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FIELD EFFICACY OF REDUCED ACTIVE INGREDIENT ZINC PHOSPHIDE FORMULATION AGAINST RODENTS

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ABSTRACT

A formulation of zinc phosphide with reduced active ingredient (40% concentrate) was evaluated for its rodenticidal activity in wheat, rice and sugarcane crops at farmer fields of Punjab, India. Comparison was made with the existing formulation (80% concentrate) and second generation anticoagulant bromadiolone (0.25% concentrate). Cereal based baits containing different doses of new (1.5, 2.0 and 2.5%) and existing zinc phosphide (2%) and bromadiolone (0.005%) were applied through burrow baiting where *Bandicota bengalensis, Mus booduga, Millardia meltada* and *Tatera indica* were the predominant rodents. The reduction in rodent activity was determined based on pre- and post-treatment bait census. Results revealed that 2% and 2.5% bait formulations of new zinc phosphide are as effective as the existing/ recommended zinc phosphide (2%) and bromadiolone (0.005%) bait formulations.

Key words: Zinc phosphide, 40% and 80% concentrate, bromadiolone, *Bandicota bengalensis*, *Mus booduga*, *Millardia meltada*, *Tatera indica* cereal bait, rice, rodent burrows, sugarcane, wheat

Rodents belong to most diverse order Rodentia of class Mammalia, with about 2277 species (Burgin et al., 2018; Singla, 2021). They cause direct damage to agricultural produce by feeding, burrowing and hoarding, and indirect loss by contaminating food grains with their fur, urine and faeces thereby spreading diseases of zoonotic importance (Singla et al., 2016; Kaur and Singh, 2019). The existing rodent control strategies include environmental, cultural, mechanical and chemical methods (Anonymous, 2021). Use of rodenticides is the most common, but several considerations are shaping their future with focus on their stability and non-target interference. Currently 2% bait formulation of 80% zinc phosphide and 0.005% bait formulation of 0.25% bromadiolone are recommended (Anonymous, 2021), and zinc phosphide is the most commonly used and forms 80-90% of rodent control operations (Buckle and Eason 2015). But these rodenticides can have negative impacts on non-target animals (Witmer et al., 2013; Thomas et al., 2011; Gabriel et al., 2012). Most of these impacts are attributed to anticoagulant poisoning, but in some cases, these are caused by accidental consumption of zinc phosphide (Muraina et al., 2018). The mortality rate of zinc phosphide poisoning is around 37-100% (Sogut et al., 2011). Also, there is no antidote known for zinc phosphide (Bilics et al., 2020). So, there is a need to recommend zinc phosphide formulation which is safe, less toxic and require more consumption to reach a lethal effect. The present study focuses on this need with determining the efficacy of new safer formulations with reduced active ingredient (40%).

MATERIALS AND METHODS

The present study was conducted in three crops i.e. wheat (*Triticum aestivum*), rice (*Oryza sativa*) and sugarcane (*Saccharum officinarum*) at farmers' fields in villages namely Bagga Khurd, Ladhowal and Bhundri (district Ludhiana), and Bandala (district Jalandhar) of Punjab, India in 2018-19 where rice-wheat is the major cropping system. Six blocks (I-VI), each further consisting of three replicated fields (of 0.4 ha each) were selected for each crop. Fields of wheat crop sown under both conventional tillage and with Happy seeder drill (rice residue incorporated as surface mulch) were selected. In wheat crop sown under rice residue management, rodenticide treatments were done at germination stage during November-December, whereas, in wheat crop sown under conventional tillage and rice crop rodenticide treatments were done before milky grain stage during March and September, respectively. In sugarcane crop, treatment was done during October-November when there is increase in sugar content in the cane. Prior to treatment, live burrow count was recorded in all the fields and the surrounding peripheral area up to 10 m width on all sides by plugging all the burrow holes in the evening and counting the number of reopened burrows in the next morning (Anonymous, 2021). Burrows of different rodent species were identified on the basis of characteristic burrow entrances (Neelanarayan, 2004). Pre-census bait consumption was recorded by placing 10 g of plain bait (cracked wheat grains smeared with 2% groundnut oil) each at 100 bait points/ ha (1kg/ ha) for two days. On third day, left over bait in each field was collected separately from each field and weighed to record the consumption (g/ 100g bait).

Burrows of blocks I to V were treated with different poison baits twice at an interval of about 15 days and one block (block VI) was kept as untreated control. Burrows of blocks I, II and III were treated with three different bait formulations of 40% zinc phosphide i.e. 1.5, 2.0 and 2.5% prepared by mixing 3.75, 5.0 and 6.25 g of zinc phosphide powder in 96.25, 95.0 and 93.75 g cracked wheat grains smeared with 2% groundnut oil, respectively. Burrows of blocks IV and V were treated with 2% bait formulation of 80% zinc phosphide and 0.005% bait formulation of 0.25% bromadiolone prepared by mixing 2.5 and 2.0 g of rodenticide powders with 97.5 and 98.0g cracked wheat grains smeared with 2% groundnut oil, respectively. All the baits were prepared a fresh depending upon the requirement (10g per burrow). Burrow baiting was done by inserting 10g of poison bait taken in a paper boat 6 inches deep inside each burrow. After 15 days of treatments, post-census bait consumption was recorded in all the treated and untreated fields by placing plain bait for two days. To determine the efficacy of treatment, % reduction in rodent activity was determined as per the method described in Singla et al. (2015). Rodent damage in all the fields was determined at preharvest stage selecting five random samples from four sides and centre of a field. Rodent damage in wheat and rice crops was estimated during April and October, respectively following Singla and Babbar (2010). Rodent damage in sugarcane was estimated during December following Singla and Babbar (2012). The values were determined as mean± SD, and significance of difference in % reduction in rodent activity, cut tillers and yield loss was determined using one way ANOVA (p=0.05).

RESULTS AND DISCUSSION

In wheat crop fields sown under rice residue management at villages Bagga Khurd and Ladhowal, district Ludhiana, burrows of *Bandicota bengalensis, Mus booduga* and *Tatera indica* were found. The reduction in rodent activity after two treatments ranged from 38.8 to 96.4%, being highest in block III treated with 2.5% formulation of 40% zinc phosphide (Table 1). No significant difference was found in reduction in rodent activity between blocks II and III. In blocks IV and V treated with already recommended bait formulations of zinc phosphide and bromadiolone, the mean reduction in rodent activity after two treatments was 82.9 and 76.4%, respectively which was at par with that obtained in block II (77.3%) and III (96.4%) treated with 2% and 2.5% bait formulations of 40% zinc phosphide. Significantly lower mean reduction in rodent activity was obtained in block I (38.8%) treated with 1.5% formulation of 40% zinc phosphide. In untreated block, there was found an increase in rodent activity. Record of rodent damage at preharvest stage revealed significantly low mean cut tillers (0.3 to 0.6%) and yield loss (7.9 to 13.7 kg/ ha) in treatment blocks II to V as compared to block I (1.3% and 30.7 kg/ ha, respectively) and untreated block VI (2.0% and 59.7 kg/ ha, respectively). In wheat sown under rice residue management, double burrow baiting with 2% formulation of 80% zinc phosphide is already recommended during germination stage (Singla, 2019), but it can be replaced with double burrow baiting of 2% or 2.5% formulation of 40% zinc phosphide to reduce non-target toxicity. In wheat crop sown under conventional tillage at villages Bagga Khurd and Ladhowal, district Ludhiana, burrows of *B. bengalensis, M. booduga, T. indica* and *Millardia meltada* were found. The mean reduction in rodent activity in block I treated with 1.5% bait formulation of 40% zinc phosphide was non-significantly low (67.0%) than that observed in blocks II to V (77.3 to 98.0%) indicating its low efficacy. Damage at pre-harvest stage revealed significantly low mean cut tillers (0.7 to 01.3%) and yield loss (17.3 to 23.3 kg/ ha) in treatment blocks II to V as compared to block I (2.3% and 42.4 kg/ ha, respectively) and untreated block VI (6.4% and 105.0 kg/ ha, respectively). No significant difference was found in efficacy of 2% and 2.5% bait formulations of 40% zinc phosphide and 2% and 0.005% bait formulations of 80% zinc phosphide and bromadiolone, respectively (Table 1).

In rice crop fields selected at village Bhundri, district Ludhiana, burrows of three rodent species i.e. *B. bengalensis, M. booduga* and *M. meltada* were found. The reduction in rodent activity after two treatments ranged from 62.7 to 86.7%, in blocks I to V with no significant difference among them. Among the three blocks treated with 40% zinc phosphide, higher reduction (76.0%) in rodent activity was obtained in block III treated with 2.5% bait formulation. In

Table 1. Efficacy of rodenticide treatments in wheat, rice and sugarcane crops

Blocks	Wheat crop						Rice crop			Sugarcane crop	
	Under rice residue management			Under conventional tillage							
	Reduction in rodent activity (%)	Cut tillers (%)	Yield loss (kg/ ha)	Reduction in rodent activity (%)	Cut tillers (%)	Yield loss (kg/ ha)	Reduction in rodent activity (%)	Cut tillers (%)	Yield loss (kg/ ha)	Reduction in rodent activity (%)	Cut tillers (%)
I	38.8± 6.1^{a}	1.3± 0.1^{a}	30.7± 3.4^{a}	67.0± 6.2^{a}	2.3± 0.7^{a}	42.4± 13.1^{a}	62.7± 18.6^{a}	0.6± 0.4^{a}	17.5± 12.0^{a}	22.5± 4.9^{a}	3.1± 0.2^{a}
II	77.3± 6.6^{b}	0.6± 0.1^{b}	13.7± 3.8^{b}	77.3± 8.6^{a}	1.3± 0.4^{b}	23.3± 7.5^{b}	68.3.± 4.2^{a}	0.5± 0.1^{a}	16.9± 4.9^{a}	82.2± 3.1^{b}	1.3± 0.4^{b}
III	96.4± 1.5^{b}	0.3± 0.1^{b}	7.9± 1.7^{b}	87.3± 4.0^{a}	0.7± 0.5^{b}	17.3± 9.7^{b}	76.0± 13.9^{a}	0.4± 0.1	13.9± 0.2^{a}	91.1± 1.7^{b}	0.9± 0.3^{b}
IV	82.9± 2.2^{b}	0.4± 0.1^{b}	9.3± 1.6^{b}	98.0± 1.7^{a}	0.8± 0.3^{b}	18.4± 7.0^{b}	80.0± 6.6^{a}	0.3± 0.1	12.6± 2.9^{a}	79.0± 6.5^{b}	1.0± 0.2^{b}
V	76.4± 2.8^{b}	0.5± 0.1^{b}	11.3± 1.2^{b}	94.3± 0.6^{a}	0.8± 0.2^{b}	18.7± 5.8^{b}	86.7± 1.5^{a}	0.3± 0.1^{a}	10.4± 2.4^{a}	70.2± 5.6^{b}	1.2± 0.2^{b}
VI	Increase	2.0± 0.1^{c}	58.7± 5.0^{c}	Increase	6.4± 2.2^{c}	105.0± 25.1^{c}	Increase	1.2± 0.4^{b}	35.2± 17.4^{b}	Increase	6.0± 1.6^{c}

Values Mean± SD; Values with different superscripts in a column differ significantly at p=0.05

blocks IV and V, the reduction in rodent activity was 80.0 and 86.7%, respectively after two treatments. Record of rodent damage at pre-harvest stage revealed significantly less cut tillers (0.3 to 0.6%) in treatment blocks compared to untreated block (1.2%). Similarly, the yield loss was also significantly low (10.4 to 17.5 kg/ha) in treatment blocks compared to untreated block (35.2 kg/ ha). Cut tillers and yield loss in all the treated blocks were almost similar (Table 1). Singh et al. (2017) recorded 44.47-65.64% reduction in rodent activity in direct seeded and 49.76-61.68% in transplanted basmati rice crops where burrow baiting was practiced with zinc phosphide at vegetative phase.

In sugarcane crop field selected at village Bandala, district Jalandhar, burrows of three rodent species i.e. *B. bengalensis, M. booduga* and *M. meltada* were found. The reduction in rodent activity was significantly low (22.5%) in block I as compared to blocks II to V (70.2 to 91.1%) with maximum reduction in activity in block III treated with 2.5% bait formulation of 40% zinc phosphide. No significant difference was found in per cent reduction in activity among blocks II to V. Record of rodent damage at pre-harvest stage revealed significantly low per cent cut canes (0.9 to 1.3%) in treatment blocks II to V as compared to block I (3.1%) and untreated block VI (6.0%) (Table 1). In sugarcane crop, it is recommended to conduct baiting with 2% zinc phosphide formulation (80%) followed by baiting with 0.005% bromadiolone after 15 days, first in July (during rice transplantation in surrounding fields) and second in October-November (after rice harvest in surrounding crops) (Singla and Babbar 2012). This can be replaced with 2.5% bait formulation of 40% zinc phosphide to reduce non-target effects.

Burrow baiting is recommended during lean period and crop germination stages to avoid non-target toxicity hazards due to less or no crop cover. But still there may be non-target toxicity caused by these rodenticide baits when dogs dig the rodent burrows and throw the bait outside the burrow leading to direct poisoning of non-targets (Muraina et al., 2018) or secondary poisoning when the natural predators consume rodents died after consuming rodenticide bait (Gabriel et al., 2012). Present study conducted in different crops concluded that 2% and 2.5% bait formulations of 40% zinc phosphide are as effective as the already recommended 2% formulation of 80% zinc phosphide and 0.005% bait formulation of 0.25% bromadiolone and can be used for managing rodent pest population in crop fields with reduced risk to non-targets.

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CONFLICTS OF INTEREST

Authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS STATEMENT

NS conceived and designed research. RS, NK and BKB conducted experiments. NS and NK analyzed data. NS, RS and NK wrote the manuscript. All authors read and approved the manuscript.

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