Critical timings and methods of rodent pest management in groundnut (*Arachis hypogaea* L.) crop

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**ABSTRACT**

The field efficacy of 2% zinc phosphide and 0.005% bromadiolone baits at two different crop stages for reducing rodent damage and yield loss in groundnut crop was evaluated. Trials were conducted at farmer’s fields at villages Powat and Sehjomajra of district Ludhiana and village Kalsian of district Sangrur in Punjab (India). Reduction in rodent activity and damage was compared when given single treatment in the month of September at pod maturity stage (using either zinc phosphide or bromadiolone) and when given two treatments, first in the month of August (using zinc phosphide) at pod formation stage and second in the month of September (using bromadiolone). Results revealed significantly (*P* ≥ 0.05) higher reduction in rodent activity with two rodenticide treatments (79.98-92.18%) than single treatment (54.37-67.82%). The reduction in rodent damage compared to untreated reference fields was found to be 87-100% in fields given two treatments and 44.43-87.54% in fields given single treatment.

**Key words:** *Arachis hypogaea*, Bromadiolone, Management, Rodents, Zinc phosphide.

**INTRODUCTION**

The groundnut, or peanut (*Arachis hypogaea* L.), is a species in the legume family Fabaceae. Groundnut is one of the vastly produced oilseed crops cultivated in more than 100 countries including China, India, USA, Nigeria, Indonesia, Mayanmar, Malaysia, Sudan, Senegal, Argentina, UK and Vietnam. Maximum production of groundnut is found in China (32.95%) followed by India (18%) and USA (6.8%) (Pound and Phiri, 2010).

Groundnut is particularly vulnerable to rodent attack being the rich source of proteins (Parshad, 1999). Groundnut is sown in last week of June or first week of July and is harvested in October with an average maturing period of 120 days. Rodent damage to groundnut may begin as early as mid-July (seedling stage) and continues until harvest (Brooks et al., 1988). In India, rodent losses to groundnut crop range from 4 to 26% (Prakash and Mathur, 1988). During the rodent outbreak in 1976 (Shah, 1979) and 1988–89 (Mittal et al., 1991; Mittal and Vyas, 1992) in Gujarat, rodents damaged up to 85% of the crop in some parts. Bindra and Sagar (1971) estimated average loss of 50 kg/ha (range 30-76 kg/ha) of groundnut yield due to field rats in Punjab, India. Rodents may damage the whole or the branches of the plant during burrowing. Parshad *et al.* (1987) calculated a total yield loss of 3.86% due to complete and/or partial damage to plants through cutting and hoarding of pods by rodents in Punjab. Loss due to hoarding of groundnuts by field rats has been reported from central India (Srivastava, 1970) and Japan (Yabe, 1981).

Rodents were also found causing severe damage to groundnuts in Pakistan, Philippines, Sudan and China (Ishaq *et al.*, 1980; Ali and Iqbal, 1984; Ali *et al.*, 1984; Baltonado and Bongolan, 1985; Islam, 1987; Brooks *et al.*, 1988; Zhang *et al.*, 1998). In Pakistan, Islam (1987) reported 17% reduction in groundnut yield due to vertebrate pests. Brooks *et al.* (1988) estimated 3.4% loss of the groundnut crop due to vertebrate pests (rodents, porcupines and wild pigs) which equaled to an average yield loss of 43 kg/ha. In China, an enclosure study of groundnut damage by the rat-like hamster, *Cricetulus triton*, has revealed 14.8-19.6% damage (Zhang *et al.*, 1998).

Timings of rat control efforts are very important so as to get good control at a reasonable cost. Controlling rats before the reproductive stage of the crop i.e. before peg formation brings substantial increase in yield (Hussain *et al.*, 1991). This growth stage was the expected time for movement of rodents into the crop fields, and this is the time when rodent control measures should be initiated (Hussain *et al.*, 2003).
This study is aimed to generate data on determination of critical timings and methods of rodent pest management in groundnut crop fields and evaluate the field efficacy of cereal based formulations of two rodenticides for reducing damage caused by rodents to groundnut crop.

MATERIALS AND METHODS
The acute rodenticide, zinc phosphide (80% technical grade powder, Excel Crop Care Ltd, Mumbai, India) and chronic anticoagulant rodenticide, bromadiolone (0.25% technical grade powder, Pest Control of India) were evaluated. Freshly prepared baits containing 2% zinc phosphide and 0.005% bromadiolone, formulated on dry and cracked grains of wheat smeared with 2% groundnut oil and 2% powdered sugar were applied. Trials on determination of critical timings and methods of rodent pest management in groundnut crop were conducted at farmers’ fields in the major groundnut growing areas i.e. at villages Powat and Sehjomajra (situated in same block) of district Ludhiana and village Kalsian of district Sangrur in Punjab (India). At each location, two plots of groundnut crop each having three replicated fields of about 0.4 ha area were selected at random. In fields of plot I at all the three locations, double treatment was conducted by applying 2% zinc phosphide in the month of August (at pod formation stage) and 0.005% bromadiolone in the month of September (at pod maturity stage). In fields of plot II, single treatment of 2% zinc phosphide was conducted at villages Powat and Kalsian and single treatment of 0.005% bromadiolone was conducted at village Sehjomajra in the month of September. No treatment was conducted in the month of August in plot II. Both the poison baits were applied @ 1kg/ha each by placing 10g of bait on pieces of paper arranged in a grid with line to line and point to point distances of 10m (Ahmad and Parshad, 1989). A separate plot III, each having three replicated fields of about 0.4 ha area was kept as untreated reference plot near the village Kalsian and the villages Powat and Sehjomajra, where no treatment was conducted. The minimum distance among different treated and untreated plots at each location varied from 300-400m. Both zinc phosphide and bromadiolone baits were exposed to rodents for 3 days, after which the residues were collected and buried deep in the soil to avoid non-target toxicity. Bait piles were also concealed under groundnut plants to prevent consumption by non-target animals. Rodent fauna infesting the selected fields were determined on the basis of characteristic burrow entrances. The efficacy of rodenticide treatments was evaluated by determining reduction in rodent activity and per cent pods damaged in treated fields compared to untreated reference fields where no control measures were taken either by the farmers. Reduction in rodent activity was determined by recording pre- and post-treatment census bait consumptions assessed over 2 days from all the treated and untreated fields. Per cent reduction in rodent activity in treated fields was calculated by employing the formula given below and described by Singla and Parshad (2010).

$$1 - \frac{t_2 \times r_1}{t_1 \times r_2} \times 100$$

Where, $t_1$ and $r_1$ are the pre-treatment bait consumptions in treated and reference fields, respectively and $t_2$ and $r_2$ are the post-treatment bait consumptions in treated and reference fields, respectively.

Rodent damage in the form of per cent pods damaged was recorded in all the treated and untreated fields. As the damage inflicted by rodents occurs unevenly (Lefebvre et al., 1978), 10 sites were sampled in each field, covering its centre as well as the four geographical sides. At each site, 2 x 2 m quadrats were placed. Five plants were uprooted from each quadrat randomly to count the total number of pods and the pods damaged by rodents (those with signs of rodent gnawing) per plant. Average number of pods damaged per plant and average density of plants/4m² were determined for each field. Percent pods damaged were calculated using the formula given below:

$$\frac{\text{Damaged pods}}{\text{Total pods}} \times 100$$

Average yield (g) per pod was determined by weighing pods of ten plants from each location. Yield loss (g/4m²) was calculated by multiply average yield per pod with number of pods damaged per plant and the average number of plants/4m² which was then extrapolated to calculate yield loss in q/ha. Yield loss saved (q/ha) by treatment was calculated by subtracting the yield loss in treated fields from that in untreated reference fields.

The net monetary benefit which can be gained with rodenticide treatments was also computed. Benefit (Rs/ha) was calculated by multiplying the yield loss of groundnut saved (q/ha) by treatment with the prevailing market price (Rs/q) of groundnut. The cost (Rs/ha) was calculated by adding the cost of rodenticides for application at 1 kg/ha, bait material and labour involved per baiting per hectare. Accordingly, the cost of one baiting of 2% zinc phosphide came out to be Rs 50.00/ha and cost of one baiting of 0.005% bromadiolone came out to be Rs 68.00/ha.

The significance of differences among mean values of different parameters under different treatments was...
determined using one-way analysis of variance and student’s t-test. The data in percentages was transformed using square root transformation before analysis.

RESULTS AND DISCUSSION

The Indian gerbil, Tatera indica Hardwicke was found to be the predominant rodent species in the fields selected for experiment at all the locations followed by the lesser bandicoot rat, Bandicota bengalensis Gray and Hardwicke; the field mouse, Mus booduga Gray and soft furred field rat, Mammalia meltada Gray. Butani et al. (2006) found B. bengalensis as the predominant rodent species attacking groundnut. They also found M. meltada, T. indica and M. booduga damaging standing crops of groundnut. Khan et al. (2012) found B. bengalensis, Nesokia indica Gray and T. indica to be associated with groundnut crop in Pakistan.

The consumption of 2% zinc phosphide and 0.005% bromadiolone baits at different locations ranged from 56.08-89.92 and 44.30-88.83 g/100g bait, respectively (Table 1) indicating no significant difference in acceptability of two kinds of baits by field rodents. There was higher consumption of rodenticide bait indicating higher rodent population in fields given single treatment in the month of September. The reduction in rodent activity in fields given two treatments was found to be significantly (P<0.05) more than in fields given single treatment at all the three locations (Table 1).

The reduction in rodent activity ranged from 79.98-92.18% in fields given two treatments and 54.38-65.93% in fields given single treatment (Table 1) indicating higher efficacy of two treatments. Treatment at pod formation stage in the month of August may thus be helpful in checking spurt in rodent population at pod maturity stage.

Also there was no significant difference in per cent reduction in rodent activity whether single treatment was given with zinc phosphide or bromadiolone in fields of plot II. Kocher and Kaur (2008) also reported no significant difference in rodent control success between groundnut fields given single treatment of zinc phosphide and bromadiolone. Authors also reported no significant difference in rodent control success between groundnut fields given double treatment of zinc phosphide followed by bromadiolone or vice-versa. Parshad et al. (1987) obtained 58% reduction in rodent activity with single treatment of 2% zinc phosphide at 80 to 90 days after planting in both irrigated and non-irrigated groundnut crop. Significantly higher rodent control was obtained with two treatments than with single treatment of any rodenticide. They suggested two applications at 10 days interval of either 0.005% broadifacoum or bromadiolone between 80-100 days after planting in groundnut fields. Brooks et al. (1988) were able to eliminate rodents from experimental groundnut plots by first treatment with 2% zinc phosphide bait blocks followed by second baiting with 0.0375% coumatetralyl in broken rice.

During present studies, in the fields given two treatments, second baiting was carried out with bromadiolone instead of zinc phosphide to avoid development of bait shyness towards zinc phosphide. The low rodent control success in groundnut crop fields treated thrice with 2% zinc phosphide was attributed to the phenomenon of bait shyness.

<table>
<thead>
<tr>
<th>Village/District</th>
<th>Plot</th>
<th>Treatment</th>
<th>Poison bait consumption (g/100g bait)</th>
<th>Reduction in rodent activity (%)</th>
<th>Pods damaged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powat/Ludhiana</td>
<td>I</td>
<td>Two treatments ZnP + Br</td>
<td>56.08±6.88</td>
<td>92.18±1.36</td>
<td>1.66±0.38</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment ZnP</td>
<td>-</td>
<td>65.93±3.73</td>
<td>7.09±0.83</td>
</tr>
<tr>
<td>Sehjomajra/Ludhiana</td>
<td>I</td>
<td>Two treatments ZnP + Br</td>
<td>60.17±13.01</td>
<td>88.28±0.57</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment Br</td>
<td>-</td>
<td>67.82±0.55</td>
<td>2.58±0.67</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>Untreated reference</td>
<td>-</td>
<td>Increase in activity</td>
<td>12.76±3.31</td>
</tr>
<tr>
<td>Kalsian/Sangur</td>
<td>I</td>
<td>Two treatments ZnP + Br</td>
<td>61.92±14.61</td>
<td>79.98±3.39</td>
<td>0.12±0.09</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment ZnP</td>
<td>-</td>
<td>54.37±10.27</td>
<td>0.38±0.19</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>Untreated reference</td>
<td>-</td>
<td>Nil</td>
<td>3.05±1.58</td>
</tr>
</tbody>
</table>

Values are Mean±SE, ZnP = 2% Zinc phosphide, Br= 0.005% bromadiolone, Values with different superscripts in a column for reduction in rodent activity and pods damaged for each village differ significantly at P≤0.05. Values in parenthesis are percent reductions over untreated reference fields.
in major field rodent species (Sridhara and Srihari, 1980). Khan et al. (2009) proposed adoption of necessary precautions to prevent development of bait shyness by avoiding repeated application of zinc phosphide or conducting intermittent application with the anticoagulant rodenticide baits. Bromadiolone application first at pod formation stage and next at pod maturity stage proved effective for management of rodents in groundnut crop (Butani et al., 2006). Alternatively, three applications of rodenticides one each at germination, pod formation and pod maturity stages using 2% zinc phosphide at any one of the stages and 0.005% bromadiolone at the other two stages effectively controlled rodents in groundnut (Butani et al., 2006). Authors suggested that the use of zinc phosphide should be restricted to one time due to possibilities of development of bait shyness in surviving populations of rodents. Khan et al. (2012) suggested 4 to 5 applications of the rodenticide baits such as brodifacoum, coumatetralyl and zinc phosphide as burrow baiting to obtain economic yields of groundnut crop.

In Bangladesh, farmers commonly used zinc phosphide and bromadiolone as poison bait, for rodent control. However, in rural areas there are several constraints for its use. Primarily, rodenticides are not affordable to the rural poor. Even, when rodenticides are widely available, due to farmers ignorance, inappropriate dose of rodenticide is used and bait shyness among the rat population is commonly seen. This shyness creates a serious problem in rodent control by developing a resistant population (Hasanuzzaman et al., 2009).

During our survey, rodent damage was found aggregated around burrows, as has been reported previously (Parshad, 1999; Singla and Parshad, 2001; Singla and Parshad, 2010). Rodent damage in the form of percent pods damaged was also found to be significantly (P≤0.05) low in fields given two treatments than in fields given single treatment at all the locations except at village Kalsian, where the damage was non-significantly low in fields given two treatments. Rodent damage in treated plots I and II at villages Powat and Sehjomajra was found to be 0.00 to 1.66% and 2.58 to 7.09%, respectively compared to 12.76% in untreated plot III. Similar damage at village Kalsian was found to be 0.12 and 0.38% in treated plots I and II, respectively compared to 3.05% in untreated plot III (Table 1). The reduction in rodent damage compared to untreated reference fields was found to be 87-100% in fields given two treatments and 44.43-87.54% in fields given single treatment. Higher damage in untreated fields and fields given single treatment than in fields given two treatments at the time of harvest is indicative of higher rodent population in untreated fields and fields given single treatment. The amount of damage to crops increases as the density of rodents increases (Lefebvre et al., 1989; Martin et al., 2007).

During present studies, rodent damage and yield loss was estimated based on number of pods damaged and were still intact with the plant. This method, however, led to underestimation of the damage because rodents also removed groundnut pods from the plant and hoarded them in their

<table>
<thead>
<tr>
<th>Village/District</th>
<th>Plot</th>
<th>Treatment</th>
<th>Average pods damaged per plant</th>
<th>Average plants/4m²</th>
<th>Yield loss (q/ha)</th>
<th>Yield loss saved (q/ha)</th>
<th>Net benefit (Rs/ha) (US$/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powat/Ludhiana</td>
<td>I</td>
<td>Two treatments</td>
<td>0.60±0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.67±1.66</td>
<td>0.32±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.27</td>
<td>8281.00 (165.62)</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment</td>
<td>2.87±0.19&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.00±1.20</td>
<td>1.57±0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.02</td>
<td>3724.00 (74.48)</td>
</tr>
<tr>
<td>Sehjomajra/Ludhiana</td>
<td>I</td>
<td>Two treatments</td>
<td>0.00±0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.20±1.39</td>
<td>0.00±0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.59</td>
<td>9465.00 (189.30)</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment</td>
<td>0.69±0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.8±0.50</td>
<td>0.38±0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.21</td>
<td>8109.00 (162.18)</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>Untreated reference</td>
<td>3.93±0.36&lt;sup&gt;c&lt;/sup&gt;</td>
<td>36.11±1.38</td>
<td>2.59±0.29&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kalsian/Sangur</td>
<td>I</td>
<td>Two treatments</td>
<td>0.06±0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.87±1.50</td>
<td>0.02±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.41</td>
<td>1399.00 (27.98)</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>Single treatment</td>
<td>0.23±0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.93±0.63</td>
<td>0.08±0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.35</td>
<td>1245.00 (24.90)</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>Untreated reference</td>
<td>1.27±0.78&lt;sup&gt;c&lt;/sup&gt;</td>
<td>18.00±1.15</td>
<td>0.43±0.26&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Values are Mean±SE, ZnP = 2% Zinc phosphide, Br = 0.005% bromadiolone, Cost of groundnut Rs 3700/quintal, Cost of single treatment of zinc phosphide/ha = Rs 50/- and of 0.005% bromadiolone/ha = Rs 68/-, 1US$ = INR 50.00, Values with different superscripts in a column for pods damaged per plant and yield loss for each village differ significantly at P≤0.05. Values in parenthesis are percent reductions over untreated reference fields.
burrows which could not be counted. Therefore, methods to assess damage by rodent pests in groundnut crop need further refinement. Brooks et al. (1988) counted the number of damaged and undamaged plants of groundnut crop from each sample site. Damaged plants appeared either dead and dried or withered and dying. Based on their studies, they reported that the visual above-ground examination of plants for damage underestimated the actual loss because rodents often remove groundnut pods below ground without killing or otherwise damaging the plants.

During present studies, average pods damaged per plant varied from 0.00 to 0.60 and 0.23 to 2.87 in fields given double and single treatment, respectively. Average yield per pod at all the locations was found to vary from 0.73-0.76g. Yield loss (q/ha) varied from 0.00 to 0.32 and 0.08 to 1.57 q/ha in fields given double and single treatment, respectively compared to 0.43 to 2.59 q/ha in untreated fields (Table 2). A significant (P <0.05) difference was observed in average pods damaged per plant and yield loss among the treated and untreated fields at all the locations. Reduction in rodent damage in treated fields from that of untreated ones resulted in save in yield loss of 0.41 to 2.59 and 0.35 to 2.21 q/ha in fields given double and single treatment, respectively with net benefit of Rs. 1399.00 to 9565.00 (US$ 27.98 to 189.30) and Rs 1245.00 to 8109.00 (US$ 24.90 to 162.18) per hectare, respectively (Table 2). The rodenticide baits are low cost interventions compared with the insecticides and fungicides. Khan et al. (1992) recorded an increase of 61.7% yield of groundnut production following control of field rats with anticoagulant baits. Ali et al. (1984) were able to significantly abridge the yield gap of 9.2 q/ha in the groundnut crop in Pakistan through rodent control efforts. The outcome of study by Khan et al. (2009) has shown a good economic return i.e. over 20-fold, by control of rodent pests in groundnut crop.

The present studies suggest the conduction of two rodenticide treatments, first with 2% zinc phosphide bait in the month of August at pod formation stage and second with 0.005% bromadiolone bait at pod maturity stage for reduction in rodent damage and yield loss in groundnut crop.

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