
**STUDIES ON FOOD PREFERENCES AND BAIT
SHYNESS IN LARGER BANDICOOT RAT
(*Bandicota indica* Bechstein)**

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**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
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J. B. NARENDRA KUMAR

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON FOOD PREFERENCES AND BAIT SHYNESS IN LARGER BANDICOOT RAT (Bandicota indica Bechstein)" submitted by Mr. J. B. NARENDRA KUMAR, for the degree of Master of Science (Agriculture) in Agricultural Entomology is a record of research work done by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore
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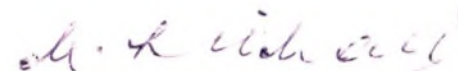
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(J.B. NARENDRA KUMAR)

To
My Beloved Parents
Sri G. Bommaiah Gowda
and
Smt. H. H. Shankaramma

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INTRODUCTION

I. INTRODUCTION

Rodents have been with us mainly as pests since the primitive man became an agriculturist and started growing and storing food grains. Their problem has become more acute in developing and under-developed countries because of availability of optimum conditions in these places for their survival and multiplication. They are generally herbivorous, feeding mainly on foodgrains, vegetables, fruits, grasses etc. They damage much more than what they eat and ruin large quantities of food materials by their urine and excreta. Considerable amount of food is hoarded in their burrows. Their gnawing habit causes damage to non-food materials including structures, buildings etc.

According to a 1982 report (Dubock) the world annual crop losses by rodents was around 30,000 million dollars while the estimated loss of foodgrains in India was 8-10% (Deoras, 1967). In 1971, the Indian pesticide association attributed annual damage of Rs.750 million to rodents (Anon, 1987). WHO estimated a saving of food grains that could feed 9,00,000 people in an year by suitable rodent control in Bombay city alone (Deoras, 1975).

Besides causing damage and losses, rodents also act as carriers of various deadly diseases like plague, rat bite fever, typhus fever, salmonellosis and leptospirosis.

Amongst the major rodent pests of India, the information available on the larger bandicoot rat, Bandicota indica is very scanty, though the species is a commensal pest of considerable significance throughout India, Burma, Kampuchea, Laos, Vietnam, Indonesia, Taiwan and Hong Kong. Damage caused is varied and extensive mostly in godowns and poultry farms (Spillet, 1968; Purushotham et al., 1984; Sridhara et al., 1988), houses and to vegetables particularly tuberous type (Barnett and Prakash, 1975). It occupies the outskirts of human dwellings, and their burrowing habits cause damage to gardens, floorings and masonry.

Although this rat is a serious economic threat and a nuisance to public health, concrete suggestions to efficiently manage them based on scientific investigations is lacking, may be because the species is ferocious. It is capable of threatening its natural enemies like cats, snakes and even dogs. There is a report of B.indica seizing a snake as food (Nandi, 1984).

Rodents are controlled mainly by way of chemical poisoning. For effective control of rodent population knowledge on two vital aspects is essential:

1. The toxicity of chemicals to be used.
2. The composition of bait material to be employed as poison carrier.

Toxicity, acceptability and safety in use are the three desirable characters of a potent rodenticide. Poisons used for rodent control are classified into [1] acute/single dose/quick acting and [2] chronic/multiple dose/slow acting rodenticides. The acute rodenticides though effective and quick in knocking down pest numbers, lack selectivity, require prebaiting and induce bait shyness. The chronic rodenticides on the other hand are mostly anticoagulants and their advantages include better efficacy and safety but they are handicapped by being slow in action, requiring baiting for several days thus escalating operational expenditure. For long term gains the control strategy should include both acute and chronic rodenticide application. For this we need toxicity data on different available acute and chronic poisons for each species of rodents since the Indian subcontinent harbours a variety of rodent fauna, each adapted to its environment and their weight ranges from 8 gm (Mus booduga and M. musculus) to more than one kg (Bandicota indica).

Since control of rodents is mostly carried out by oral chemical poisoning, to be effective the operation needs a highly acceptable bait carrier for poisoning. For rodents the choice of bait becomes a very delicate matter since the order is known for versatile feeding habits which depend upon availability of food in their habitat (Prakash, 1962; Landry, 1970; Reichman et al., 1979). The food selection is

also influenced by taste, texture, nutritional value and previous experience of the food (Sridhara, 1977; Sridhara and Krishnamoorthy, 1978). Additives like 50% sugar/sweet from molasses, corn syrup and 3-10% vegetable oil are known to improve the acceptability of baits (Brooks and Rowe, 1979; Howard and Marsh, 1974; Shimizu, 1982).

Rodents have evolved the capability of distinguishing harmful and harmless foods (Kalat and Rozin, 1973; Bharadwaj and Prakash, 1982a) which endows them with a natural protection against poisoning. Consequent to ingestion of sublethal dose of poison, animals surviving will experience the physiological distress of the rodenticide and learn to associate the same with the foods ingested and in future either totally or partially avoid such foods. This phenomenon is poison shyness or bait shyness and is recorded for several species of rodents (Rzoska, 1954; Revusky and Garcia, 1970; Prakash and Jain, 1971; Prakash *et al.*, 1975a; Sridhara and Srihari, 1978, 1980a and 1980b; Sridhara, 1983a, 1983b). In such situations control of bait shy rodents becomes a problem. Knowing the duration of retention of this behaviour is vital to decide the subsequent application of same poison.

Although Bandicota indica is a commensal and field pest of south and south-east Asia, information available on its feeding behaviour is meagre and on toxicity almost nil. Keeping emphasis on toxicity of available rodenticides, best

palatable bait and development of bait shyness, the present investigation is aimed at generating the following information for the effective control of Bandicota indica.

1. Food preference studies in Bandicota indica so as to evolve the best bait to carry the poison.
2. Studies on bait shyness of B. indica towards zinc phosphide and silmurin.
3. To determine the toxicity of zinc phosphide and silmurin in the laboratory.
4. To determine the toxicity of chronic rodenticides like Bromadiolone and Brodifacoum in the laboratory.
5. To evaluate zinc phosphide, Bromadiolone, Brodifacoum and Aluminium phosphide fumigation under field conditions for the control of B.indica.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1 LOSSES CAUSED BY RODENTS TO AGRICULTURE CROPS

In India, a number of studies have been conducted to estimate losses due to rodents, but they are either restricted to a particular area or crop. In the paddy fields in Uttar Pradesh, 7.1-21.5% of plant tillers were destroyed by rodents. This figure was 5.2 to 65.3% at Madras. The tiller damage reduced the paddy yield upto 59.5% and that of straw upto 45.7% (Jotwani and Beri, 1968). Chakraborty (1975) reported total loss to paddy as about 261 kg/ha whereas, Sridhara and Krishnamoorthy (1979a) estimated an annual loss of 72 kg paddy/ha in Karnataka. Damage to groundnut crop in Andhara Pradesh was 6-9% at seedling stage, 18.2-25.8% at growth stage and 41 -7.6% at maturity (Jotwani and Beri, 1968).

A fair amount of losses, caused especially by bandicoot, occurs due to their hoarding propensity. Wagle (1927) recovered more than 600 earheads of rice from a bandicoot rat burrow. Deoras (1966) recovered 14 kg of paddy, groundnut and millet from 30 burrows of the same species. Singh et al., (1965) reported retrieving 2764 kg of grains from the rodent burrows in 15 villages in Central India. Roy (1974, 1980) reported hoarding of 5.7% of paddy in the burrows of

Bandicota bengalensis whereas, Chakraborty (1975) and Rao (1980) revealed hoarding of 3.2 and 1.75 kg of grains per burrow respectively.

Plantation crops are no exception to rodent depredation. More than 11% of coconut palms were destroyed by rats in Andhra Pradesh (Krishnamurthy et al., 1967); the loss of nuts and the number of attacked trees were maximum (17.1%) during the rainy and winter seasons. Kidavakoya (1955) reported that the coconut yield in Laccadive Islands was reduced by 50% due to rodent damage. In Karnataka, Urs (1979) reported 1-8% damage to coconut saplings in nursery amounting to an annual loss of Rs 471-3250/ha. Bhat (1978) reported damage to cocoa plantation in Kerala, Tamilnadu and Karnataka to the tune of 8.0 to 51.3%.

Rodents also inflict considerable damage to vegetables. In Rajasthan it was estimated to be 8.7% (Advani and Mathur, 1982).

2.2 LOSSES TO STORED FOOD GRAINS

Assessment of damage to stored food grains vary to a greater extent. Dykstra (1966) reported an overall loss of grains due to rodents in India to be 25% in the field before harvest and 25-30% in storage. Other sources quote losses upto 1,000,000 tonnes of stored food and seed grains by rodents annually, exclusive of the losses prior to harvest

(Garg and Agarwal, 1963; Sinha and Ram, 1963). In a 100m² godown space at Howrah, the annual loss of grains due to rodents was reported to be 4200 kg (Spillet, 1968). Amongst species reported to depredate on stored food in godowns are Bandicota indica, B.bengalensis and Rattus rattus (Spillet, 1968; Frantz, 1975).

2.3 ROLE OF FEEDING BEHAVIOUR IN BAIT SELECTION

Rodent control programme, to be effective needs a highly acceptable bait carrier for poisoning since the most popular and practical method of managing rats continues to be by oral chemical poisoning. Although the normal food of rodents depend on their immediate environment the success of control operation depends on the acceptability of man made diet (Majumder et al., 1969). Hence, the primary step in evolving the control strategies will be to formulate an attractive bait which should be designed after conducting the food preference studies for each species in the habitat.

2.3.1 Factors influencing food selection

In rodents, food selection is influenced mainly by factors like flavour, water content, energy value and physiological effects. In addition, social interactions and early experience do affect selection of food (Barnett and Prakash, 1975; Sridhara, 1977). When wide variety of natural food is available in abundance, most of the field rodents turn selective feeders (Prakash, 1969).

It is observed that food composed of smaller particles is preferred over larger sized particles in Rattus rattus (Khan, 1974), R.meltada (Jain et al., 1974) M.hurrianae (Prakash and Kumbakarni, 1962), B.bengalensis (Sridhara and Srihari, 1986), M.platythrix (Sridhara and Krishnamoorthy, 1978) and squirrels (Bhat, 1979).

Most of the rodents prefer moist baits than dry baits. Harrison and Woodville (1950) observed that boiled rice was most preferred by R.rattus than the raw grains. They also observed that the rats fed on boiled rice consumed less water compared to those which were fed on raw grains.

It was reported that addition of sweetening agents and salt have no impact or a little effect on the consumption of bait materials (Prakash and Mathur, 1987).

Conflicting results are reported in respect of consumption of oily foods. A few species consume more bait if vegetable oil is added (T.indica, B.bengalensis, R.norvegicus and R.rattus) whereas, in M.hurrianae, R.meltada, M.platythrix, bait consumption declined due to addition of oil. Therefore, Prakash and Mathur (1987) felt that the role of additives like vegetable oil which have no distinct taste is more to adhere the poison particles to the bait rather than to increase its acceptability.

Rodents (especially laboratory rats) prefer food of

high nutritional value (Jackson, 1965; Barnett, 1966). But this well known fact does not hold good with field rodents, because they may change their diet seasonally which depends upon the availability of food in their respective environment (Prakash, 1962).

Food consumption among rats depend on their body weight and varies from 7.8 to 21.1 per cent of the body weight (Leslie and Ranson, 1954). The daily intake of food by R.rattus, T.indica, and B.bengalensis with respect to per cent of body weight is reported to be 8,6 and 8gm respectively (Anon, 1966). Krishnamurthy et al., (1967) reported that average daily food intake of young R.rattus (66-77g) was 12.25% and the adults (200-254g) consume 8.26% of their body weight. Sridhara and Srihari (1979b) compared the food and caloric intake of B.indica (biggest rat) and M.platythrix (smaller mouse). In their experiment, M.platythrix exhibited a higher rate of calorific ingestion than B.indica, but the total food consumption of a single B.indica was observed to be seven times more than that of M.platythrix. Based on their results they recommended 30g of food for baiting B.indica and around 10g for baiting M.platythrix.

2.3.2 Neophobia (New food/new object avoidance)

Wild rats are extremely difficult to trap or poison, a fact known to farmers, householders and warehouse keepers

from time immemorial. The difficulty is attributed to rat's ability to be wary and elusive. However, experiments have proved that rats avoid strange objects initially even if it happens to be food. This phenomenon is called Neophobia and extends to even containers and site of food placement (Barnett, 1975). This behaviour is an important barrier in rodent control operations since it protects rats from the consequences of curiosity and exploration such as traps and poison (Barnett, 1956). To overcome neophobia prebaiting with plain bait atleast for 3 days is recommended so that they will get accoustomed to feed on the new bait and can readily accept the poison bait later (Bharadwaj and Prakash, 1984).

2.3.3 Bait shyness

During control operation, when Zinc phosphide treated bait is provided to rodents they may sample very small quantity of it which results in ingestion of only a sublethal dose of poison. This small amount of poison causes gastrointestinal distress leading to partial or total refusal of poison bait. This behavioural change due to ingestion of sublethal dose of any acute rodenticide is called bait shyness which has been extensively studied against a number of species (Chitty and Southern, 1954; Rzoska, 1954; Revusky and Garcia, 1970; Prakash and Jain, 1971; Sridhara and Srihari, 1978; Sridhara, 1983a,b). Experiments with

R.norvegicus (Hankins et al., 1973) and R.rattus (Barnett et al., 1975) revealed that once the avoidance has developed, the discrimination does not depend on the olfactory sense, but it is probably the taste organs which are responsible for it.

Bait shyness towards Zinc phosphide has been demonstrated in almost all Indian species viz. Bandicota bengalensis, Mus platythrix (Sridhara and Srihari, 1978; Sridhara, 1983a), Tatera indica (Prakash and Jain, 1971), Meriones hurrianae (Prakash and Jain, 1971), Rattus meltada (Prakash et al., 1975a) and R.rattus (Bharadwaj and Khan, 1979).

Both Norway rat and B.bengalensis became bait shy after ingesting sublethal doses of silmurin (Chitty and Southern, 1954; Usha Devi and Krishnamoorthy, 1982).

Recently brodifacoum, a single dose anticoagulant rodenticide was found to be effective against bait shy rodents (Bharadwaj and Prakash, 1982b).

2.4 TOXICOLOGY

Chemical poisoning is the most successful, widespread and practical method of killing rodents. Based on the rapidity of action, the rodenticides are classified into two groups.

2.4.1 Acute poisons

i. **Zinc phosphide** : Although there are many acute rodenticides available, only zinc phosphide is used in majority of rodent control programmes, because it is easily available and is effective for majority of Indian rodent species. Based on the laboratory studies, effective concentrations of Zinc phosphide for different Indian rodent species were reported to be 1.5-2.5% in the bait (Prakash et al., 1969; Poche et al., 1979; Advani et al., 1982). Depending on the purity of the chemical LD50 values ranged from 43-56 mg/kg for albino rats (Krishnakumari et al., 1980), 35 mg/kg for M.hurrianae (Prakash et al., 1969) and 25 mg/kg for B.bengalensis (Htun and Brooks, 1979). But Srihari et al., (1979) claimed 20 mg/kg as the lethal dose for B.bengalensis.

ii. **Silmurin** : Ready to use baits containing 0.05% pure scilliroside (Srivastava et al., 1980) and 0.075% -0.1 % silmurin caused 100% mortality of R.rattus (Pahwa et al., 1982). Although low concentrations of silmurin (0.025-0.05%) were lethally effective in killing B.bengalensis (Brooks and Htun, 1980), other workers failed to get satisfactory mortalities of other rodent species with silmurin even at 0.1% in the bait (Christopher et al., 1982; Rai et al., 1982; Chopra

et al., 1984). Chandele et al., (1984) compared the efficacy of Zinc phosphide and silmurin and found that in Zinc phosphide and silmurin treated plots the rodent activity was reduced to 76.47% and 94.88% respectively (7 days after poisoning).

2.4.2 Chronic poisons

These are basically anticoagulants of which some are derived from coumarin and others are inandiones. Among the coumarin derivatives warfarin (Rodafarin, Hexamarin, rodeth, Fumarin or Ratafin) is effective against R.norvegicus and M.musculus in concentrations of 0.005% or 0.025% in standard bait bases. For a complete kill, minimum of 4 days feeding was required for R.norvegicus and B.bengalensis whereas, M.musculus required 28 days feeding for 100% kill (Rowe and Redfern, 1968).

Susceptibility of B.bengalensis to warfarin has attracted the attention of many workers and conflicting results have been reported. Deoras et al., (1972) found B.bengalensis to be very susceptible to warfarin. Contradicting this, Renapurkar et al., (1973) reported bandicoots to be considerably tolerant to warfarin with only 80% B.bengalensis succumbing after 10 days feeding on 0.025% warfarin. Sridhara (1979), Brooks et al., (1980) also confirmed the susceptibility of B.bengalensis to warfarin.

In field conditions rodent activity was found to be

reduced by 79.6% in a population dominated by B.bengalensis (Durairaj and Gurupras ad, 1975). However, Warfarin was reported to effectively kill the initial population, but the efficacy declined with the successive baiting (Sridhara, 1979).

Since, widespread use of warfarin-like compounds have resulted in the development of resistance among rodents, Hadler and Shadbolt (1975) treated a new series of hydroxycoumarin derivatives which resulted in the development of second generation anticoagulant rodenticides which include bromadiolone, brodifacoum and difenacoum.

i. **Bromadiolone** : Also known as "Super caid" and "Maki" was found to be effective against several species of rodents. Sridhara et al., (1988) have established the LD50 value of bromadiolone as 1.58 mg/kg for B.bengalensis. They have also suggested that B.bengalensis can be effectively killed by feeding 0.005% bromadiolone in cereal bait for a single day. Also, wax cakes containing 0.005% bromadiolone are effective in killing several species of dryland rodent pests like T.indica, R.meltada, M. booduga, M.platythrix and B.bengalensis and the commensal rats, R.rattus and B.indica. Crown baiting of 50% palms with 2-3 wax cakes of bromadiolone per palm for effective control of rodents in coconut plantations was recommended.

Maddaiah et al., (1988) evaluated bromadiolone for its efficacy against house rat R.rattus in laboratory. Feeding tests with 0.005% and 0.0025% bromadiolone mixed with baits produced 100% mortality in rats after 2 and 3 days feeding respectively. Subiah and Mathur (1984) reported that bromadiolone (0.005%) required only a single day feeding to achieve 100% mortality in T.indica, R.meltada, M.musculus and M.platythrix whereas, M.booduga and M.hurrianae required 3 days feeding to get 100% mortality and for B.bengalensis and F.pennanti it was 2 and 4 days respectively. Chopra and Sood (1981) in their laboratory experiment revealed that to get 100% mortality of B. bengalensis 3 days feeding of 0.005% bromadiolone was essential. Agarwal and Gargav (1988) found that 0.005% bromadiolone bait and cake gave 100% mortality within 2.7-9.33 days and 3.3-12.3 days respectively while 0.002% poison gave 66.3% mortality. Mathur and Bhadauria (1985) evaluated bromadiolone in large scale in fields against bandicoot rats and found that 0.005% bromadiolone was able to control more than 93% of rats by 12th day. Purushotham et al., (1984) observed the order of susceptibility to 0.005% bromadiolone in poultry farms as: R.rattus > M.musculus > B.indica. Wagle (1987) reported that bromadiolone at 0.005% was effective in killing B.bengalensis, B.indica, R.meltada and M.booduga. Marsh (1977), Gill and Redfern

(1980) reported that non-resistant R.norvegicus required a single day feeding of 0.005% bromadiolone for 100% kill whereas, resistant ones required 4 days feeding.

- ii. **Brodifacoum** : Also called "PP 581", "Talon", "Klerat" was developed specially for the control of Warfarin resistant rats and mice. LD50 of brodifacoum for Norway rats and M.musculus was found to be 0.26 mg/kg and 0.40 mg/kg respectively (Redfern et al., 1976). For gerbils, LD50 value was found to be 0.08-0.10 mg/kg (Mathur and Prakash, 1981).

Chopra et al., (1983b) reported that one day feeding of 0.005% ready-to-use brodifacoum bait provided complete kill of R.rattus, R.meltada, B.bengalensis, M.musculus and M.platythrix. Saxena and Sharma (1981) conducted feeding tests to evaluate brodifacoum against M.hurrianae and recorded 100% mortality at 0.00125 and 0.005% concentrations. They also found that females were more susceptible to the rodenticide than males.

In field trials it was found to require longer feeding periods for effective control. Mathur and Prakash (1982) obtained 90.5% control in a desert rodent population using 0.002% brodifacoum for 10 days. Soni et al., (1985) found that brodifacoum was more effective than bromadiolone at 0.005% concentration in both humid and non-humid regions. But both the anticoagulants

required more time to kill rodents than aluminium phosphide fumigation. Sheikher et al., (1988) conducted field trials to know the combined efficacy of Zinc phosphide (2.4%), brodifacoum (0.005%) and bromadiolone (0.005%) and found that single baiting with Zinc phosphide followed by baiting with brodifacoum or bromadiolone resulted in 77.77-95.4% rodent mortality.

2.4.3 Fumigation

Although Krishnamurthy and Prem Singh (1967) pointed out the advantages of aluminium phosphide over other poisons, information on its efficacy to Indian rodent species and under Indian conditions has been reported only recently compared to reports on the efficacy of other chemical poisons.

Fumigants include hydrogen cyanide, pellets of aluminium phosphide, chloropicrin, methyl bromide, ethylene dibromide, carbon monoxide, carbon dioxide etc. (Fitzwater and Prakash, 1978). Chandraurkar et al., (1972) reported the distribution of phosphine from aluminium phosphide tablets in an artificial burrow. Muthu et al., (1980) evaluated the inhalation toxicity of phosphine to albino rats in the laboratory. They found the LD50 value as 0.22 mg/L and the minimum lethal dose was 0.4 mg/L within 6 hrs exposure to the fumigant.

In irrigated fields of Rajasthan, Advani and Mathur (1981) achieved 95% success in killing rodents by aluminium

phosphide fumigation. The order of species susceptibility to the fumigant was Mus sp. > R.meltada > M.hurrianae > T.indica. In the rice and wheat fields of Punjab, aluminium phosphide reduced rodent burrows by 80-83% (Chopra, 1984). In rice fields, all the Mus sp. were killed but only 63-69% of B.bengalensis could be eliminated, whereas in wheat fields the species-wise susceptibility was Mus sp.- 100%, R.meltada-91.69%; B.bengalensis-50%. Earlier Srihari and Sridhara (1978) also demonstrated the lower susceptibility of larger animals to the fumigant. According to them Mus sp. succumbed earlier than gerbils and bandicoots.

Advani and Mathur (1981) reported that the cost of fumigating one hectare of highly infested crop land was Rs 53.10 as against Rs 1.80 by Zinc phosphide. Greaves et al., (1977) however, reported a low cost-benefit ratio for aluminium phosphide in comparison to other rodenticides in Pakistan.

Another factor influencing fumigant efficacy was number of tablets used. Higher concentrations gave better efficacy in both laboratory and field conditions (Sridhara and Srihari, 1979a; Jain and Das, 1980).

Fitzwater and Prakash (1978) and Prakash (1976) recommended the use of aluminium phosphide for the control of bait shy population which survived the Zinc phosphide treatment. Sridhara and Krishnamoorthy (1979b) also suggested that fumi-

gation should be carried out after Zinc phosphide treatment for effective control of rodent species.

Laboratory studies indicated enhancement in the efficacy of aluminium phosphide when humidity was higher (Sridhara and Srihari, 1979a). In paddy fields 77-88% relative humidity was optimum to kill about 80% population (Sridhara and Krishnamoorthy, 1979b). Prakash (1968,1978) suggested that the areas with adequate humidity for direct fumigation should be treated during maximum littering activity of rodents so as to kill all the young ones. Soni et al., (1985) conducted field trials of aluminium phosphide, bromadiolone and brodifacoum to compare their efficacy and found that aluminium phosphide was more effective in humid regions. Also, bromadiolone and brodifacoum required more time to kill rodents than the fumigant.

2.5 BIOLOGY AND ECOLOGY OF Bandicota indica BECHSTEIN

The above mentioned review of literature on rodent control and aspects relevant to control throw light on the fact that B.indica is the species least studied with insignificant information available on its habit, habitat and reproductive behaviour. There is absolutely no information on toxicology of rodenticides to this species. Knowledge on the finer aspects of feeding behaviour and bait shyness are also lacking. The literature available indicates that this species is larger than Bandicota bengalensis with rounded ears and

blackish brown long dorsal hairs with tips. Adult body weight is 500 to 1000g or more (Barnett and Prakash, 1975).

It occupies the outskirts of human dwellings such as compounds, gardens, stables and outhouses. They may burrow under floors, even through masonry with burrow systems organized in colonies of upto fifteen burrows (Arjunwadkar and Gadgil, 1974). The burrow openings are very large and a single burrow system may spread over 300m² (Barnett and Prakash, 1975).

The species is nocturnal and fossorial, feeding on grasses, roots and other plant structures. It damages the crops when burrows are near crops. Like R.rattus, it often depends on household refuse. Food grains are hoarded in burrows in appreciable quantity. It is reported that this rat breeds throughout the year and 10-12 young ones are born in a litter (Barnett and Prakash, 1975).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 PROCUREMENT AND MAINTENANCE OF RATS

Larger bandicoot rats, Bandicota indica (B.indica, plate 1) were procured by digging burrows and netting the animals in Hesaraghatta village (25 Kms from Bangalore). After their transportation to the laboratory, the animals were caged individually in metal cages of size 35x35x50 cm (Plate 3). They were acclimated to the laboratory conditions by maintaining them on standard rat feed pellets (supplied by M/s Lipton India, Bangalore; Plate 4) and ad lib. water for 15 days. Food was provided in cylindrical metal dishes (8 cm diameter, 4.5 cm height) made of galvanized iron with a central opening of 4.4 cm diameter. Water was made available in Hindalium cups.

3.2 FOOD PREFERENCE STUDIES

Food preference studies were carried out with the objective of formulating a highly acceptable cereal bait. Tests were carried out to establish the best preferred cereal amongst the locally grown cereals. In the second set of experiments cereals were provided in three forms - whole grain, broken and flour to know if texture affects the rate of consumption. The third set of experiment was on the effect of different concentrations of oils to select the best



Plate 1. Adult Bandicota indica Bechstein.



Plate 2. A typical burrow of B.indica

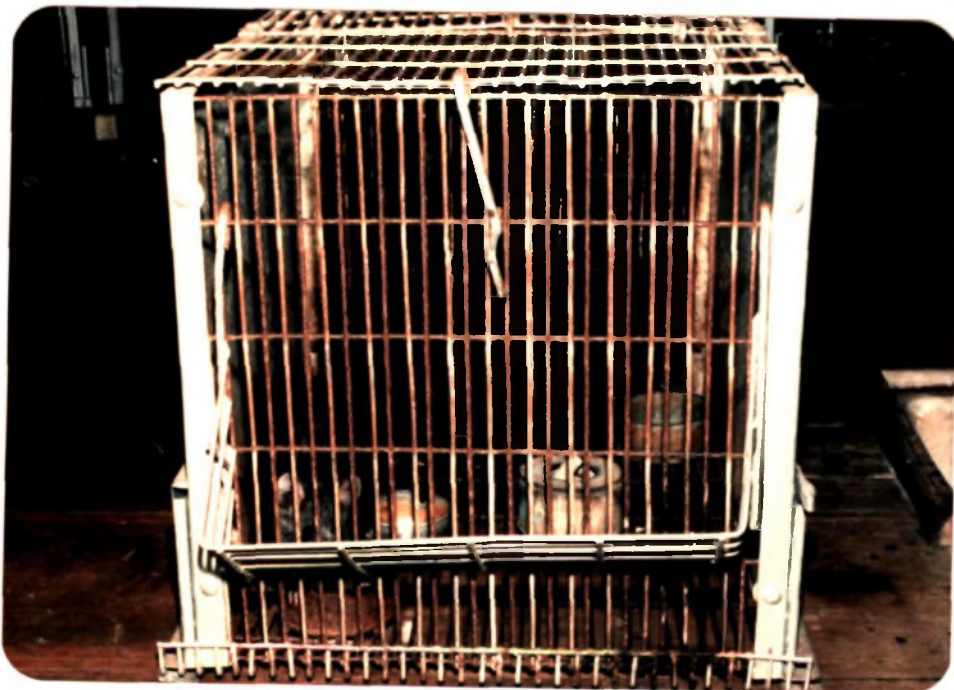


Plate 3. B.indica maintained in a laboratory cage



Plate 4. Standard rat feed on which B.indica were maintained



Plate 5. Bait containers with different cereals used during multiple choice test

preferred concentration of commonly used oils. Finally the effect of sugar and salt on bait consumption were tested.

3.2.1 Cereal preference studies

The experimental animals were sexed, weighed and introduced into their cages. Each animal was given 50gm of each of the following cereals in five different bait containers (Plate 5): Rice (Oryza sativa), ragi (Eleusine coracana), wheat (Triticum aestivum), jowar (Sorghum bicolor) and maize (Zea mays). The amount of each cereal consumed daily by each animal was recorded, after taking spillage into consideration. The daily intake of different cereal grains was converted to g consumed per 100g body weight of the animal. A total of 6 animals (3 females and 3 males) were used for the experiment. Daily consumptions were recorded for 35 continuous days and the mean was calculated for each animal. The preferential order of cereal intake was established by using Kruskal-Wallis one way analysis of variance (Segal, 1956).

3.2.2 Texture preference studies

In this study, a group of individually caged animals (n=4) were provided with rice in different textures i.e., whole grain, cracked form and flour in separate containers. The consumption of each texture was recorded and converted to g consumed per 100g body weight, after taking spillage into consideration. Similar texture preference studies were

carried out for wheat, jowar and maize on different groups of rats. Since size of ragi grain was small, it was tested only in whole grain and flour form.

3.2.3 Oil preference studies

Locally available edible oils like groundnut oil (Arachis hypogaea), coconut oil (Cocos nucifera) and gingelly oil (Sesamum indicum) were selected for this study. Individual animals of a group of rats (n=4) were provided with 50 g of best preferred cereal in its best liked texture mixed with 2,3,4,5 and 10% concentrations of groundnut oil in separate containers. The daily intake of the same was recorded and converted to g consumed per 100g body weight. By following the same procedure best preferred concentrations of coconut oil and gingelly oil (n=4) was established in two separate groups of rats.

In a fourth test (n=4) the best preferred concentration of groundnut, coconut and gingelly oil was tested as to which of them is more liked by offering best cereal bait mixed with best liked concentration of the above oils in a triple choice test.

The order of preference of different concentrations of each oil and also the preference between the three oils was established by Kruskal-Wallis one way analysis of variance (Segal, 1956).

3.2.4 Studies on effect of additives on bait intake

In this study, the effect of addition of 2% sugar and 2% salt on bait consumption was tested. Accordingly a batch of fresh rats (n=4) were given a choice of 50g of rice bait (rice flour + 10% groundnut oil), 50g of rice bait + 2% sugar and 50g of rice bait + 2% salt. The amount consumed in each case was recorded and converted to g consumed per 100g body weight. The relative acceptabilities were ranked after Kruskal-Wallis one way analysis of variance (Segal, 1956).

3.3 STUDIES ON BAIT SHYNESS IN B.indica

3.3.1 Occurrence and persistence of bait shyness towards Zinc phosphide in B.indica

After the acclimation of adult rats (n=4) to laboratory conditions, each animal was provided with 50g of best preferred bait (rice flour + 10% groundnut oil) and 50g of least preferred bait (jowar grains) in separate containers for 4 continuous days and the intake was recorded. On the 5th and 6th day sublethal quantity (0.05%) of Zinc phosphide was added to the best preferred bait and the food preference test was continued upto 7 days. The persistence of bait shyness was checked at fortnightly intervals upto 75th day by providing the best preferred bait and jowar. The daily intakes were converted to g consumed/100g body weight. Rate of ingestion of two foods prior to, during and after poison addition were compared by student "t" test. Decline in the

consumption of poison mixed food indicated development of bait shyness.

3.3.2 Occurrence of bait shyness towards silmurin in B.indica

After weighing and sexing, the rats (n=4) were individually caged. Each rat was provided with 50g of best preferred bait (rice flour +10% groundnut oil) and 50g of least preferred bait (maize flour). The intake of each was recorded for 4 continuous days. On the 5th and 6th day sub-lethal dose of silmurin (0.001%) was added to the best preferred bait and given along with least preferred bait in separate containers. The intake of plain and poison baits were recorded for 4 days. The intake of plain rice bait and maize flour was compared by using student 't'test. Using the same test, the consumption of plain and poison bait was also compared.

3.3.3 Bait shyness of B.indica towards cereal components of poison bait

In this experiment, food preference studies were conducted upto 3 continuous days with individually caged rats (n=6) by providing 50 g each of cereal mixture (rice+ragi+jowar) and standard rat feed in separate containers. On the 4th day sublethal dose (0.05%) of Zinc phosphide was added to cereal mixture and given along with standard rat feed and the intake of both was recorded. From 6th to 9th day 50g

each of rice (one of the components of cereal mixture) and standard rat feed were given and the intake of both were recorded. From 10th to 13th day 50 g each of ragi and rat feed were given and from 14th to 17th day 50 g each of jowar and rat feed were given. In each case daily intake was recorded and converted into g consumed per 100g body weight. After computing the means, the data were plotted.

3.3.4 Bait shyness of B.indica towards components of poison bait

The selected batch of rats were weighed, sexed and kept in individual cages (n=4). They were provided with 50g of a highly preferred bait (rice flour + 10% groundnut oil) and 50g of a lowly preferred bait (maize flour) for 3 continuous days. On the 4th and 5th day 0.05% Zinc phosphide was added to the highly preferred bait. From days 6-8, the animals were given 50g each of rice flour + 10% groundnut oil, rice flour + 10% coconut oil, ragi flour + 10% groundnut oil and ragi flour + 10% coconut oil, and thus exposed to both the components of poison bait in the first, to the cereal component in the second, to the oil component in the third and a fresh bait in the fourth. Daily intake were converted into g/100g body weight, means of which were plotted.

3.3.5 Response of bait shy B.indica towards new foods

Individually caged rats (n=3) were provided with 50g each of highly preferred (rice flour + 10% groundnut oil) and

lowly preferred (maize flour) food for 3 days. On the 4th and 5th day sublethal dose (0.05%) of Zinc phosphide was added to the highly preferred food and given along with maize flour. From 6th to 8th day, they were given with 50g each of rice bait, fresh jowar, ragi and maize flour. Consumptions for each day were converted into g consumed/100g body weight, means were calculated and plotted.

3.3.6 Response of bait shy B.indica towards new poison

After the selection of rats, they were weighed, sexed and individually caged (n=4). Each was provided with 50g of highly preferred (rice flour + 10% groundnut oil) and 50g of lowly preferred (maize flour) food for 3 continuous days. On the 4th and 5th day sublethal dose (0.05%) of zinc phosphide was added to best preferred food. From 6th to 9th day they were given 50g of each of rice bait mixed with 0.001% silmurin and maize flour and the intake was recorded in all the cases. Consumption on each day was converted into g consumed per 100g body weight, means were calculated and plotted.

3.4 TOXICOLOGY

Rodenticides used were

- a) Acute poisons : Zinc phosphide and silmurin
- b) Chronic poisons : Brodifacoum and Bromadiolone
- c) Aluminium phosphide

- i. Zinc phosphide (Zn_3P_2) is a greyish black powder [Plate 6(1)] having distinct garlic-like odour of phosphine. It is slightly soluble in alkaline solution and in oils but insoluble in alcohol or in water. Its toxic action is due to the evolution of phosphine gas which injures kidney, liver and lung followed by death after a few hours due to collapse of lungs and cardiac arrest.
- ii. Silmurin is commonly called as Red squill or Scillirocide ($C_{32}H_{44}O_{12}$) with empirical formula [(6 β -(acetyloxy) -3 β (β -D -glucopyranosyloxy)-8, 14-dihydroxy-4, 20, 22-trienolied)]. It is a bright yellow compound [Plate 6(2)] with a molecular weight of 620-670 and decomposition point of 168-170°C. It is easily soluble in alcohol, dioxan, ethylene glycol, glacial acetic acid and less soluble in water. It is technically 1% pure chemical.
- iii. Brodifacoum [$(C_{31}H_{23}O_3Br)$, 3-(3-(4' bromobiphenyl-4-yl)-1,2,3,4-tetrahydronaphthyl-1-yl)-4-hydroxy-coumarin)] is available in the form of ready-to-use cakes of 0.005% a.i. [Plate 6(3)].
- iv. Bromadiolone [$(C_{30}H_{23}Br O_4)$, 3-(4-hydroxy-3-coumarinyl), 3-phenyl - 1-(4-bromo-P-biphenyl) propanol] is also available in the form of ready-to-use cakes of 0.005% a.i. [Plate 6(4)].

- v. Aluminium phosphide (Al PO_4) is available in the form of tablets which release phosphine gas (PH_3) in humid air [Plate 6(5)].

3.4.1 Toxicity of Zinc phosphide to B.indica

Adult rats (n=8) after having weighed and caged individually, were provided with 30g of rice bait (rice flour + 10% groundnut oil) for 3 days. On the 4th day 2% Zinc phosphide was added to the bait. After 24 hours, the intake of poison bait as well as the mortality were recorded. The actual quantity of poison ingested (mg/kg) was calculated. Similar procedure was followed to evaluate the same poison at 1.5% (n=8) and 1.0% (n=8).

3.4.2 Toxicity of silmurin to B.indica

Similar to the above experiment, individually caged adult rats (n=6) were provided with 30g of rice bait (rice flour + 10% groundnut oil) for 3 days. On the 4th day 0.1% silmurin was added to the rice bait and given. After 24 hrs the intake of poison bait as well as mortality were recorded. The actual quantity of poison ingested (mg/kg) was calculated. Similar procedure was followed to evaluate the same poison at 0.05% (n=4).

3.4.3 Toxicity of Bromadiolone (0.005%) to B. indica

Each individually caged animal (n=6) was exposed to

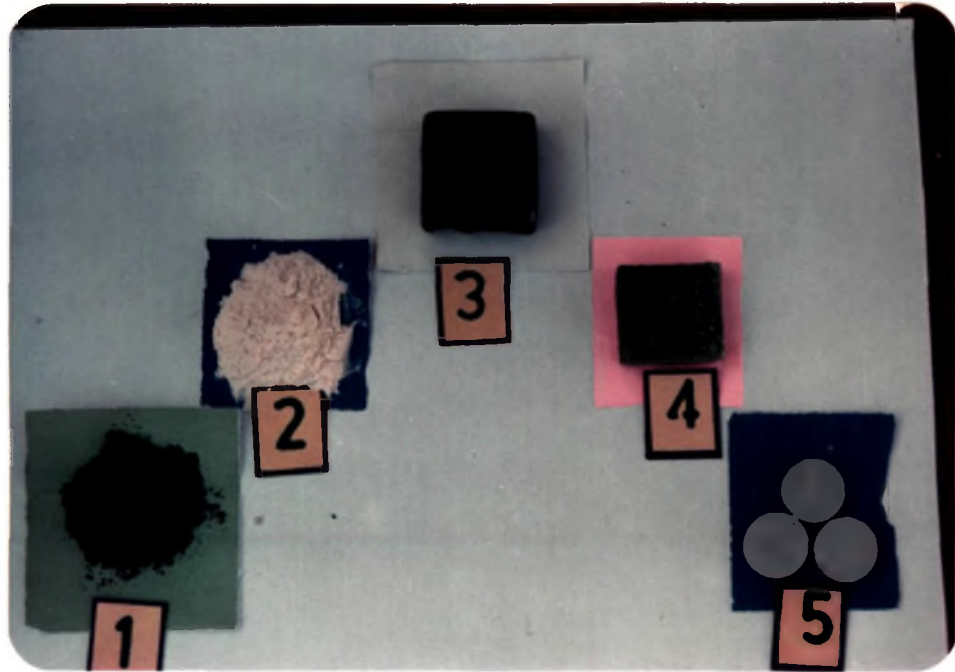


Plate 6. Rodenticides evaluated:

- | | |
|------------------------|-----------------|
| 1) Zinc phosphide | 2) Silmurin |
| 3) Brodifacoum | 4) Bromadiolone |
| 5) Aluminium phosphide | |

single bromadiolone cake (20g) for 24 hours and the intake was recorded. There after they were provided with standard rat feed upto a period of 3 weeks during which record of mortalities was noted.

Similarly in a second set of experiment larger bandicoots (n=6) were exposed to bromadiolone cakes for 48 hours. The amount of poison ingested (mg/kg) was calculated and mortalities (if any) were observed until three weeks.

3.4.4 Toxicity of Brodifacoum (0.005%) to B.indica

Similar to the above experiment, individually caged adult rats (n=4) were provided with a ready-to-use cake of brodifacoum (0.005%) weighing 20gms. After 24 hours, the consumption of the cake was recorded and the rats were maintained on rat feed for 3 weeks during which mortalities were recorded.

A second set of adult rats (n=4) were given brodifacoum cakes for 48 hours after which they were fed on rat feed for 3 weeks during which mortalities were recorded.

3.5 FIELD EVALUATION OF RODENTICIDES AGAINST B. indica

3.5.1 Field evaluation of zinc phosphide against B. indica

This experiment was conducted behind U A S cafeteria where burrows of B.indica were found (Plate 7). Prior to the experiment all the burrows were plugged with loose soil in

the evening. On the next day morning the burrows which were found open (live burrows) were counted and were prebaited with 20g of rice flour + 10% groundnut oil for 3 days. On the 4th day, live burrows were baited with 1.5% Zinc phosphide in rice bait and plugged with soil. Burrows found open after 24 hrs were considered to represent surviving population. Since burrow count is considered as reliable index of field rodent population (Barnett and Prakash, 1975) percent reduction in the burrows represented the percent population killed.

3.5.2 Field evaluation of Bromadiolone (0.005%) against B. indica

This experiment was conducted behind U A S Dairy where burrows of B.indica were evident (Plate 8). Live burrow counting was done as explained in the previous experiment. To each of the live burrow, one bromadiolone cake (0.005%) was introduced and the opening was closed as usual. Three weeks later, live burrow count was taken. From pre and post control burrow numbers, per cent reduction in bandicoot population consequent to bromadiolone poisoning was calculated.

3.5.3 Field evaluation of Brodifacoum (0.005%) against B.indica

This experiment was conducted in a poultry farm near Thimmasandra (20 Kms from Bangalore) where infestation of B.indica was observed (Plate 9). Prior to the experiment all



Plate 7. Burrows baited with zinc phosphide during field evaluation (behind UAS cafeteria, GKVK)



Plate 8. Burrows baited with bromadiolone during field evaluation (behind UAS Dairy, Hebbal)

the burrows were closed in the evening. On the next day morning live burrow counting was done. To each live burrow a brodifacoum cake (0.005%) was introduced and after 3 weeks live burrow counting was again done. Per cent reduction in population due to brodifacoum poisoning was calculated from burrow counts prior to and after poisoning.

3.5.4 Field evaluation of aluminium phosphide to control

B.indica

This experiment was also conducted in a poultry farm near Thimmasandra (Plate 10). Prior to the experiment all the burrows were closed in the evening and live burrow counting was done on the next day morning. To each live burrow one tablet of aluminium phosphide (3g each) was introduced and the burrows were tightly closed with soil. After 24 hours the burrows found open were recorded. Difference between pre and post control live burrows was converted into per cent reduction in live burrows which in turn represented per cent kill of rodents.



Plate 9. Burrows baited with brodifacoum during field evaluation in a poultry farm at Thimmasandra



Plate 10. Burrows fumigated with aluminium phosphide during field evaluation at Thimmasandra

EXPERIMENTAL RESULTS

IV. RESULTS

4.1 FOOD PREFERENCE OF Bandicota indica

4.1.1 Cereal Preference

It is evident that the larger bandicoot rat, B.indica preferred rice (1.96 \pm 1.05) compared to ragi (1.58 \pm 0.93), wheat (1.09 \pm 1.57), jowar (0.89 \pm 0.99) and maize (0.16 \pm 0.18) (Table 1; Fig.1). The preferential order of cereal intake by B.indica is rice > ragi wheat > jowar > maize. (H=11.89, Kruskal-Wallis one way analysis of variance).

4.1.2 Texture preference of Cereals

Among the five cereals with different textures tried, B.indica preferred flour form compared to broken and whole grain in all the cereals (Table 2; Fig.2 & 3). The preferential order towards texture of cereals is flour > broken grains > whole grains for the cereals tested [rice, H=6.59; Fig.2; ragi, H=5.33; Fig.3a; wheat, H=7.73, Fig.3b; Jowar, H=4.77, Fig.3c; maize, H=8.35, Fig.3d; Kruskal-wallis one way analysis of variance).

4.1.3 Preference Towards Different Concentrations of Oils

The larger bandicoot rat has preferred the bait with 10% groundnut oil (2.88 \pm 0.03) compared to the baits with 2% (0.09 \pm 0.06), 3% (0.13 \pm 0.06), 4% (0.28 \pm 0.13) and 5%

TABLE 1 : Cereal preference of Bandicota indica

Sl. No.	Sex	Body Weight (g)	Cereal intake/day(g/100 g body weight)				
			RICE	RAGI	WHEAT	JOWAR	MAIZE
1.	F	385	2.31	2.21	0.26	0.43	0.13
2.	F	390	2.81	0.29	0.5	2.27	0.1
3.	F	400	0.86	2.93	0.62	0.21	0.55
4.	M	500	1.83	1.32	0.32	2.27	0.06
5.	M	275	3.48	2.13	0.26	0.13	0.03
6.	M	580	0.46	0.62	4.58	0.001	0.06
421.67±96.21			1.96±1.05	1.58±0.93	1.09±1.57	0.89±0.99	0.16±0.18

M = Male; F = Female; Values are mean ± Standard Deviation

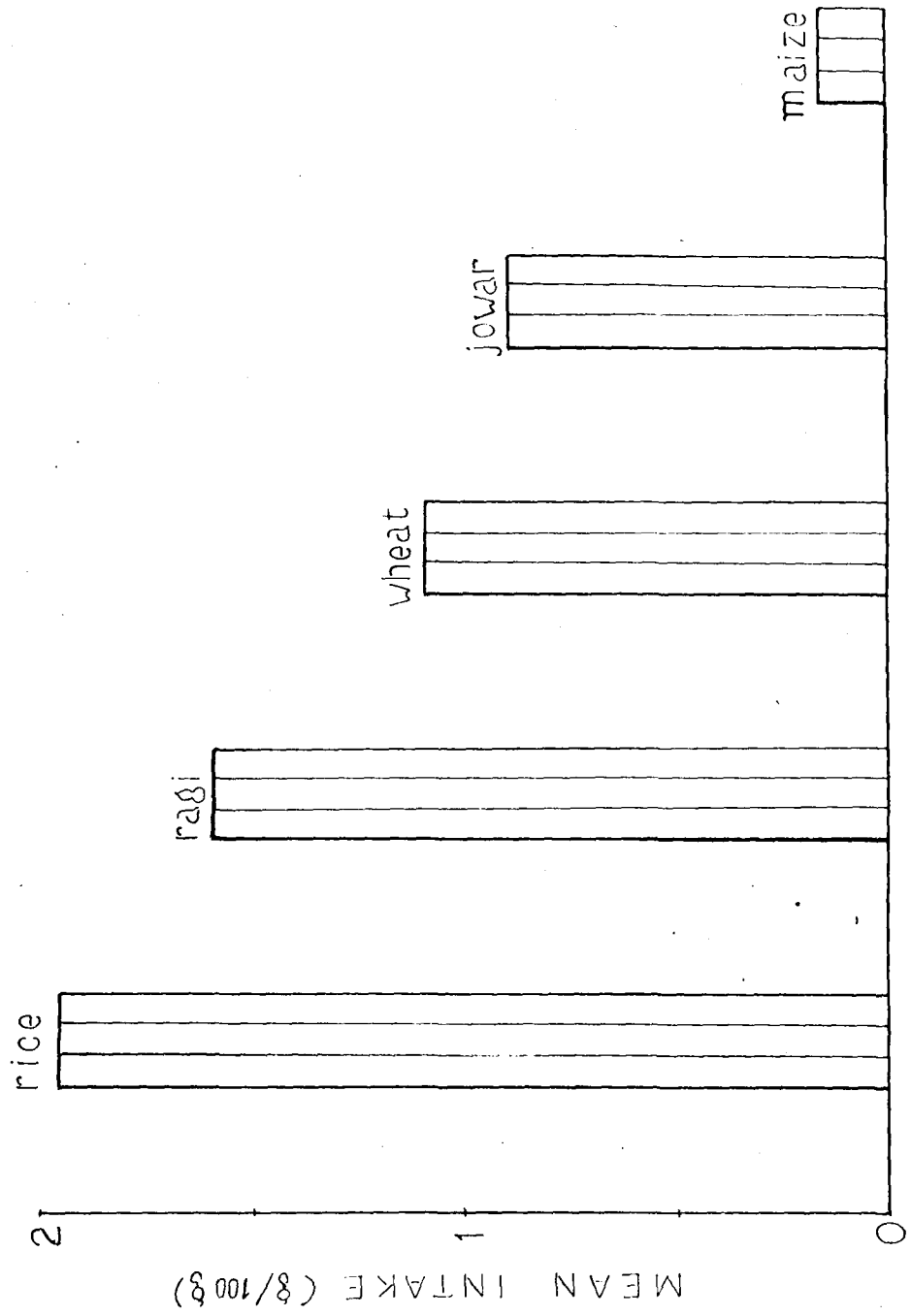


FIG.1 : MEAN DAILY CONSUMPTION OF CEREALS BY *B. indica*

TABLE 2 : Texture preference of cereals by B. indica

Cereals	Intake of different textured cereals/day			H
	Whole grains	Broken form	Flour	
Rice	0.48 \pm 0.19	2.08 \pm 1.42	3.19 \pm 1.03	6.59
Ragi	1.09 \pm 0.77	ND	4.31 \pm 1.47	5.33
Wheat	0.58 \pm 0.65	1.04 \pm 0.67	3.62 \pm 0.29	7.73
Jowar	2.01 \pm 0.40	2.99 \pm 1.19	4.07 \pm 0.55	4.77
Maize	0.88 \pm 0.49	1.51 \pm 0.83	5.56 \pm 0.79	8.35

n = 4; Values are mean \pm SD

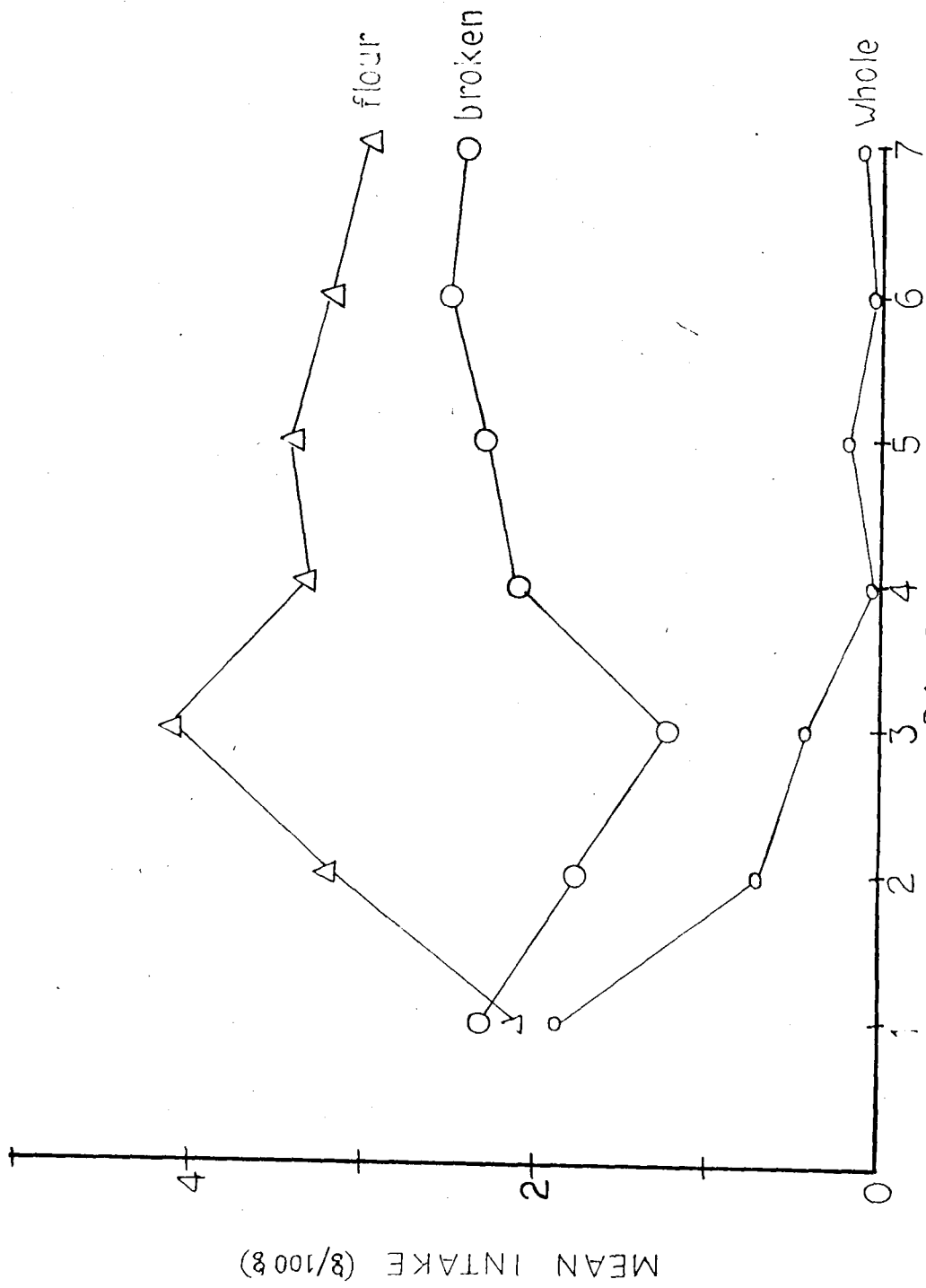


FIG.2: TEXTURE PREFERENCE OF RICE BY *B. indica*

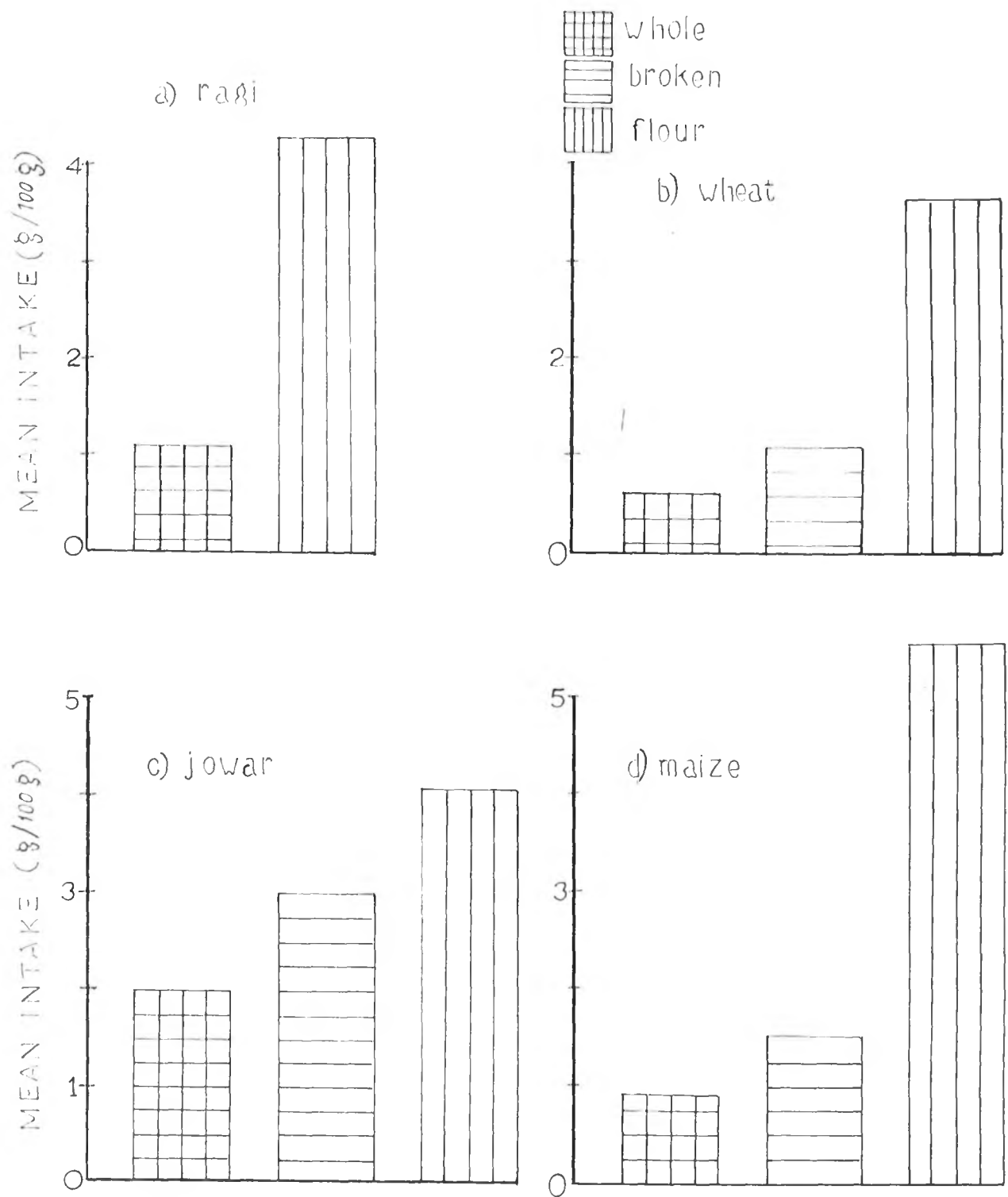


FIG.3:TEXTURE PREFERENCE OF RAGI,WHEAT,JOWAR AND MAIZE BY B. indica

(1.96 \pm 0.38) groundnut oil (Table 3; Fig.4a). Hence the preferential order towards baits with different concentrations of groundnut oil can be represented as 10% > 5% > 4% > 3% > 2% (H=16.29; Kruskal wallis one way analysis of variance).

Similarly bait with 10% coconut oil (1.59 \pm 0.29) was preferred compared to the baits with 2% (0.19 \pm 0.19), 3% (0.32 \pm 0.02), 4% (0.56 \pm 0.18) and 5% (1.21 \pm 0.14) coconut oil (Table 3; Fig.4b). Hence the preferential order towards baits with different concentrations of coconut oil can be represented as 10% > 5% > 4% > 3% > 2% (H=14.09; Kruskal-Wallis one way analysis of variance).

But in case of gingelly oil (Table 3; Fig.4c) the results indicate that the bait with 4% is preferred (0.85 \pm 0.23) compared to 3% (0.75 \pm 0.09), 10% (0.60 \pm 0.49), 5% (0.59 \pm 0.07) and 2% (0.22 \pm 0.24) concentrations (H=8.76; Kruskal-Wallis one way analysis of variance).

When groundnut oil, coconut oil and gingelly oil at their preferred concentrations (10%, 10% and 4% respectively) were tried, B.indica preferred to feed on bait containing 10% groundnut oil (1.96 \pm 0.47) compared to the baits containing 10% coconut oil (1.31 \pm 0.24) and 4% gingelly oil (0.85 \pm 0.21) (Table 4; Fig.4d). Hence, the preferential order of B.indica towards oils can be represented as 10% groundnut oil > 10%

TABLE 3 : Preference towards different concentrations of oils in B. indica

Oils	Bait intake at different concentrations of oils (g/100 g body weight)				Preferential intake of oils (Conc.)
	2%	3%	4%	5%	
Groundnut oil	0.09+0.06	0.13+0.06	0.28+0.13	1.96+0.38	2.88+0.03 10%>5%>4%>3%>2%
Coconut oil	0.19+0.19	0.32+0.02	0.56+0.18	1.21+0.14	1.59+0.29 10%>5%>4%>3%>2%
Gingelly oil	0.22+0.24	0.75+0.09	0.85+0.23	0.59+0.07	0.6 +0.49 4%>3%>10%>5%>2%

n = 4, Values are mean + SD

TABLE 4 : Preference towards different oils in B.indica (10% groundnut oil v/s 10% coconut oil v/s 4% gingelly oil)

Sl. No.	Sex	body wt. (g)	Intake of bait with different oils		
			bait with 10% groundnut oil	with 10% coconut oil	with 4% gingelly oil
1.	M	875	1.43	0.96	0.59
2.	F	675	1.78	1.34	0.70
3.	F	490	2.72	1.64	1.11
4.	F	630	1.91	1.31	0.98
		667.5+137.86	1.96+0.47	1.31+0.24	0.85+0.21

n = 4; Values are mean \pm SD

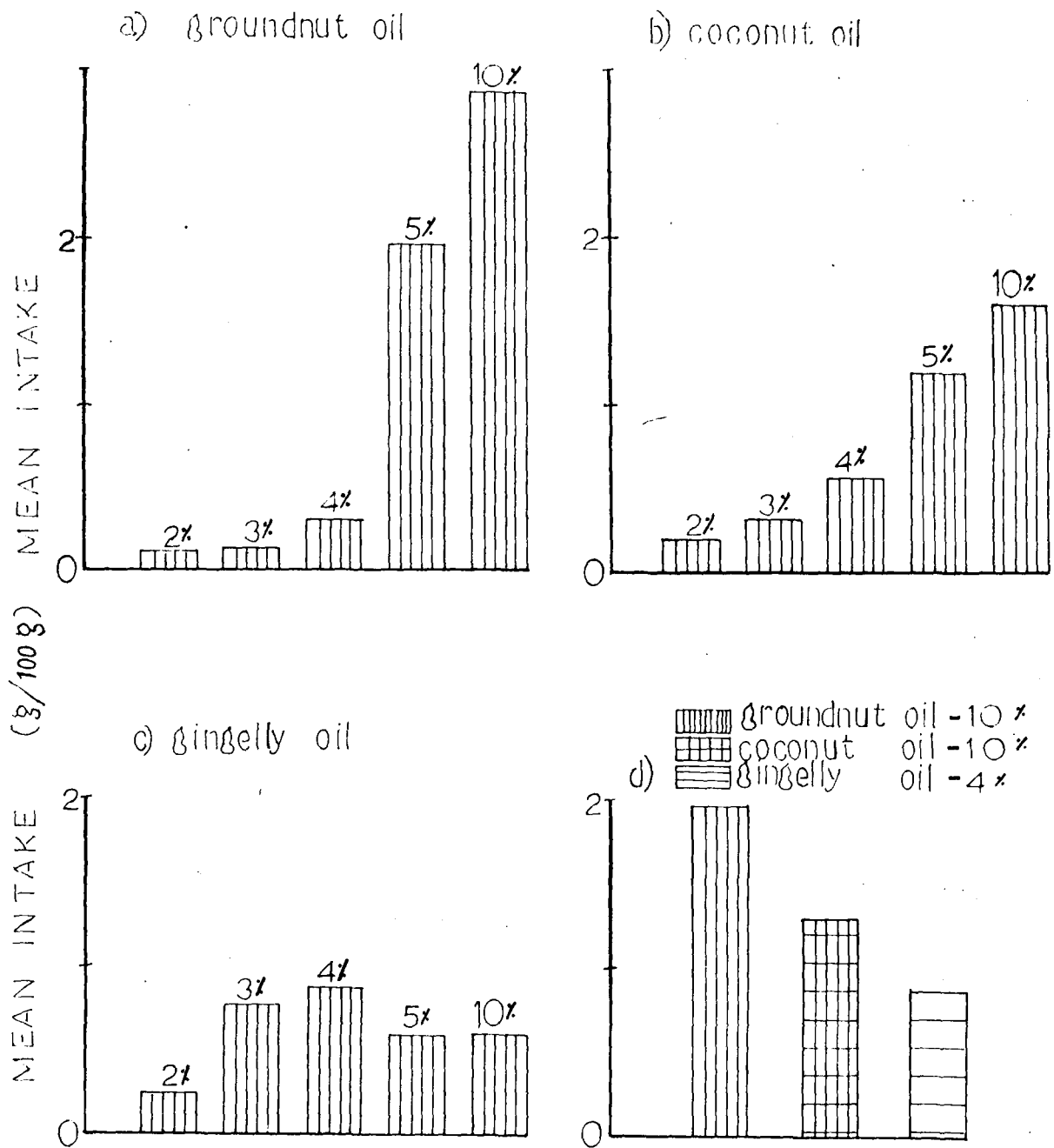


FIG. 4: PREFERENCE TOWARDS OILS AT DIFFERENT CONCENTRATIONS BY B. indica

coconut oil > 4% gingelly oil (H=8.12; Kruskal wallis one way analysis of variance).

4.1.4 Preference Towards Additives (Salt and Sugar)

When B.indica were given rice bait (rice flour + 10% groundnut oil), rice bait + 2% sugar and rice bait + 2% salt, the intakes were 1.24 ± 0.29 , 1.19 ± 0.21 and 1.13 ± 0.29 respectively (Table 5; Fig.5) and did not differ significantly. Hence, additives have no effect on food consumption (H=2.4; Kruskal Wallis one way analysis of variance).

4.1.5 Food consumption of B.indica as per cent body Weight

From Table 6 it is evident that the intake of food as per cent of body weight ranged from 3.57 during the test on additives to 5.68 during cereal preference test. The order of intake is, bait with additives < bait with oil < cereal bait < different textured cereal bait. However when the consumption is compared as calorific intake, there is no difference in calorific ingestion during the different feeding tests.

4.2 BAIT SHYNESS IN Bandicota indica

4.2.1 Bait Shyness Towards Zinc Phosphide

From days 1-4, the experimental rats consumed more of rice bait compared to jowar grains ($t < 0.01$) but on 5th day when 0.05% Zinc phosphide was added to rice bait, its consum-

TABLE 5 : Preference towards additives (salt and sugar) exhibited by B.indica

Sl. No.	Sex	body weight (g)	Intake of bait (g/100g body weight)			
			Bait with 2% salt	Bait with 2% sugar	plain bait	
1.	M	875	0.81	0.95	0.85	
2.	F	675	0.99	1.16	1.25	
3.	F	490	1.58	1.53	1.67	
4.	F	630	1.15	1.14	1.19	
		667.5 \pm 137.86	1.13 \pm 0.29	1.19 \pm 0.21	1.24 \pm 0.29	

n = 4; Values are mean \pm SD

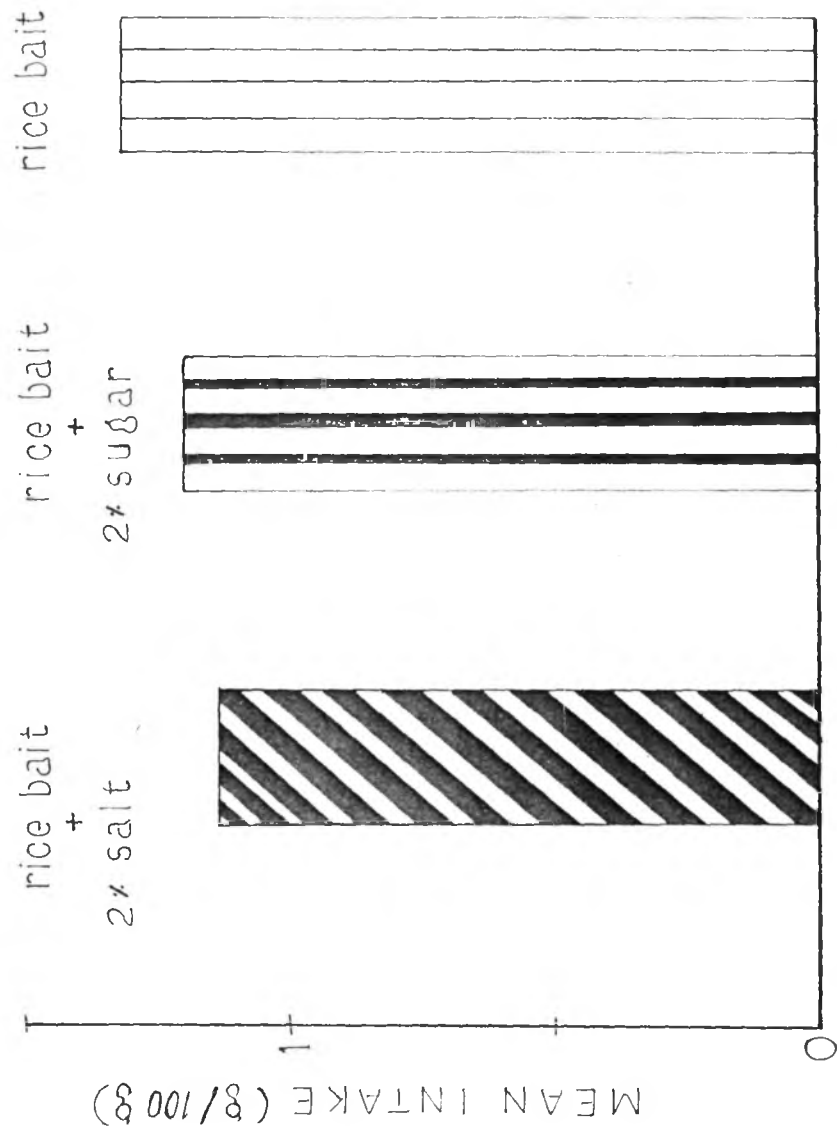


FIG.5: PREFERENCE TOWARDS ADDITIVES
IN B. indica

TABLE 6 : Food consumption of B.indica as per cent body weight during different tests

	Cereal preference	Texture preference	Oil preference	Additive preference
Body weight	4 21.67+96.21	581.25+136.66	667.5+137.86	667.5+137.86
Total food intake (g)	23.95	39.12	27.30	23.83
Per cent daily intake with respect to body weight	5.68	6.73	4.09	3.57

ption decreased significantly ($t < 0.01$) indicating development of bait shyness (Table 7; Fig.6). Further tests on bait shyness on 15th, 30th, 45th and 60th days after poison exposure indicated the persistence of bait shyness as seen by lower consumption of rice bait. Only on 75th day, there was a reversal in food preference with rice bait being consumed more (Table 7; Fig.6).

4.2.2 Bait Shyness Towards Silmurin

When rice bait and maize flour were given for 4 days the former was preferred to the latter ($t < 0.01$). But when sublethal dose of silmurin (0.001%) was added to it on 5th day, there was reversal in food consumption with maize flour being consumed more than the rice bait ($t < 0.01$) thus indicating that B.indica became bait shy towards sublethal poisoning of silmurin (Table 8, Fig.7).

4.2.3 Bait Shyness Towards Cereal Components of Poison Bait

The consumption of cereal mixture was comparatively higher than rat feed for first three days (Fig.8). But when 0.05% Zinc phosphide was added to cereal mixture, its intake reduced and that of rat feed increased denoting that the rats have become bait shy. When such bait shy rats were given rat feed versus ragi, rat feed versus rice bait and rat feed versus jowar, results indicated avoidance of poison linked rice and jowar for a day and ragi for two days after which the animals shifted their preference to cereals (Fig.8).

TABLE 7 : Bait shyness in B.indica towards zinc phosphide

Baits provided	INTAKE (g/100g)							
	During poisoning				Post poison period			
	1-4 days	5-6 days	15th day	30th day	45th day	60th day	75th day	
Rice bait	3.86±0.39	1.45±0.66	1.31±0.99	1.16±0.79	1.79±1.05	3.54±2.36	5.21±2.24	
Jowar	1.46±0.27	2.93±0.36	5.19±1.53	5.02±0.71	6.03±2.1	6.72±1.17	2.48±1.46	
t <	0.01	0.01	0.02	0.001	0.02	0.05	0.1	

n = 4; Values are mean ± SD

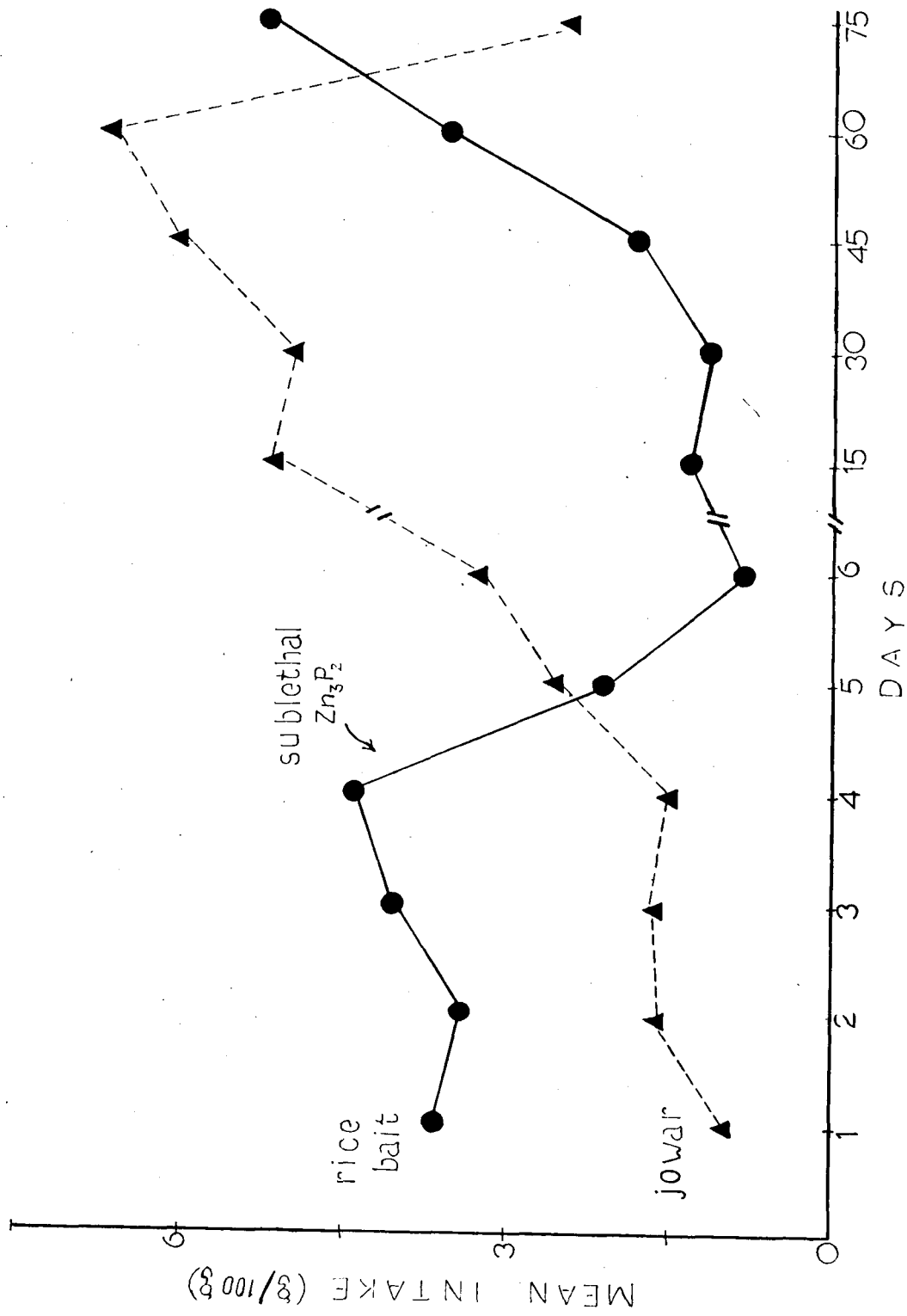


FIG.6: OCCURRENCE AND PERSISTENCE OF BAIT SHYNESS
TOWARDS ZINC PHOSPHIDE IN B. indica

TABLE 8 : Bait shyness in B.indica towards silmurin

	Intake (g/100g)	
	Prior to poisoning	Post poison Period
	(1-4 days)	(5-9 days)
Rice bait	3.29±0.61	0.83±0.58
Maize flour	0.64±0.19	3.07±0.78
t <	0.001	0.01

n = 4; Values of mean ± SD

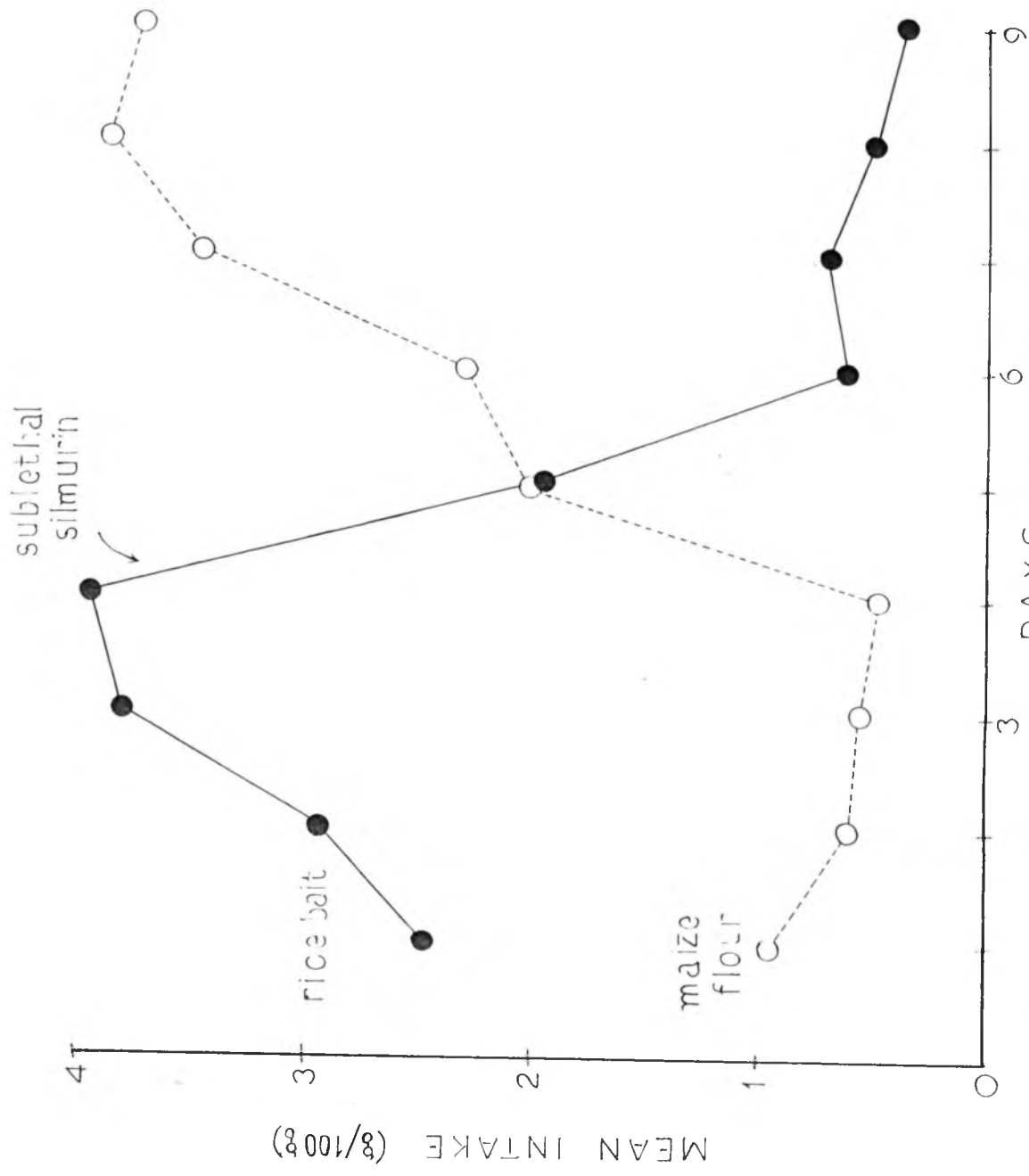


FIG.7: OCCURRENCE OF BAIT SHYNESS TOWARDS

SILMURIN IN *B. indica*

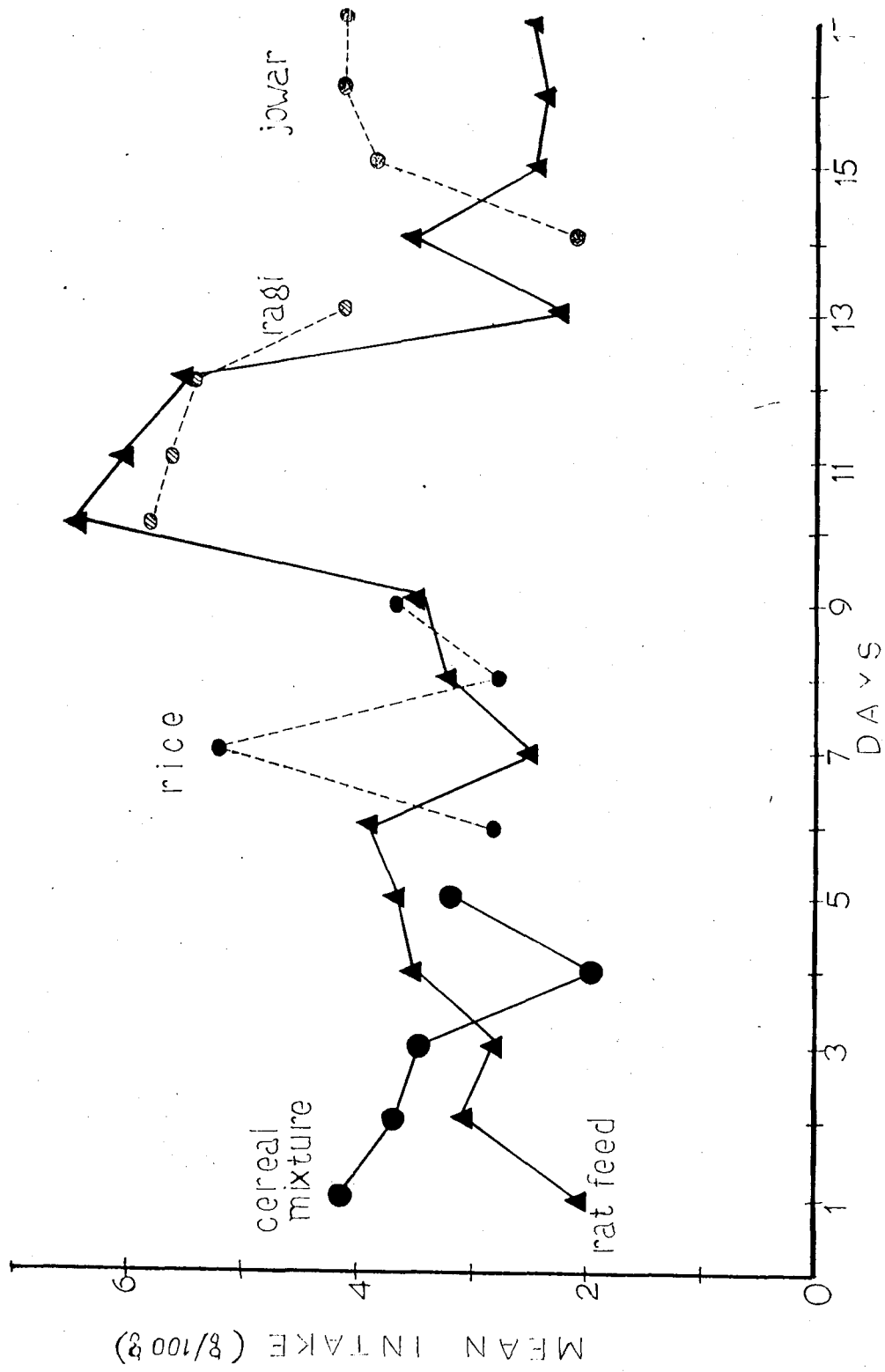


FIG. 8: BAIT SHYNESS OF *B. indica* TOWARDS CEREAL COMPONENTS OF POISON BAIT

4.2.4 Bait Shyness Towards Components of Poison Bait

From days 1 to 3, the rats consumed more of rice +10% groundnut oil than maize flour (Fig.9). But when 0.05% zinc phosphide was added to rice bait, there was a decline in its intake than that of maize flour (Fig.9). When these animals were given a choice of rice flour + 10% coconut oil (poison associated cereal with a fresh oil), ragi flour + 10% groundnut oil (fresh cereal with poison associated oil), rice flour + 10% groundnut oil (poison associated bait) and ragi flour +10% coconut oil (new cereal with new oil), the first three were consumed significantly less than the ragi flour + 10% coconut oil indicating that bait shyness extends towards both cereal and oil component of poison bait (Fig.9).

4.2.5 Response of Bait Shy B.indica Towards New Poison

When the rats were given plain rice bait versus maize flour, the former was consumed more (Fig.10). Addition of 0.05% zinc phosphide rendered the subjects bait shy and poison mixed rice bait was consumed less than maize flour (Fig.10). These rats when given a choice of plain maize flour and rice bait containing 0.001% silmurin, consumed more of maize flour and avoided silmurin mixed rice bait. This experiment established that bait shy rats reject a new acute rodenticide.

4.2.6 Response of Bait Shy B.indica Towards New Foods

Exposure to sublethal doses of Zinc phosphide in rice

- rice bait
- - -○ maize flour
- ▲—▲ ragi flour + 10% Coconut oil
- △—△ ragi flour + 10% Groundnut oil
- ◉—◉ rice flour + 10% Coconut oil

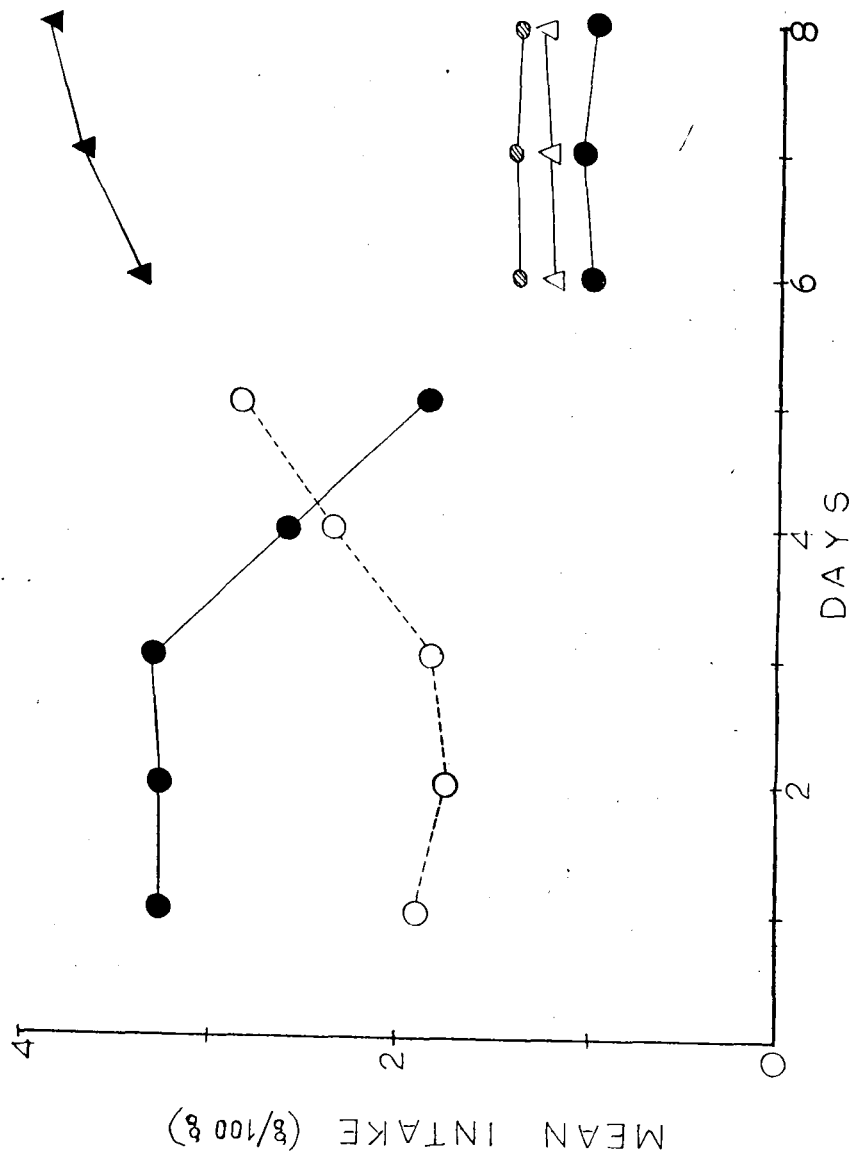


FIG. 9: BAIT SHYNESS OF *B. indica* TOWARDS COMPONENTS OF POISON BAIT

●—● rice bait
 ▲—▲ maize flour
 ⊗—⊗ rice bait +
 0.001% simmurin

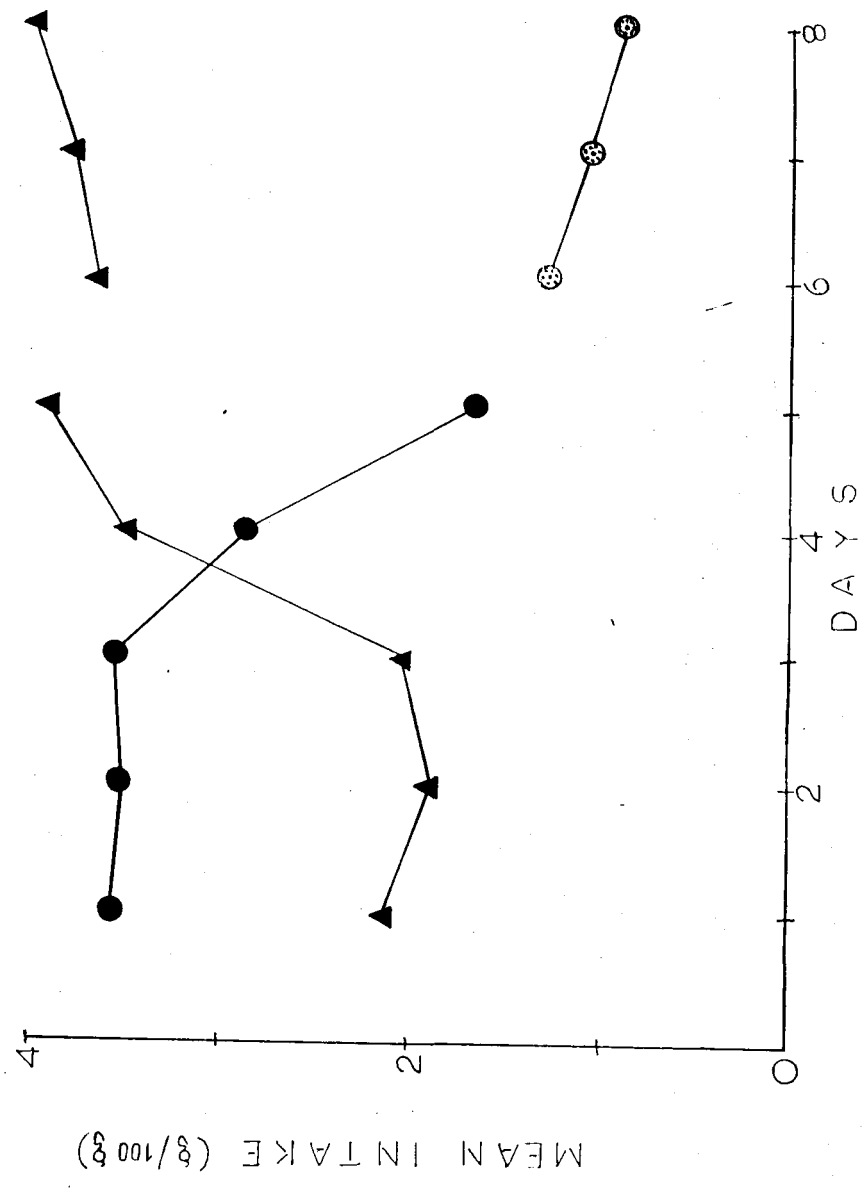


FIG.10: RESPONSE OF BAIT SHY *B. indica* TOWARDS NEW POISON

bait resulted in its lower consumption compared to maize flour (Fig.11), thus demonstrating development of bait shyness. When these rats were given new foods namely ragi and jowar, the consumption of these were lower to maize flour but higher than rice bait. This indicates that the rats avoiding poison linked bait, are neophobic to new foods but ingest more of maize flour which was found safe and harmless (Fig.11).

4.3 LABORATORY EVALUATION OF RODENTICIDES

4.3.1 Toxicity of Zinc Phosphide to B.indica

The results presented in Table 9 clearly indicate that both the baits with 2% and 1.5% zinc phosphide caused 100% mortality in B.indica. But the same poison at 1.00% concentration resulted in only 87.5% mortality. The results also reveal that as the concentration of poison is increased, the bait consumption declines. The lethal dose ingested is 22.8 mg/kg at 2% and 26.55 mg/kg at 1.5% zinc phosphide.

4.3.2 Toxicity of Silmurin to B.indica

The results presented in Table 9 clearly indicate that the rice bait with 0.1% silmurin caused 100% mortality. But the same poison at 0.05% concentration resulted only in 25% mortality. The lethal dose ingested was 8.3 mg/kg at 0.1%.

4.3.3 Toxicity of Bromadiolone (0.005%)

Exposure to bromadiolone cake (0.005%) for 24 hrs caused

- rice bait
- - ● maize flour
- ▲—▲ jowar
- ragi

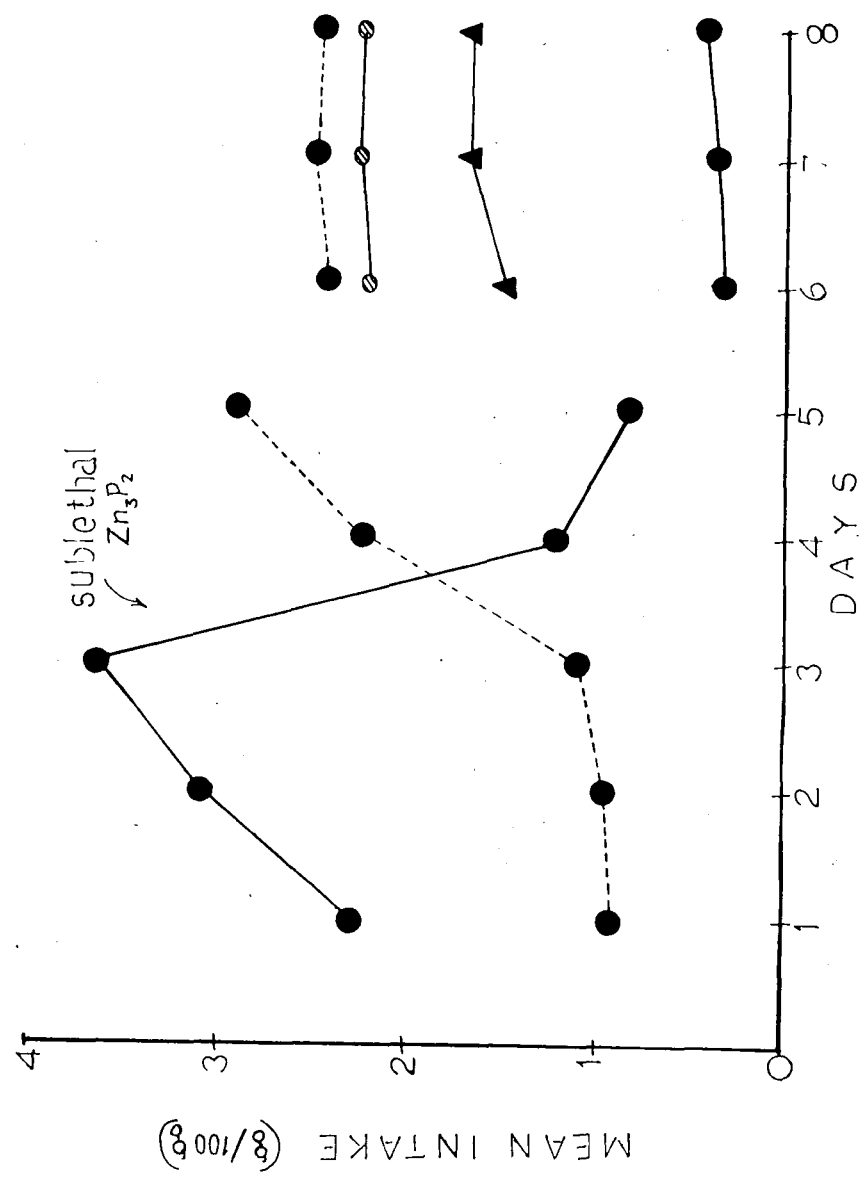


FIG.11: RESPONSE OF BAIT S-HY B. indica TOWARDS NEW FOODS

TABLE 9 : Toxicity of Zinc phosphide and Silmurin to B.indica

Concentrations used	No. of animals used	Average body weight(g)	Average consumption of poison bait (g/100g)	poison consumed (mg/kg)	No. dead	Mortality after 24 hrs (%)
I. Zinc phosphide						
2%	8	679.38 (490-875)	1.14 (0.21-3.54)	22.8 (4.2-70.8)	8	100%
1.5%	8	681.88 (570-800)	1.77 (0.71-3.95)	26.55 (10.65-59.25)	8	100%
1.0%	8	499.38 (570-850)	2.03 (0.56-6.29)	20.3 (5.6-62.9)	7	87.5%
II. Silmurin						
0.1%	6	402.5 (270-550)	0.83 (0.007-1.58)	8.3 (0.07-15.8)	6	100%
0.05%	4	468.75 (430-500)	0.58 (0.2-1.19)	2.9 (1-5.9)	1	25%

100% mortality (Table 10) within an average of 11.2 days (range 7-17 days). Exposure to 48 hrs also resulted in 100% mortality within an average of 11.5 days (range 6-17 days). Poison ingested increased when exposed for 48 hrs (3.09 mg/kg) compared to 12 hrs exposure (2.87 mg/kg).

4.3.4 Toxicity of Brodifacoum (0.005%)

Brodifacoum cake when fed for 24 hrs did not induce any mortality even though the animal has ingested some quantity of poison (0.27mg/kg). But when the same was exposed for 48 hrs it caused 100% mortality within an average of 11 days (range 7-17 days). Active poison ingested was 1.79 mg/kg (Table 10).

4.4 FIELD EVALUATION OF RODENTICIDES

4.4.1 Field Evaluation of Zinc Phosphide Against B.indica

The active burrow count was 12 before poisoning which got reduced to 2 after baiting with 1.5% zinc phosphide for a day. This represents 83.33% reduction in the population (Table 11).

4.4.2 Field Evaluation of Bromadiolone (0.005%)

The live burrow count after single application of bromadiolone resulted in nil count representing cent per cent success with the poison in field conditions (Table 11).

4.4.3 Field Evaluation of Brodifacoum (0.005%)

The live burrow count was 15 before brodifacoum

TABLE 10 : Toxicity of bromadiolone (0.005%) and Brodifacoum (0.005%) to B.indica

Feeding period (days)	Average body weight (g)	Average bait consumed (g/100g)	Poison ingested (mg/kg)	Mortality	Days to death	
					Mean	Range
I. Bromadiolone						
1	659	5.73 (3.13-8.54)	2.87 (2.69-3.04)	6/6	11.2	7-17
2	543	6.17 (3.2-9.56)	3.09 (1.6-4.78)	6/6	11.5	6-17
II. Brodifacoum						
1	455	0.54 (0.02-1.95)	0.27 (0.01-0.975)	0/4	-	-
2	463.75	3.57 (3.28-3.84)	1.79 (1.64-1.92)	4/4	11	7-17

poisoning. After baiting it was reduced to 2 representing 80% elimination of rodents (Table 11).

4.4.4 Field evaluation of aluminium phosphide

From the results presented in Table 11, it is evident that when live burrows of B.indica were treated with aluminium phosphide tablets (3 g each) it reduced the live burrows from 15 to 5 indicating 66.67% mortality.

TABLE 11 : Field evaluation of rodenticides for the control of B.indica

Rodenticides employed	Live burrow counts		% reduction in the burrow counts
	Prior to control	After control	
Zinc phosphide	12	2	83.33
Bromadiolone	5	0	100.00
Brodifacoum	15	2	80.00
Aluminium phosphide	15	5	66.67

DISCUSSION

V. DISCUSSION

5.1 FOOD PREFERENCES

One of the main factors responsible for the high degree of adaptability and proliferation of rodents is their versatile feeding habits. At the same time wild rodents are sensitive and discriminate about food odours and tastes. Although they are capable of sampling all the foods provided, "marked preference" is exhibited for some foods and "slight preference" for others (Barnett and Spencer, 1953). They are capable of narrowing down their choice to two and in some cases to a single food (Barnett, 1966). Food preference is influenced by factors like flavour, water content, calorific value, physiological effects, early experience and social interactions (Barnett and Prakash, 1975; Sridhara, 1977). Naturally these factors will vary for each species and are bound to result in feeding habits specific to each species. This is amply demonstrated by several studies on cereal preference, effect of additives like oil, sugar and salt.

5.1.1 Cereal preference

Bandicota bengalensis preferred rice flour + 10% groundnut oil (Sridhara and Srihari, 1986), Tatera indica chose whole ragi + 2% groundnut oil and Rattus meltada liked

broken ragi + 1% groundnut oil (Bindra and Sagar, 1970; Sridhara and Krishnamoorthy, 1978). The lone study on B.indica indicated whole or broken rice with 7-10% groundnut oil as the preferred food (Sridhara and Srihari, 1983). The present experiments show rice as the best liked cereal (Table 1; Fig.1).

For effective control of rodents, data on second and third preferred baits is also important because more often it becomes necessary to use a different poison in a different bait to kill bait shy rodents after the initial knockdown of pest population. Rice, wheat and millet/pearl millet are the three most preferred baits for Indian rodents. The second preferred cereals are jowar, maize and gram (Prakash and Mathur, 1987). But the present experiment show ragi and wheat as the next preferred cereals after rice for B.indica (Table 1; Fig.1).

5.1.2 Texture preference

The preference of rodents for smaller grains or food composed of smaller particles is reported for several species viz. Gerbillus gleadowi (Prakash et al., 1975b) R.meltada (Jain et al., 1974), R.rattus (Khan, 1974), B.bengalensis (Kamal and Khan, 1977; Sridhara and Krishnamoorthy, 1978; Sridhara and Srihari, 1986) and M.booduga (Rao et al., 1977). B.indica resembles other species in this aspect (Table 2, Fig.2).

5.1.3 Oil preference

The role of oil in influencing food choice is controversial. A few species like T.indica, B.bengalensis, R.norvegicus and R.rattus consume more bait when vegetable oil is added (Sridhara and Srihari, 1986; Prakash and Mathur, 1987) whereas, in others like M.hurrianae, R.meltada, G.elliotti, M.booduga and M.platythrix bait consumption declined when oil was added. For other species addition of oil had no impact (Prakash and Mathur, 1987). For B.indica addition of 10% groundnut oil enhanced bait intake compared to addition of 10% coconut oil and 4% gingelly oil (Fig.4d).

5.1.4 Effect of additives on bait intake

So far experimental evidences suggest that addition of sweetening agents like sugar or salt have no impact on bait intake (Sridhara and Srihari, 1986; Prakash and Mathur, 1987). Apart from no visible effect, sugar influences bait shyness positively (Bharadwaj and Prakash, 1979) and employing sugar in the bait definitely enhances the cost of rodent control operation. Since the current study also established that neither 2% sugar nor 2% salt affected bait intake of B.indica (Fig.5) it can be concluded that for the control of this species, baits need not contain either of these components.

5.1.5 Food Consumption of B.indica as per cent body weight

The rate of food intake converted as per cent body weight in the present study varied from 3.57 to 5.68 during different tests (Table 6). This value is the least compared to other rodent species studied (Leslie and Ranson, 1954; Krishnamurthy et al., 1967). This can be easily understood when one considers the fact that in mammals the metabolic rate is inversely correlated with body weight, with larger mammals exhibiting lower rates of metabolism and hence even per cent food intake is also lower.

5.2 BAIT SHYNESS

During poisoning operation using acute rodenticides if pest ingests sublethal doses, the surviving populations learn to associate the physiological ill effects with the bait and avoid such baits in future. The duration of such bait shyness depends both on the species and the duration of poison exposure.

5.2.1 Bait shyness towards acute poisons

The duration of bait shyness increase with Zinc phosphide exposure time, with single exposure it lasted for 20 days while four days poisoning resulted in 30 days avoidance (Rao and Prakash, 1980). Bait shyness towards Zinc phosphide persisted for 10-15 days in Gerbillus gleadowi (Rana et al., 1975), and Funambulus pennanti (Kumari and Prakash, 1981), 35

days in M.hurrianae (Prakash and Jain, 1971), 75 days in R.rattus and M.platythrix (Prakash et al., 1975a; Rao and Rajabai, 1978), 115 days in T.indica (Prakash and Jain, 1971), 135 days in R.meltada (Prakash et al., 1975a) and 120 days in M.platythrix (Sridhara and Srihari, 1980a). In the present study B.indica showed bait shyness towards Zinc phosphide upto 75 days (Fig.6) thus resembling the other commensal R.rattus (Prakash et al., 1975a).

Studies on bait shyness towards silmurin are scanty. Chitty and Southern (1954) reported bait shyness towards silmurin persisting upto one year in R.norvegicus while only development of bait shyness towards silmurin was reported for B.bengalensis (Usha Devi and Krishnamoorthy, 1982). Current studies demonstrate that even B.indica develops bait shyness towards silmurin (Table 8; Fig.7).

5.2.2 Bait shyness towards components of poison bait

Cowan (1978) found that even after changing the bait on subsequent days poison shyness continued. Changing the oil did not reduce the development of bait shyness in T.indica but if both bait and poison were changed, the second exposure was effective (Prakash and Ojha, 1978). Bharadwaj and Khan (1979) suggested that if the grain form of cereal in the poison bait is replaced with flour form, bait shyness can be abated. However, Sridhara (1983a, 1983b) and Krishnamurthy

et al., (1967) clearly demonstrated that once developed bait shyness extends to cereal, oil and poison components of poison bait in B.bengalensis, T.indica and R.rattus. A similar trend is observed in the present study also i.e., B.indica avoids all the components of poison associated bait (Fig.9). There were also reports that bait shy B.bengalensis, T.indica and R.rattus are more neophobic (Sridhara, 1983a, 1983b; Krishnamurthy et al., 1967). B.indica also exhibits similar behaviour (Fig.11).

At present Zinc phosphide is the most commonly used acute rodenticide in India with no other alternative for quick and effective knockdown of rodent populations, the only drawback being development of bait shyness in surviving population. B.indica is no exception with bait shyness extending to cereal, oil and poison components of bait. Bait shy bandicoots were also shown to develop neophobic behaviour thus making prebaiting necessary and leading to higher cost of control. Suggestions to kill bait shy rodents include using a new poison in a new bait (Sridhara, 1983a & b), providing texturally different bait (Bharadwaj and Khan, 1979) or to fumigate residual burrows (Prakash and Jain, 1971). Studies on M.hurrianae have shown that by mixing 0.4 per cent conspecific female urine with the bait, bait shyness can be overcome to some extent in both the sexes (Kumari and Prakash, 1980), the effect attributed to the pheromone present in the urine. This pheromonal blocking of bait

shyness is the most promising approach at present if proved viable for other species also.

5.3 LABORATORY EVALUATION OF ACUTE RODENTICIDES

5.3.1 Zinc phosphide

In baits, zinc phosphide is used at 0.75-5% concentration but it should not be used above 2% beyond which acceptability is retarded and poison aversion increases (Bharadwaj and Prakash, 1982a). Two percent poison in the bait gave effective control of B.bengalensis, T.indica and M.platythrix both in the laboratory and field (Sridhara, 1979; Poche et al., 1979). Experiment on B.indica in present study also indicate 1.5 and 20 % as optimum for effective mortality (Table 9).

5.3.2 Silmurin

Stabilized rodenticide at 0.015% in cereal bait was lethal to Norway rats (Maddock and Schoof, 1970). Ready to use baits containing 0.05%, 0.075% and 0.1% silmurin effected cent percent death of R.rattus (Srivastava, et al., 1980). Low concentrations (0.025-0.05%) of silmurin were effective against B.bengalensis (Brooks and Htun, 1980) but both R.rattus and M.booduga did not succumb completely to even 0.1% poison (Christopher et al., 1982; Chopra et al., 1984). B.indica succumbed to 0.1% silmurin in this study but at 0.05%, only 25% mortality could be achieved (Table 9).

5.4 LABORATORY EVALUATION OF SECOND GENERATION ANTICOAGULANTS

A major breakthrough in rodent control was the advent of second generation anticoagulants namely difenacoum, bromadiolone and brodifacoum. They are of recent origin (10-12 years) and combine the positive characters of acute rodenticides without their disadvantages. Although Indian workers have not evaluated difenacoum, reports exist about its toxicity to B.bengalensis (Brooks et al., 1980) and tolerance.

5.4.1 Bromadiolone

Bromadiolone was effective when fed for 1-2 days against R.rattus and R. melta (Jain, 1980; Chopra et al., 1983a) while Balasubramanyam et al., (1986) could get only 83% mortality. Single exposure was adequate for killing T.indica (Jain, 1980; Parshad et al., 1985), B.bengalensis (Sridhara et al., 1988), M.platythrix (Chopra et al., 1983a) and 4 days were required for F.pennanti (Anon, 1983). B.indica in the present study succumbed after single exposure within a period of 3 weeks (Table 10).

5.4.2 Brodifacoum

Brodifacoum fed for 1-2 days killed R.melta (Chopra et al., 1983b; Soni and Prakash, 1985). Feeding for 1-3 days was enough for R.rattus (Jain et al., 1982; Parshad et al.,

1985). Three days exposure was needed for T.indica and M.hurrianae (Soni and Prakash, 1985) while B.bengalensis required one day feeding (Brooks et al., 1980; Parshad et al., 1985). Single exposure was effective for B.indica (Tongtavee, 1980) and three Mus species (Chopra et al., 1983b; Balasubramanyam et al., 1986). Present experiments demonstrating two days feeding for 100% mortality contradict Tongtavee's(1980) observation that brodifacoum feeding for a day gives 100% mortality of B.indica (Table 10).

5.5 FIELD EVALUATION OF RODENTICIDES

5.5.1 Zinc phosphide:

Mann and Bindra (1974), Advani et al., (1982) reported 84% and 93% reduction of field rodents in wheat fields using 2% zinc phosphide. In paddy fields 73% reduction (Sridhara & Krishnamoorthy, 1979a) and 92.5% in vegetable fields is reported (Advani and Mathur, 1982). The present evaluation in field represents 83.33% Kill (Table 11).

5.5.2 Second generation anticoagulants

Mathur and Prakash (1981) found brodifacoum to be more effective than coumatetralyl and chlorophacinone in field trials. Bromadiolone was effective in killing rodents in poultry houses (Purushotham et al., 1984). The order of efficacy in fields around Tirupati was brodifacoum > bromadiolone > warfarin. In the present study bromadiolone gave

higher reduction of rodents than brodifacoum (Table 11).

5.5.3 Aluminium phosphide

Fumigation with aluminium phosphide was more effective than sodium cyanide in lower Sind of Pakistan (Greaves et al., 1977). About 80% reduction of rodents is reported for irrigated fields of Rajasthan (Advani & Mathur, 1981), rice and wheat fields of Punjab (Chopra, 1984), wet and dryland crops in Karnataka (Sridhara and Srihari, 1979a; Sridhara and Krishnamoorthy, 1979b). However, all these authors concluded that larger species succumb at a lower rate and slowly. This may explain the lower efficacy of the fumigant obtained in the present field evaluation (Table 11).

Zinc phosphide at 1.5 and 2 per cent in the bait was effective in the laboratory and field trials in the present study confirming similar potency of this acute rodenticide against other rodent species of India. Silmurin laboratory trials also indicated the poison to be effective as in the case of B.bengalensis (Brooks and Htun, 1980), but the chemical induced bait shyness at sublethal doses (Fig7). Bromadiolone and brodifacoum needed 1 and 2 days feeding (respectively) to give effective kill in the laboratory (Table 10) indicating that these second generation anticoagulants hold out much promise for killing B.indica in godowns and residential premises. Field trials also support (Table 11) this recommendation. However, aluminium phosphide

was least effective in field evaluation (Table 11) confirming the earlier workers' (Sridhara and Srihari, 1979a) contention that larger species do not succumb easily to fumigation and that to be effective aluminium phosphide requires humidity (Sridhara and Krishnamoorthy, 1979b; Sridhara and Srihari, 1979a), a condition difficult to obtain in the typical habitat of B.indica i.e., godowns, poultry farms, houses etc.

SUMMARY

VI. SUMMARY

Bandicota indica or larger bandicoot rats are highly adaptable to variety of habitats. They are nocturnal and fossorial with ferocious nature. They are omnivorous and important from the extent of damage caused to buildings, structures etc. They have also become a severe threat to poultry farms.

They prefer to feed on rice compared to other cereals such as ragi, wheat, jowar and maize which stand in the next order of preference, with flour being more liked than broken and whole grains. Additives like salt or sugar will not enhance the bait intake, but with the addition of 10% groundnut oil the bait intake will be enhanced.

B.indica exhibit bait shyness towards sublethal doses of acute poisons such as Zinc phosphide and silmurin. Bait shyness towards Zinc phosphide persisted upto 75 days, suggesting that during this period the same poison should not be used successively. When they feed on poison associated cereal mixture, bait shyness will not be extended to individual cereals significantly. But when they become bait shy towards a palatable bait, they will extend shyness towards its components such as cereal, oil as well as the poison component. Once they become bait shy towards a poison, they

are also capable of rejecting a bait containing new poison. Also, such bait shy animals will prefer to feed on familiar alternate food rather than new foods thus exhibiting neophobia towards unfamiliar alternate foods. Hence, it is essential to make the new food familiar by prebaiting for successive poisoning.

For their effective control, acute poisons such as Zinc phosphide can be used at the concentration of 2.0% and silmurin at 0.1%. Also, ready to use cakes of second generation anticoagulants such as bromadiolone (0.005%) and brodifacoum (0.005%) can be employed for 1 and 2 days respectively to achieve satisfactory mortalities. Fumigation with aluminium phosphide is not so effective compared to above poisons in killing B.indica.

FUTURE LINE OF WORK

Even though Bandicota indica is familiar and common around human habitat studies on it are still scanty.

Hence, the following gaps may be suggested for future investigation:

- A. Aspects of breeding biology.
- B. Aspects of population ecology.
- C. Behavioural aspects such as social behaviour and bait aversion behaviour.
- D. Application of the above information to formulate an effective control strategy.

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