cont. 2008, 50:136-138.