

Effectiveness of Warfarin for Controlling the Lesser Bandicoot Rat (*Bandicota bengalensis*) in Field Crops of Pothwar Plateau, Pakistan

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Abstract: The efficacy of a 0.025% warfarin formulation against the lesser bandicoot rat (*Bandicota bengalensis*) was evaluated in groundnut and wheat crops in district Chakwal of the Pothwar Plateau, Pakistan. The baiting was started at early flowering stages of the respective crops using a broken rice formula (with additives) by placing bait stations near active burrow systems over a three weeks period in wheat and a two weeks period in groundnut crop. Bait consumption was monitored three-times per week and the bait was replenished at each visit. The efficacy of the treatment was assessed using three separate and independent census methods: i) monitoring bait consumption, ii) tracking activities, iii) burrow activities. After the three week treatment period in wheat crop, the mean reductions were: bait consumption, 99.3%; tracking activities, 96%; burrow activities, 82.3%. The reductions in these three parameters after two weeks treatment in groundnut crop were 86.6%, 74.4% and 85.4%, respectively. Results are discussed in relation to stage of the crop, availability of alternate food, migration, and other ecological and behavioural factors.

Keywords: *Bandicota bengalensis*, warfarin, rodent control, wheat, groundnut, crops

INTRODUCTION

The Pothwar (uneven) Plateau, situated between latitudes 32°33' and 34°3' N and longitudes 71°89' and 73°37' E, covers a total area of 1.82 million ha, of which only 0.61 million ha are cultivated (Punjab Barani Commission Report, 1976). Dry farming is the dominant land use. Wheat is a major winter crop (November-May) with inter-cropping of grams, lentils and mustards. Groundnut or peanut together with millets form two important crops of the summer (May-October) season (Beg *et al.*, 1985; Ahmad, 1990). The climate in the plateau is semi-arid warm to hot with subtropical winter and monsoon.

The Plateau provides habitat to five rodent species; the Indian gerbil (*Tatera indica*), the lesser bandicoot rat (*Bandicota bengalensis*), *Mus* species, the short-tailed mole rat (*Nesokia indica*), and the bush rat (*Golunda ellioti*) (Hussain *et al.*, 2002, 2003). However, Brooks *et al.* (1988) could record only the presence of the bandicoot rat, the short-

tailed mole rat and the Indian gerbil in groundnut crop. Both wheat and groundnut crops are highly vulnerable to rodent attack at mature stages. In groundnut the damage starts at the stage of peg formation or when the nuts are immature or milky and in wheat at the stage of panicle formation. The majority of farmers (77%) realise that vertebrate pests (rodents mainly) are a problem while 44% consider them a factor restricting the increase of groundnut production (Ahmad, 1991). Brooks *et al.* (1988) estimated a 3.4% loss of the groundnut crop in this area due to rodent pests. Khan *et al.* (1992) recorded an increase of 61.7% yield of groundnut production following control of the field rat. A survey carried out in 1978-79 revealed up to 10% rodent damage to standing wheat crop in the Pothwar area (Fulk *et al.*, 1980b).

A number of rodenticides (including acute and, single and multiple dose anticoagulants) are registered in Pakistan, and are being marketed under different formulations and trade names. The use of anticoagulant rodenticides is considered highly effective and safe due to their delayed mode of action and the availability of a perfect antidote, vitamin K₁. The delayed action prevents the association of cause (the rodenticide) and effect

(symptoms of toxicity), and as a result conditioned bait aversion (or bait shyness – a factor usually associated with acute rodenticides) does not occur. The present study was conducted to investigate the field efficacy of a first generation anticoagulant, warfarin, against the lesser bandicoot rat infesting groundnut and wheat crops in Pothwar Plateau of Pakistan.

MATERIALS AND METHODS

Study site and design

The study was carried out in crop fields near village Dhudial, district Chakwal of Pothwar Plateau. The groundnut and wheat crop fields were selected at the early flowering stages. This is the time when rats move into the crops (Hussain *et al.*, 2003) and farmers apply any control measure. During site selection, emphasis was given to the level of rodent infestation, growth stage of the crop and easy logistic approach. It was also kept in view that no anticoagulant had been used in the area for at least previous two years.

Three experimental fields of groundnut crop, each having a size of about one hectare, were selected while for wheat crop, eight fields were selected. The wheat fields varied in size, approximately between 0.2 -1.0 hectare. In both the crops, a distance between any two nearest fields was not less than 100 meters to avoid migration effect (Fulk *et al.*, 1980a). Each plot was considered as a replicate unit for the respective experiment/treatment.

Bait composition

The bait was prepared from a technical grade (99.9% pure) of warfarin (Bell Laboratories, Inc. Madison, WI 53404 USA). The bait was composed of warfarin (0.025%), broken rice grains (92%), dry milk powder (2.5%), fish meal (2.5%), vegetable (sunflower) oil (3%) and pink food colour. First, a master mix (0.5%) was prepared by adding the active ingredient in dry powdered milk and finely ground fish meal (50:50 ratios). The bait was prepared from this master mix in an electric mixer. Broken rice grains were first coated with the vegetable oil by using half the quantity of oil. Then the master mix was added and mixed thoroughly. Finally the second half of the oil was added and the

machine was run for 15 minutes to mix the bait thoroughly. During mixing a pink dye was added as a warning colour.

Bait application and evaluation

The bait was presented in earthen bowls of 6.5 cm radius and of 2.5 cm depth placed underneath a tin sheet cover (bait station) keeping both ends open for free accessibility to the rodents and to protect from non-target animals and climatic factors. Bait stations were placed near 2-3 active burrow openings (of the bandicoot rat) with more than one bait station placed near large burrow systems (Poché *et al.*, 1980, 1986). Initially 150 g bait was placed in each bowl. After the bait was laid, it was inspected and weighed on the 2nd, 4th, 7th, 9th, etc., days. These were Mondays, Wednesdays, and Saturdays following the Saturday on which the bait was first laid (Drummond and Rennison, 1973). During each visit, the bait in each bowl was weighed to the nearest 1g using a spring balance. If all the bait was eaten, the quantity of replenished bait was increased to provide a surplus. Damp or soiled bait was replaced at each visit. A bait station was scored as positive if rodent activity signs were found on the bait bowl or if at least 1g of bait had been eaten. At each visit, the untouched bait bowls were used as reference for that particular day to monitor any change in weight of the bait due to climatic factors like rain and humidity. This measured factor was added or subtracted when calculating the actual bait consumption from each bowl. The baiting was carried out for two weeks in groundnut and for three weeks in the wheat crop.

Pre- and post-treatment censuses were taken using vinyl tiles (15 x 15 cm) as tracking boards. The pre-treatment rodent activity was recorded before the placement of bait stations in the field and the post-treatment activity was taken after removal of the bait stations. Half of each tile was painted with duplicating ink and other half was left blank. The tracking tiles were positioned in the evening and recovered the following morning for three consecutive nights. The tiles were placed in parallel rows along the length of the field with a distance of 10-15 m from each other. The distance between the rows was also kept at 10-15 m. The row of the tiles placed along the boundary of the field was

approximately 2 m inside the field dike. Each tile was checked for rodent tracks and was scored as either positive or negative. The positive tiles were rated according to four classifications: 0= 0 mark; 1= 1 to 25% covered; 2= 26-95% covered and 3= 96-100% covered with tracks (Quy *et al.*, 1993).

A relative population measure was also made by quantifying active burrow systems. The burrow systems were counted from each field before the start of treatment and again following treatment. Before counting, all the burrows were plugged with earth and the following morning only fresh openings were counted. This reduced the chance of counting any dead or inactive burrows.

RESULTS

At the time of warfarin treatment, in both the groundnut and wheat crops, the bandicoot rat was found as a dominant species. The populations of other species, the Indian gerbil, the *Mus* spp. and the short-tailed mole rat, if present, were restricted on the field boundaries. Furthermore, the bait stations were deliberately placed near active burrow openings of the bandicoot rat. The presence of the bandicoot rat was confirmed from the rodent tracks on tracking tiles, burrow systems and dead animals. From all the experimental fields only carcasses of bandicoot rats were found.

Groundnut crop

In groundnut crop the consumption of the bait decreased gradually and in a similar pattern the ratio of positive bait points (*i.e.* the number of points showing take by rats at each visit divided by the number that showed a take on the day of peak intake) decreased (Fig. 1). Thus number of points from which bait was eaten during each visit was highly correlated with the quantity of bait eaten ($r = 0.94$; $F = 48.63$; $DF = 5$; $P < 0.001$). At the end of the trials, on day 16, an 86.6% reduction in bait intake had been achieved while the proportion of the positive bait points was reduced by 68.1%. The percent reduction in rodent activity estimated by counts of active burrow systems was 85.4% and by tracking tiles was 74.4% (Table I).

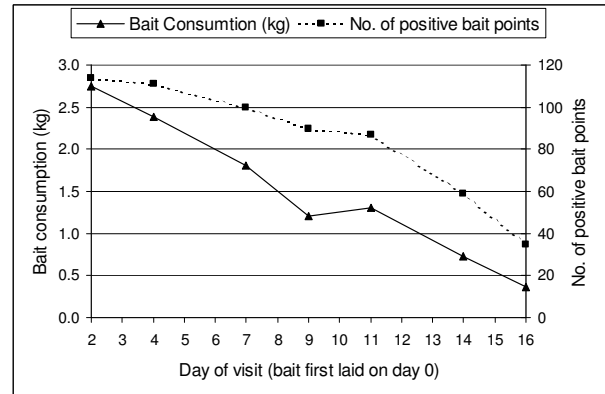


Fig. 1. Warfarin (0.025%) bait intake by the lesser bandicoot rat (*Bandidota bengalensis*) in groundnut crop on Pothwar Plateau, Pakistan.

Wheat crop

The consumption pattern of warfarin (0.025%) bait in wheat crops is shown in Figure 2. The number of points with bait taken was positively correlated with the quantity of bait consumed ($r = 0.89$; $F = 34.29$; $DF = 9$; $P < 0.001$). The peak "take" occurred on day 7, both in terms of the frequency of 'positive' bait stations and the total amount of bait taken. The cumulative results from all the fields between day 2 and day 7 showed an increase in bait take from 4.1 to 4.8 kg (16.4%), and an increase in 'positive' bait stations from 110 to 116 (5.5%). There was a decrease in both parameters (with some fluctuations) towards the end of the treatment. From the day of peak intake (day 7), bait consumption decreased by 99.3% while the number of 'positive' bait stations decreased by 94.8%. In 50% of the fields, both the parameters were reduced by 100%. Furthermore, assessments of tracking counts and burrowing activity indicated reductions of 96% and 82% over the course of the whole treatment (Table II).

DISCUSSION

The presence of the bandicoot rat at the maturity stages of wheat and groundnut crops is supported by some earlier studies on the Pothwar Plateau (Fulk *et al.*, 1980b; Brooks *et al.*, 1988; Hussain *et al.*, 2002, 2003). The selection of bait materials used in the present was based on earlier published information. Rice has been reported

Table I.- Change in test parameters considered to reflect the reduction (%) in activity of the lesser bandicoot rat (*Bandicota bengalensis*) after two weeks treatment using warfarin (0.025%) bait in groundnut crop on Pothwar Plateau, Pakistan.

Field No.	Field size (ha)	Reduction (%) in rodent activity as measured by			
		Bait consumption	No. of positive bait points	Tracking activity counts	Burrow system activity
1	1	84.6	67.6	66.7	83.7
2	1	81.4	64.9	75.0	86.7
3	1	89.8	74.4	78.1	85.7
All Fields		86.6	69.3	74.4	85.4

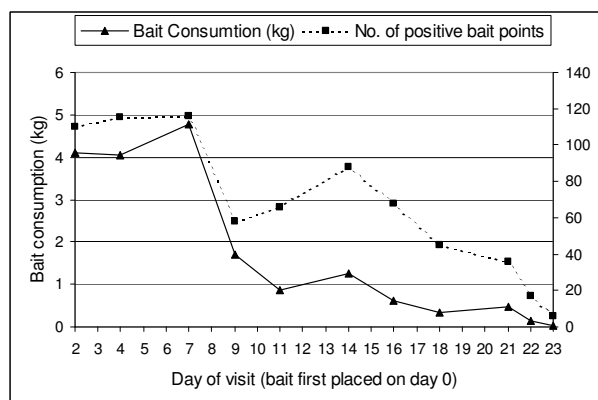


Fig. 2. Warfarin (0.025%) bait intake by the lesser bandicoot rat (*Bandicota bengalensis*) in wheat crop on Pothwar Plateau, Pakistan

among the favourite foods of the bandicoot rat both under captivity and in field conditions (Kamal and Khan, 1977; Karim, 1994; Bhaduarua and Mathur, 1993; Jalihal *et al.*, 1980). This rat has been reported to feed on insects, birds, young rats and mice (Lathiya, 1978; Frantz, 1977; Chakraborty, 1977). Shafi *et al.* (1993) observed that minced meat (2%) increased the palatability for the bandicoot rat to 72.7% over the plain bait. Similarly vegetable oil improved palatability of the baits for the bandicoot rat when tested in the laboratory and under field conditions (Marsh, 1988; Ahmad and Parshad, 1985). A diet, containing 10% fishmeal (after Brooks *et al.*, 1980); 5% dried milk and 3% vegetable oil, as used in laboratory studies on bandicoot rats (Hussain and Prescott, 2002) has proved a successful feed for maintaining the rats.

Although there was large variations between

the fields but an overall estimate showed that bait uptake and the ratio of positive points attained their maximum after 7 days of treatment in the wheat crop but on day 2 in the groundnut crop. The following decline was not as steep as observed in the case of the Norway rat (Drummond and Rennison, 1973). Quy *et al.* (1992) suggested that the time taken to reach the maximum number of bait takes is dependent upon two processes; bait take frequency is increased both by additional rats finding and feeding on bait and by rats that have already eaten bait returning with increasing frequency to the bait points. Neophobia (new object reaction) toward unfamiliar bait and bait station can also cause delay for starting on a new food (Inglis *et al.*, 1996).

The method of Drummond and Rennison (1973) reflects the success of the treatment in terms of bait consumption which measures the changes in the size of the population that is willing to consume the baits. Complete cessation of feeding does not necessarily indicate complete kill of the rat infestation and a careful inspection is required by examining other signs of rodent activity (Rennison, 1977). It has been suggested that additional activity monitoring methods should be used to measure the success of a treatment (Spaulding and Jackson, 1983; Quy *et al.*, 1992; Cowan and Townsend, 1994). Although, the bait consumption data in wheat crop indicated 96-100% control in all the fields, the observation on burrowing activity revealed that control success was not more than 82.3% with a large variation among the fields (42.9-90.9%). However, in groundnut crop both of these parameters were found in support of each other.

Table II.- Change in test parameters considered to reflect the reduction (%) in activity of the lesser bandicoot rat (*Bandicota bengalensis*) after three weeks treatment using warfarin (0.025%) bait in wheat crop of Pothwar Plateau, Pakistan.

Field No.	Field size (ha)	Reduction (%) in rodent activity as measured by			
		Bait consumption	No. of positive bait points	Tracking activity counts	Burrow system activity
1	1.0	100	100	100	90.9
2	0.5	96.5	91.7	91.8	87.5
3	0.5	100	100	94.5	81.8
4	0.5	100	100	93.8	90.0
5	0.4	98.0	83.3	80.2	60.0
6	0.2	97.2	70.0	100	42.8
7	0.4	100	100	88.5	81.8
8	0.6	99.5	93.3	100	81.8
All fields		99.3	94.8	96.0	82.3

The use of "signs" (burrows, runways, faecal pellets, gnawing) is a long established technique for obtaining a relative measure of rodent abundance or population size. The numbers of active burrows before and after bait placement has been used to provide relative population measures in agricultural areas by Prakash *et al.* (1971), Durairaj and Guruprasad (1977) and Mathur and Prakash (1984). However, Rao (1980) claimed that the number of live burrows cannot be taken as a reliable estimate of bandicoot populations, since the mean number of bandicoot rats per burrow varies, especially during the breeding months. In the present study, although dead rats were seen outside some burrow openings within 10 days from start of baiting, these burrows remained active for quite a long time which may favour the observation of more than one animal living in each burrow system. This is particularly likely as the treatment period coincided with their peak breeding activity. Another possibility is the rapid invasion of burrow systems by survivor rats from the same population or from peripheral populations due to the void created by poisoning.

The tracking activity index method is an indirect census method that measures the changes in levels of rodent activity (Kaukeinen, 1979, 1984) and thus produces indices of rat activity (Taylor *et al.*, 1981). Reductions in such indices may not necessarily reflect the size of the population except where they are close to 0% or 100%. Factors likely to produce errors in this method include adverse

weather conditions that may reduce rodent activity and changes in the behaviour (e.g. home range) of surviving rats following control measures (Quy *et al.*, 1993; Cowan and Townsend, 1994).

The application of tracking activity index and burrow system counts methods provided a better understanding of the treatment and did not agree (in all cases) with the output of Drummond and Rennison (1973) method. The difference can be related to behaviour of rodents toward rodenticide baits or other possible factors as given in the following paragraphs.

i) The bandicoot rat was studied in a wild habitat and 'new object reaction' (neophobia or effect of novelty) behaviour toward the unfamiliar baits or bait stations might have some effect on lag time for switching their feeding to the bait (Barnett, 1975; Brunton *et al.*, 1993; Inglis *et al.*, 1996).

ii) With the passage of time the crop grew mature and good quality grain food was available in the field to the rats. Hence the food supply for the rats was abundant, easily accessible and continuous. Apart from curiosity, there was little incentive for rats to eat from the bait points. This would have affected the feeding so the animals have taken longer time to consume a lethal dose, thus resulting in the prolongation of the treatment period. Parshad *et al.* (1985) suggested that the tillering stage of the crop appears to be suitable for rodent control in wheat. At the milky grain stage, they achieved only

46% success in controlling field rats in wheat crop with bait containing 0.005% brodifacoum. However this success increased to 78.5% when the same bait was used at maturity stage. Ahmad and Parshad (1989) also reported 64-67% control success with bromadiolone (0.005%) in wheat crop at maturity stage.

iii) The bandicoot rats start eating the vegetative parts (green matter) of wheat plants from the tillering stage (November) and it becomes a significant part of the diet in January (41.5%) and goes up to 71% in March after that time the wheat grain become the sole diet of the animal (Hussain *et al.*, 1994). Green plants are apparently one of the richest natural sources of vitamin K₁ (Sebrell and Harris, 1954) and this may have an antidotal action against the anticoagulant (Lowenthal and Rivera, 1979; MacNicoll and Gill, 1993). It can be assumed that when a rat starts feeding on anticoagulant bait, the corresponding green matter intake will decrease which would reduce the chances of a vitamin K₁ antidotal action. However, the feeding under field conditions is a variable parameter dependent on a number of behavioural and ecological factors such as available quality and quantity of alternate food, inconsistent feeding on bait and 'stop-feed' effect due to the appearance of poison symptoms (Hussain, 1998). Under these situations, the environmental level of vitamin K₁ available to the rats could help to undermine the effect of anticoagulants, especially the less toxic multi-feed anticoagulants like warfarin.

iv) The maturity periods of the crops coincide with the peaks in breeding activities of the bandicoot rat (Hussain *et al.*, 1994). Continuous recruitment in the population from in- and outside of the treated area is a possible factor.

v) One individual *B. bengalensis* was able to survive a warfarin dose of 79.1 mg kg⁻¹ (Hussain and Prescott, 2002). There is a high likelihood that such individuals would survive a warfarin treatment, and that this would result in the selection of the resistance phenotype within the population.

vi) In laboratory feeding tests the prolonged feeding on warfarin bait produced a cessation of eating in some individual bandicoot rats (Hussain, 1998). Where such animals consumed a sub-lethal dose, they recovered and then resumed feeding.

Such a strategy could enable rats to survive an anticoagulant treatment.

vii) Beside all these possibilities, attainment of peak intake or prolonged feeding on the anticoagulant bait may also be attributed to rodent immigration into the fields. In the area under present study, the sizes of crop fields are very small (0.1-1.0 ha) due to special topography and small (1.9-9.8 ha) land holding (Ahmad, 1990). The crops in the area are not consistent by space and age. So different fields had different maturity stages and some fields adjacent to cultivation were occupied by barren/ grazing lands. Furthermore, the cultivated fields have thick and undisturbed boundaries to avoid land erosion. This type of mixed habitat among the cultivated fields provides ideal conditions for the rodents to maintain their population during non-cropping seasons (Hussain *et al.*, 2002). The populations are mainly attracted to the crop fields only when good shelter and food are available. Poché *et al.* (1980, 1986) observed migration of rodents in the field as the wheat crop matures. In such a type of habitat, the size of the treated field has also considerable effect on the success of the control. Ahmad and Parshad (1989) have reported that single bromadiolone baiting in wheat fields resulted in 52.49% control success in area of 2.3 ha, 90.65% in 8 ha and 95.39% in 36 ha. It may be suggested that to produce scientifically sound information from such a type of habitat a large area should be treated surrounding the test treatment crop fields to avoid the pronounced effect of immigration.

CONCLUSIONS

The bait containing 0.025% warfarin proved successful, at more than 80%, in controlling rodent infestation in the field crops of the study area. The method of Drummond and Rennison (1973) was applied for the first time against the bandicoot rats, a rodent species other than the one it was established for. Employing of additional methods (burrow system counts and tracking activity) for the evaluation of control success further helped to understand the factors which are operating under field situation. The success of the treatments evaluated by the three independent methods

revealed that the bait consumption parameter is not sufficient to estimate the surviving population if the rats are not willing to eat the bait due to some behavioural or ecological factors.

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