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Evaluation of Bait Formulations of Coumatetralyl (Racumin) for Rodent Control in Wheat Crop in Pothwar Zone

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ABSTRACT

Rodents pose a significant threat to wheat crop, leading to substantial yield loss in agricultural systems. Therefore, there is a need of effective methods for the control of field rats by using chronic poisons. This study aimed to evaluate the preferred bait base at each stage of wheat crop growth (initial, heading and maturity) and its effectiveness by adding chronic poison. Overall, screening of 4 bait bases (wheat, rice, maize and millet), all in cracked form were carried out in multi-choice feed preference tests. Millet was used as control while millet+maize, millet+wheat and millet+rice in 50:50 ratio were used as treatments. Screening of three bait additives (peanut butter, egg-shell and cooking oil) was carried out by adding in the top ranked bait base in the 4% ratio. Evaluation of poison bait was carried out by adding developed bait at each stage and millet (control) with coumatetralyl (0.0375%). Bait base and additives test were carried out at each stage while poison test was carried out at maturity stage of wheat crop. Results showed that millet, wheat and peanut butter were more preferred for poison baiting at initial stage of wheat crop while millet, rice, peanut butter and racumin are the effective combinations for controlling field rats at maturity stage of wheat crop. It is recommended that rodent control strategies should be adapted based on the growth stage of the wheat crop, with bait base preferences shifting from millet and wheat to millet and rice as the crop matures.

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Key words
Rodents, Control, Rodenticides, Coumatetralyl, Bait formulations, Crop stages

INTRODUCTION

Rodents can cause significant damage to field crops in developing countries, as well as to stored produce and infrastructure, affecting food security and income of small-holder farmers. Wheat (*Triticum aestivum*) and groundnuts (*Arachis hypogea*) are important cash crops for local farmers in Pakistan. Damage levels in crops can vary from insignificant to very significant (>30%) or to almost complete crop loss. In Pakistan, rodent damage to wheat crop, in majority of cases, has been studied in Central Punjab. Among the field rats *Bandicota bengalensis* has been studied as the most abundant and damaging rodent pest in wheat fields followed by *Nesokia indica, Millardia meltada* and *Mus musculus* (Beg *et al.*, 1980). Beg and Khan (1977) calculated 7.5% damage to wheat in Faisalabad District. Beg *et al*. (1978) conducted a study in four districts of central Punjab and estimated 5 % reduction potential of yield. On a much larger scale Fulk *et al*. (1980) estimated rodent damage to 1978 and 1979 in Punjab, Sindh and NWFP and found that 5 % of the farms sampled had more than 10 % of yield loss due to rodent damage. This study also indicated that the losses were severe in rain-fed areas and where wheat is grown after rice harvest. As an example of the severe levels of rodent damage to crops was reported in 1956 in the district of Sialkot which revealed that the quantity of grains (rice and wheat) lost due to rodents was enough to feed the population of the district (0.3 million at that time) for ten years.

Five species of field rodents (*Bandicota bengalensis, Nesokia indica, Tatera indica, Golunda ellioti* and *Mus musculus*) have been reported in the agriculture fields of Pothwar region (Hussain *et al*., 2003). The lesser bandicoot rat (*B. bengalensis*) is one of the most abundant rodent pests in field crops of Pakistan. It is also a serious problem of wheat throughout southern and Southeastern Asia. Pakistan has two isolated populations of this rat, one throughout central and northern Punjab and in the southern part of Khyber Pakhtunkhwa province, and the other in the

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southern Sindh (Smiet *et al*., 1978).

The majority of the rural communities of the Pothwar are dependent on farming (i.e., wheat, groundnut, millet/maize and sorghum) where 90% of their farm sizes are less than two hectares and the majority of farming is conducted by small-holder farmers. Rodents are fossorial animals (those both foraging and sheltering underground). They feed primarily on root systems of the plants and cut them from lowest part to eat the sweet and milky part of the stem and on aboveground consume herbaceous plant parts (Sarwar, 2016). Management of rodents is generally most effective when utilizing an integrated pest management (IPM) approach that incorporates multiple techniques. Of these potential management tools, rodenticide application is generally the preferred option by pest control professionals and land managers which is the quickest and least expensive management tool available for rodents (Baldwin *et al*., 2016).

Rodenticide baits consist of a nontoxic food base, flavor, attractants, additional additives (such as bittering, moisture-resistant, coloring and preservative agents) and toxic active substance. Food composition plays a key aspect for bait efficacy as it ensures its palatability. Baits may be based on acute (Henry *et al*., 2022) and anticoagulant active ingredients (McGee *et al*., 2020). Anticoagulants belong to the chronic rodenticides with the delayed mode of action. They stop the blood coagulation process in the liver via interruption of the vitamin K cycle, which results in a fatal haemorrhage after several days (typically 4-10 days). This delay prevents rodents from connecting the signs of toxicity with the consumed food, which favours anticoagulants over the acute rodenticides. Although mode of action in terms of mortality is not instant, they may inhibit food acceptance quite rapidly (Frankova *et al*., 2017).

The cumulative rodent population abundance indices in wheat crop in all growth stages were *B. bengalensis* (21%), *N. indica* (11.1%), *T. indica* (7.77%) and *G. ellioti* (2.22%) (Munawar *et al*., 2022). In wheat, an analysis between damage levels at different crop stages showed significant differences, the overall rodent damage was highest at maturity with 10.74% followed by flowering (6.4%) and tillering (3.5%) (Munawar *et al*., 2022).

Mostly, the limited bait consumption is a serious issue in many control campaigns against pest rodent species, worldwide. So, comparatively more preferred food baits are needed to attract rodent species in the area (Berry and Alleva, 2010). The bait may become more palatable by adding certain food additives in the plain bait in an optimum concentration, so that the target species consumes a lethal dose of the rodenticide.

A number of studies have shown the enhancement of the bait consumption by adding a variety of additives for different small rodent species, such as *Rattus norvegicus, Rattus rattus, Mus musculus* and *B. bengalensis* (Singla and Kanwar, 2014). Shafi *et al*. (1990) role of some taste additives to enhancer poison bait acceptance in the black rat, *Rattus rattus*. The literature reveals the use of cereals in whole-some, cracked form as well as mixed with additives such as vegetable oil, egg-shell, egg yolk, minced meat, sugar, spices and flavours (Pervez *et al*., 2003). In another study, feed preference of rodents was carried out for locally available and palatable food grains viz. millet (whole), wheat (cracked) and rice (broken) and taste additives namely whole egg (5%), egg-shell (5%), peanut cracked (5%) and yeast (2%) that were offered mixed in millet-wheat (50:50 body wt.) bait (Shahwar *et al*., 2024). In rice and wheat, coumatetralyl bait usage either inside the burrows or in bait stations is the two better delivery methods (Hussain *et al*., 2002).

The main aim of this study was to evaluate the preferred bait base and additives at each stage of wheat crop growth and its effectiveness by adding chronic poison.

MATERIALS AND METHODS

Study site

The study area was selected under wheat cultivation at National Agricultural Research Centre NARC, during the year 2024. The total area of NARC is about 600 ha (approximately 1500 acre). The geographical location of NARC is (longitude: 33.69 "N and latitude: 73.03'E). A variety of crops grown at NARC which includes different agronomical crops such as rice, sugarcane, wheat, maize fodder, pulses and horticultural crops such as orchards of citrus, grapes, and guava etc. Infestation of rodents at NARC campus has been reported for the last many years (Brooks *et al*., 1987; Shahid and Ahmed, 2013).

Survey and selection of treatment sites

A thorough survey of wheat field area was carried out to see level of rodent infestation. Treatment sites were selected after thorough survey of field area where sufficient number of active burrows system and fresh droppings were found. Six number of burrow systems were selected and each treated as a single replication. A minimum of 340 meters distance was maintained between each burrow system.

Design of experiment

The feeding test was carried out at three different stages of wheat crop i.e., initial, heading and maturity stage. At each stage screening of both bait bases and bait additives were carried out but poison baiting was carried out at maturity stage of the crop only.

Screening of bait bases in multi-choice feeding tests were carried out to identify the most preferred cereal grain as a bait base by taking average daily intake (ADI) with 06 replications. A total of 4 treatments were used and prepared in following ratios:

(i) Millet+Wheat 1:1; (ii) Millet+Rice 1:1; (iii) Millet+Maize 1:1 and (iv) Millet.

Screening of bait additives/enhancers was carried out by adding in the top ranked bait base in 4% proportion along with bait base alone (control) in multi-choice feeding tests with 06 replications. Peanut butter, cooking oil and egg shell in 4% proportion were incorporated as taste additives (bait enhancers). Candidate food consumption data were recorded by taking ADI for 6 consecutive days.

Evaluation of poison bait was carried out by adding developed bait at each stage and millet (control) with coumatetralyl (0.0375%).

Bait application methodology

Each candidate bait was presented in environmentally safe PVC bait stations measuring 30 cm long and 08 cm in diameter keeping both ends open for free accessibility of rats and to protect the bait consumption from non-target animals and other climatic factors. Bait stations were deliberately placed near active burrow openings of the bandicoot rat. In each test 100 g of each candidate food was offered each day in each bait station. Food consumption was recorded daily; taking spillage into account i.e., left over and spillage were calculated after 24 h interval and weighed to calculate ADI using electronic balance with accuracy to 0.1gram of each candidate bait.

Bait was replenished on daily basis and position of the bait stations was changed daily to avoid place preference trend. At least 5 days lag period was maintained between multi-choice feed preference test of bait bases and bait additives.

Statistical analysis

Descriptive statistics were performed to compute means and standard errors (±) of the data. Mean food consumption data was analysed by one way ANOVA with test foods as main factors. In order to assess the significant differences among means, least significant difference (LSD) test was applied. LSD test demonstrated the significant differences between the mean values of different treatments at 5% level of significance. Percentage preference values for different baits were calculated by dividing test food by total food consumption and then multiplying by 100.

RESULTS

Evaluation of cereals in multi-choice feeding test

To see the preference of different cereal grains and bait additives by bandicoot rat at different stages of wheat crop, experiments were carried out at NARC campus fields. Feed preference of cereal grains were carried out by offering these grains, simultaneously in a multi-choice food preference tests to identify most preferred bait base at initial, heading and maturity stage of wheat crop. Mean daily consumption and percentage preference of cereals at each stage is given in Table I.

Consumption of bait bases at initial stage revealed that combination of millet+wheat was most preferred (39.81%) followed by millet+maize (23.48%), millet (22.98%), and millet+rice (13.70%) (Table I). Analysis of variance revealed that there was significant difference in the consumption between different grain baits ($F= 7.70$, $P=0.001$).

Consumption of bait bases at heading/flowering stage showed more consumption of each cereal grain as compared to initial stage. But the most preferred grain bait was millet+rice (28.18%) which revealed a shift of bait preference at flowering stage. Bait consumption pattern of other cereal grains were millet+maize (24.96%), millet+wheat (23.6%), and millet (23.24%). Analysis of variance revealed that there was significant difference in the consumption between different grain baits ($F= 7.51$, $P=0.001$).

At maturity stage same pattern was observed as millet+rice was the most preferred grain bait i.e., 37.16%. Bait consumption pattern of other cereal grains were millet (32.58%), millet+maize (16.12%), and millet +wheat (14.12%). Analysis of variance revealed that there was significant difference in the consumption between different grain baits ($F= 38.54$, $P=0.00$). The analysis of daily consumption of all foods showed that *B. bengalensis* sampled each food daily; none of the food was totally rejected in spite of daily rotation of the foods.

Evaluation of additives in multi-choice feeding test

Taste of food plays a significant role in food preference trend. Bait shyness problems may be overcome by using attracting palatable bait. The most preferred combination of bait base of each stage was further evaluated with the addition of different additives at 4% concentration. Mean daily consumption and percentage preference of additives at each stage is given in Table II. It was observed that most preferred bait combination at initial stage was millet+wheat+peanut butter i.e., 31.53%. While bait consumption pattern of other baits were millet+wheat+cooking oil (24.46%), millet+wheat+egg-shell (21.89%) and millet+wheat (20.10%). Analysis of variance revealed that there was significant difference in the consumption between different bait additives (F= 4.28, P=0.017).

Table I. Mean daily consumption (g Mean ±SEM) and percentage preference of bait bases at different growth stages.

Bait bases offered			
Millet	**Millet+Wheat**	**Millet+Rice**	**Millet+Maize**
Crop growth stage: Initial			
38.00 ± 7.29 (22.98%)	65.83 ± 4.82 (39.81%)	22.67 ± 5.01 (13.70%)	38.83 ± 19.61 (23.48%)
Crop growth stage: Heading			
354.8 ± 9.71 (23.24%)	360.3 ± 9.27 (23.6%)	430.1 ± 14.81 (28.18%)	381.0 ± 15.04 (24.96%)
Crop growth stage: Maturity			
84.16 ± 4.49 (32.58%)	36.50 ± 8.98 (14.12%)	96.00 ± 5.88 (37.16%)	41.66± 4.95 (16.12%)

Consumption of bait was higher at heading/flowering stage same as cereal bait consumption. But the most preferred bait was millet+rice+peanut butter (28.70%) which showed peanut butter as the most preferred bait additive. Bait consumption pattern of other bait additives were millet+rice+cooking oil (25.79%), millet+rice (23.45%), and millet+rice+egg-shell (22.04%). Analysis of variance revealed that there was significant difference in the consumption between different bait additives (F= 2.84, P=0.064).

Consumption of bait additives at maturity stage revealed that combination of millet+rice+peanut butter was mostly consumed i.e 70.40% followed by millet+rice+cooking oil (17.31%), millet+rice+egg-shell (6.26%), and millet+rice (6.0%). Analysis of variance revealed that there was significant difference in the consumption between different grain baits (F= 12.12, P=0.00).

Evaluation of preferred bait along with poison at maturity stage

The bait base combination along with 3 types of additives were evaluated at each stage and the most preferred bait of each stage was further evaluated for the control of bandicoot rat using chronic poison, coumatetralyl (0.0375%). Results of the offered baits on daily basis for a span of 6 days revealed that highly significant preference was given to millet+rice+peanut butter+ racumin (63.87%) (Table III). Mean daily consumption and percentage preference of preferred bait along with poison at maturity is given in Table III.

The consumption rate tended to be decreased abruptly and little or no bait consumption was recorded on 5th day. Bait consumption pattern of other baits were 26.56% for millet+wheat+peanut butter+racumin and 9.56% for millet+racumin. The values of analysis of variance were (F=4.046, P=0.039).

Table II. Mean daily consumption (g) and preference (%) of bait base with additives at different growth stages of wheat crop.

Bait additives offered			
Millet+Wheat	**Millet+Wheat +Peanut butter**	**Millet+Wheat+ Eggshell**	**Millet+Wheat+ Cooking oil**
Crop growth stage: Initial			
85.83 ± 7.44 (20.10%)	134.7 ± 10.58 (31.53%)	93.50 ± 7.62 (21.89%)	113.0 ± 14.81 (24.46%)
Crop growth stage: Heading			
235.8±19.42 (23.45%)	288.7 ± 15.02 (28.70%)	221.7 ± 14.19 (22.04%)	259.3 ± 20.14 (25.79%)
Crop growth stage: Maturity			
11.50 ± 4.75 (6.00%)	134.8 ± 29.19 (70.40%)	12.00 ± 2.54 (6.26%)	33.16 ± 16.13 (17.31)

Table III. Mean daily consumption and percentage preference of preferred bait along with poison at maturity stage of wheat crop.

Bait bases offered	Mean consumption (g)
Millet+Racumin	13.50 ± 5.45 (9.56%)
Millet+Rice+Peanut Butter+Racumin	90.16 ± 27.17 (63.87%)
Millet+Wheat+Peanut Butter+Racumin	37.50 ± 19.28 (26.56%)

DISCUSSION

Rodent populations fluctuate with different crop seasons and growth stages in the agricultural systems. They are known to damaging seedlings and mature crops (Sarwar, 2015). Crop stage is an important factor influencing damage levels. In the present study, the highest damage was observed during maturity stages in wheat fields. Similar findings were observed by Miller *et al*. (2008), for *Rattus tanezumi* in the rice terraces of Banaue, in northern Luzon, Philippines. Research trials in the present study were conducted at three different growth stages of wheat crop to evaluate the preferred bait base at each stage. Munawar et al. (2020), collected data from a wheat crop at three different growth stages to determine the mean intake of the formulated bait.

Experimental findings of the present study proposed that mean per day consumption of millet+wheat (as a bait base) and millet+wheat+peanut butter (as additive bait) was recorded to be highly preferred at initial stage of wheat crop. Bandicoot rat might be attracted to wheat initially due to the distinctive aroma from the wheat field. This natural scent could serve as a strong attractant, influencing the feeding behaviour of the rats during this critical crop growth stage. At other growth stages i.e., flowering and maturity stage, the bait base preference was shifted to the combination of millet+rice. In another study of Naeem *et al*. (2011), same grains were evaluated under captivity which revealed the highest consumption of millet (2.67±0.40), followed by maize (1.75±0.39), rice (1.12±0.33), and wheat (0.65±0.18), respectively.

Taste of food plays a significant role in food consumption. Bait shyness problems may be overcome by using attracting palatable bait. Several studies have been conducted to enhance existing rodent control strategies, aiming to improve their effectiveness by incorporating various locally available palatable foods or bait additives (Pervez et al., 2005; Naeem *et al*., 2011). In this experiment peanut butter, cooking oil and egg shell in 4% proportion were incorporated as taste additives (bait enhancers). Peanut butter in 4% concentration significantly enhanced the consumption of bait at each stage of crop. Another study of Munawar et al. (2020), confirmed that mixing egg shells and peanut butter with zinc phosphide and brodifacoum improved bait acceptance, and there was minimal bait shyness for rodent control. The variation observed could be attributed to differences in the base materials used in the bait. From previous and present studies it can be assumed that use of peanut oil at 4% concentration may enhance bait intake as compared to using egg shell, cooking oil or plain bait.

Poison baiting was not carried out during the initial and flowering stages of the wheat crop to prevent a significant reduction in the bandicoot rat population at the established baiting points. Since the study required consistent rodent activity across all crop stages, early poison baiting could have compromised the continuity of data collection. To ensure reliability and comparability, all baiting trials were conducted at the same pre-established points throughout the wheat crop.

According to Hussain *et al*. (2003), there was a 92% reduction in live burrow activity with the use of zinc phosphide (2%), and a similar reduction of 92.2% was observed with coumatetralyl (0.0375%). These results support the current study in which we observed gradual decrease in consumption rate and no bait consumption was recorded on 5th day. The analyses of daily consumption of all foods showed that *B. bengalensis* sampled each food daily; none of the food was totally rejected in spite of daily rotation of the bait stations under test.

CONCLUSION

It can be concluded from current study that millet ± wheat in (50:50) ratio and peanut butter in (4%) concentration as an additive found most effective for poison baiting at initial stage of wheat crop while millet ± rice in (50:50) and peanut butter in (4%) concentration and racumin (0.0375%) are an effective combination for controlling field rats at maturity stage of wheat crop. Rodent control strategies should be adapted based on the growth stage of the wheat crop, with bait base preferences shifting from millet and wheat to millet and rice as the crop matures. Further studies should be performed to evaluate different bait base combinations and other bait additives/ enhancers at different plant growth stages across a variety of crops, including wheat, rice, maize, groundnut, pulses, and horticultural crops.

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Ethical statement

The authors comply with all the laws and regulations that apply to science and profession during the period of studies.

Generative AI and AI-assisted technology statement

The authors have declared that no generative AI or AI-assisted technologies were used to create this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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